

CSM Abstracts

The *Journal of Orthopaedic & Sports Physical Therapy* is pleased to publish abstracts of the 2020 Combined Sections Meeting (CSM), which will take place in Denver, CO, February 12-15, 2020. This collection of abstracts provides a glimpse into the research presented as part of the scientific programming of the Academy of Orthopaedic Physical Therapy and the American Academy of Sports Physical Therapy. The number and variety of the presentations scheduled for the CSM are testimony to the exciting and far-reaching research activities taking place in the field of physical therapy.

The abstracts presented in the following pages are reviewed and selected by members of the research committee for each Academy. The abstracts are not, however, reviewed by the Associate Editors or the Editor-in-Chief of the *Journal of Orthopaedic & Sports Physical Therapy*. By design, each abstract presents only a brief summary of a research project—and thus does not permit full assessment of the scientific rigor with which the work was conducted. Publication and presentation of these abstracts serve the purpose of sharing new research ideas, and, in many cases, the abstract presented offers only preliminary results that may require further refinement and future validation. Nonetheless, presenting this often preliminary type of research information at meetings such as the CSM plays an important role in encouraging dialog among researchers, clinicians, and educators that contributes to advancing the research process and, where appropriate, translation into clinical practice.

The CSM provides a valuable forum for learning from clinical and research experts in physical therapy and related fields. Moreover, unlike reading a manuscript in a journal, attending a professional conference presents us the opportunity to interact with the authors—our colleagues—by asking questions and exchanging ideas. Dive in, and engage.

I look forward to seeing you all in Denver!

Sincerely,



Clare L. Ardern, PT, PhD
Editor-in-Chief, *JOSPT*

Academy of Orthopaedic Physical Therapy Platform Presentation Abstracts OPL1-OPL64

The abstracts below are presented as prepared by the authors. The accuracy and content of each abstract remain the responsibility of the authors. In the identification number above each abstract, OPL designates an Academy of Orthopaedic Physical Therapy platform presentation.

OPL1

PHYSICAL IMPAIRMENT AND PERFORMANCE-BASED LOW BACK PAIN SUBGROUPS FOR ENHANCED PROGNOSTIC CLINICAL DECISION MAKING

Jason M. Beneciuk, Steven Z. George

PURPOSE/HYPOTHESIS: Determine if an empirically derived subgrouping approach based on physical impairment measures would provide additional decision-making capabilities when combined with STarT Back Tool (SBT) risk status.

NUMBER OF SUBJECTS: Secondary analysis of patients ($n = 144$, 61.0% female; mean age $\pm$ SD, 41.3 ± 13.5 years; 47.9% chronic) receiving physical therapy for low back pain.

MATERIALS AND METHODS: SBT and mobility (lumbar flexion, extension, lateral bending, and passive straight-leg-raise range of motion) and performance (bilateral straight-leg-raise and sit-up) testing were administered as components of a previously validated physical impairment scale. Outcome measures consisted of the numeric pain-rating scale (NPRS) and Oswestry Disability Index (ODI) administered at intake and 4 weeks later. Hierarchical agglomerative cluster analysis created distinct cluster profiles among intake impairment-based measures without considering demographic characteristics, SBT risk, or outcome measures. One-way ANOVA and chi-square analysis identified differences between physical impairment-based subgroups on demographic and clinical measures. Two-way ANOVA models tested for statistical interactions between SBT and impairment-based subgroups on NPRS and ODI scores. Kappa statistic and ANOVA tested for patterns between combined SBT and impairment-based subgroups on NPRS and ODI scores.

RESULTS: Three impairment-based subgroups emerged from cluster analysis including Low Risk Impairment ($n = 42$), Medium Risk Impairment ($n = 52$), and High Risk Impairment ($n = 50$) groups. The Low Risk Impairment subgroup was characterized with greater lumbar mobility and more successful performance tests compared to the High Risk subgroup ($P < .01$). The Low Risk Impairment group was also younger (-8.1 years; SE, 2.7) and had lower ODI scores at intake (-12.2 points; SE, 3.3), when compared to the High Risk subgroup ($P < .01$). The Medium Risk Impairment subgroup had lower lumbar mobility ($P < .01$), but similar bilateral straight leg raise performance tests ($P = .51$) as the Low Risk Impairment subgroup. Agreement across combined low, medium, and high risk subgroups was low ($\kappa = 0.02$; 95% CI: 0.00, 0.14). SBT-by-impairment subgroup interactions were present for ODI scores at 4 weeks ($P = .03$).

CONCLUSIONS: Three empirically derived impairment subgroups distin-

guished between lumbar mobility and performance testing with age and disability levels influencing subgroup allocation. SBT and the newly derived impairment risk subgroups were not redundant as there was low agreement with psychosocial and impairment risk groups. Furthermore, combined SBT and impairment-based risk groups improved prediction of 4-week ODI outcomes.

CLINICAL RELEVANCE: There is potential to combine SBT with impairment-based risk subgroups to enhance clinical decision making for predicting low back pain disability outcomes. Future research will determine if this combined subgroup approach can improve outcome prediction accuracy compared to a single subgroup approach or allow for better intervention tailoring based on physical impairment and psychosocial characteristics.

OPL2

MOVEMENT IMPAIRMENTS, PROVIDER RECOMMENDATIONS, AND PATIENT DECISIONS AFTER EVALUATION FOR NONARTHRITIC HIP PAIN

*Lindsey Brown, Kathryn Martin, John Ryan,
Stephanie Di Stasi*

PURPOSE/HYPOTHESIS: Patients with nonarthritic hip pain (NAHP) display abnormal movement which may be addressed with physical therapy (PT). Patients and physicians may struggle to decide if PT may be beneficial. The purpose of this study was to evaluate the relationships between movement impairments, provider recommendations, and patient decisions after a combined surgeon and physical therapist evaluation for NAHP. We hypothesized patients who reported no prior PT treatment, received PT recommendations, and included PT in their final treatment plan would display more impairments.

NUMBER OF SUBJECTS: Thirty-eight (72% female; mean $\pm$ SD age, 36 ± 10 years; BMI, 30.0 ± 5.7 kg/m²).

MATERIALS AND METHODS: Participants were examined by a surgeon to confirm NAHP, then a physical therapist to identify and record posture and movement impairments during sitting, sit to stand, standing, single-leg stance and squat, and gait which were subtotaled based on sagittal or frontal plane (maximum of 9 and 11, respectively). The surgeon and physical therapist discussed and recorded a joint recommendation; clinicians were not required to agree on a single treatment. Participants recorded their final treatment plan after a shared decision-making process with both clinicians. Joint recommendation and final plan were dichotomized based on inclusion of PT or not. Total movement impairments were compared based on past PT for hip pain (yes or no), joint

recommendation (PT or not), and final decision (PT or not) using independent t tests ($P < .05$). Sagittal and frontal impairment subtotals were also compared using these methods.

RESULTS: Participants presented with an average $\pm$ SD of 2.7 ± 1.5 sagittal and 5.1 ± 2.2 frontal plane impairments. Participants who reported past PT ($n = 19$) presented with fewer sagittal impairments (1.9 ± 1.3) than those who had not tried PT (3.6 ± 1.3 , $P < .01$), but no difference in total or frontal impairments ($P > .10$). Twenty-two joint recommendations included PT; 20 of 22 had an initial PT recommendation by the physical therapist. Although nonsignificant, these 22 participants displayed more total impairments (8.5 ± 2.5) than the remaining 16 participants (6.9 ± 2.9 , $P = .07$). Twenty-six participants included PT in their final plan (20 had PT in their joint recommendation). These 26 participants presented with more total impairments (8.5 ± 2.6) than those who did not include PT in their final plan (6.5 ± 2.8 , $P = .03$).

CONCLUSIONS: Participants had impairments noted in both sagittal and frontal planes across 6 functional tasks. Those who previously tried PT presented with fewer sagittal plane impairments, indicating previous PT may have had some impact on posture and movement. As expected, participants for whom PT was recommended presented with more impairments. Participants often agreed with recommendations to pursue PT, and those who decided on PT presented with more impairments.

CLINICAL RELEVANCE: Physical therapists can identify and treat movement impairments for NAHP adding to surgeon expertise for structural pathology. Interdisciplinary evaluation provides a collaborative understanding of impairments and treatment options to inform the treatment planning process and provide value to the patient from a team perspective.

OPL3

LOW BACK PAIN-RELATED WALKING IMPAIRMENTS ARE ASSOCIATED WITH PAIN SENSITIVITY, MOVEMENT-EVOKED PAIN, AND PSYCHOLOGICAL FACTORS

Katie Ann Butera, Steven Z. George, Paul Anthony Freeborn, Janki Patel, Mark Donald Bishop, Steve Coombes, Emily Jane Fox

PURPOSE/HYPOTHESIS: Low back pain (LBP) is a leading cause of disability. However, disability is often measured via self-report, and thus, increased understanding of functional performance in individuals with LBP is needed. Further, factors that may contribute to functional performance deficits in this population have not been established. Therefore, the purpose of this study was to determine how selected nervous system factors—pain sensitivity, movement-evoked pain, and psychological factors—were associated with a functional performance task—walking—in individuals with LBP.

NUMBER OF SUBJECTS: Forty-eight adults with LBP (24 male; mean age, 45 years).

MATERIALS AND METHODS: Participants underwent assessment of factors representing nervous system processing including pain sensitivity testing (pressure pain thresholds), psychological factor assessment (positive coping and pain catastrophizing), and movement-evoked pain (pain rating during each walking task). Participants also completed the Oswestry Disability Index. Walking function was assessed using a 12-camera motion analysis system to quantify speed during a “fastest-comfortable” and “obstacle negotiation” condition. Walking data were separated via median split into fast and slow groups for each condition (4 groups total). For each walking condition, separate 1-way ANOVAs tested slow versus fast group differences on pain sensitivity, movement-evoked pain, and psychological factors.

RESULTS: All 4 groups reported low disability (range, 13%–23%). The slow groups were 0.6 m/s slower than fast groups for both walking conditions (clinically meaningful difference; $P < .05$). The slow group for the ‘fastest comfortable’ condition demonstrated higher pain sensitivity, higher movement-evoked pain, and lower positive coping (all, $P < .05$). The slow group for the ‘obstacle negotiation’ condition demonstrated higher pain

sensitivity, higher movement-evoked pain, lower positive coping, and higher pain catastrophizing (all, $P < .05$).

CONCLUSIONS: Individuals with LBP who walked more slowly demonstrated less favorable nervous system processing via sensory, psychological, and movement-evoked pain profiles. These findings were consistent across 2 walking tasks important for maintaining physical activity levels and participation in life roles. Although self-reported disability was low in this LBP sample, nervous system factors of different constructs were still associated with walking impairments.

CLINICAL RELEVANCE: Study findings support clinical evaluation of pain sensitivity, movement-evoked pain, and psychological factors as these may impact walking function in individuals with LBP. However, future studies are needed to confirm these findings in higher disability populations and across other areas of physical performance. Future studies using multivariate approaches will aid in establishing which nervous system factors interact and potentially contribute to the transition from functional impairment to persistent disability. These subgroups may effectively characterize LBP clinical phenotypes and guide personalized interventions to optimize function.

OPL4

NECK MUSCLE COMPOSITION IN PERSISTENT WHIPLASH-ASSOCIATED DISORDER: RELATIONSHIP WITH NECK-RELATED DISABILITY

Brad Callan, Joshua A. Cleland, James Matthew Elliott, David Walton, Morey Joel Kolber

PURPOSE/HYPOTHESIS: Neck pain and related symptoms following a motor vehicle collision (MVC) can significantly influence the quality of life for some people. While the MVC related mechanics of the head and neck gives rise to the term whiplash, the developing signs and symptoms of neck related disability are often complex and clinically known as whiplash-associated disorder (WAD). Muscle fatty infiltrate (MFI) has been associated with persistent WAD, but its influence on the generation and maintenance of the complex signs and symptoms is largely unknown. The purpose of this study was to evaluate the relationship between MFI, baseline demographic variables, and self-report measures on persistent WAD.

NUMBER OF SUBJECTS: Ninety-seven.

MATERIALS AND METHODS: Participants presenting to an academic emergency medicine department in Chicago, IL enrolled in a parent longitudinal cohort study investigating recovery from whiplash injury (ClinicalTrials.gov identifier: NCT02157038). Within 1 week of the MVC, an MRI of the cervical spine was performed to quantify the percentage of MFI. At baseline, neck related disability was measured using the Neck Disability Index (NDI), and age, sex, height, and weight were recorded. At 2 weeks, 3 and 12 months post-MVC, a coregistered MRI of the cervical spine was performed, and NDI scores were collected. At 12 months post MVC, participants were classified into 1 of 2 groups: Recovered (NDI $< 10\%$) or persistent WAD (NDI $> 10\%$). Using logistic regression, baseline measurements were used to determine which variables, or interactions between variables, were significant predictors of persistent WAD, and how the variables combined for model prediction. The variables were analyzed at each time point to assess changes in their predictive strength.

RESULTS: At baseline, several variables were found to be predictive of membership for the persistent WAD group: female sex, increased MFI and sleep disturbance (as measured on the NDI), and an interaction between MFI and sleep disturbance. For persistent group classification, odds ratios (ORs) from 1.25 to 4.46 were reported for the variables and an R^2 for the model ranged from 0.18 to 0.25. Across 12 months, the effects of MFI, sex, and sleep disturbance remained significant, while the MFI and sleep disturbance interaction was lost. Over time, the OR for MFI and sleep disturbance increased significantly but sex did not, and the R^2 range increased to 0.51 to 0.70 at 12 months.

CONCLUSIONS: Results demonstrate an association with females, increased MFI, and sleep disturbance on persistent WAD. With time, the strength of the OR for MFI and sleep disturbance increased implying greater predictive strength, and the prediction of persistent WAD increased across time using these variables.

CLINICAL RELEVANCE: Emerging factors, including neck MFI and sleep disturbances, especially in females, suggest that a program targeting MFI and sleep quality may help decrease the prevalence of persistent WAD.

OPL5

IMPLEMENTATION OF A BUNDLE FOR EXERCISE AND TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION FOR CHRONIC MUSCULOSKELETAL PAIN: THE BEST PROJECT

Carol G. Thompson Vance, Dana Dailey, Jennie Embree, Stephanie Gilbertson-White, Keela Herr, Glenn Abernathy, Nicholas Butler, David A. Katz, Maia Hightower, Barbara A. Rakel, Kathleen Anne Sluka

PURPOSE/HYPOTHESIS: Our purpose was to develop, implement, evaluate and disseminate an electronic prescription bundle for 2 nonpharmacological pain treatments, exercise (EX) and transcutaneous electrical nerve stimulation (TENS) for use by primary care providers for treating chronic musculoskeletal pain. We hypothesized that implementation of the electronic bundle would increase prescription frequency of EX and TENS.

NUMBER OF SUBJECTS: We recruited primary care providers from Family Medicine ($n = 11$) and Internal Medicine ($n = 16$) at the University of Iowa Hospitals and Clinics. Early adopters ($n = 10$) were those who prescribed $>30\%$ above clinic means for TENS and EX.

MATERIALS AND METHODS: We used a pre-post quasi-experimental design, informed by Rogers' Diffusion of Innovation model for adoption of the electronic prescription bundle. The bundle consists of a chronic pain order set based on clinical practice guidelines, with electronic prescriptions for TENS and EX that were integrated into the Electronic Patient Information Chart (EPIC) by Health Care Information Systems. Provider prescription behaviors for TENS, EX, and pain medications (opioid and nonopioid) were collected for 2 years prior to the study onset (baseline), and throughout implementation. Feedback collected from formative focus groups of providers was used to inform development of the bundle and implementation strategies. Educational materials were developed for providers and patients and reviewed by physical therapists trained in chronic pain management and reviewed by individuals with chronic pain. Hands on training sessions and in-clinic support for use of the bundle were provided.

RESULTS: Baseline prescribing behavior for each clinic averaged 3%, 4% for TENS; 16%, 25% for opioids, and 69%, 74% for nonopioid analgesics; EX was not trackable. Following implementation, prescriptions averaged 16%, 20% for TENS; 11%, 18% for opioid analgesics; 68%, 79% for nonopioid medications and 4%, 8% for EX. There was wide variability in usage of the bundle between clinics and providers. On average, early adopters prescribed TENS in 21% (13%-35%) and EX in 9% (6%-12%) of patients while nonadopters showed virtually no use of the electronic prescriptions.

CONCLUSIONS: We developed an electronic prescription bundle for nonpharmacological treatments in EPIC that increased TENS and EX prescriptions and decreased opioid prescriptions. Overall, providers were more comfortable with prescribing TENS than EX. They reported time and workflow as barriers, and in-clinic support by a primary care nurse as the greatest facilitator to use of the bundle.

CLINICAL RELEVANCE: Clinical practice guidelines recommend nonpharmacological interventions as preferred first line treatments for chronic pain yet use of nonpharmacological interventions are low. EX and TENS are effective, low-cost treatments for chronic pain that are not yet considered first-line treatments in primary care. As primary care is often the first point of contact for a patient with chronic pain, providing evidence-based nonpharmacological choices for providers would provide a method to improve adherence to clinical practice guidelines.

OPL6

NONSPECIFIC EFFECTS OF OSTEOPATHIC MANIPULATIVE TREATMENT FOR LOW BACK PAIN

Jacek Cholewicki, John Michael Popovich, Angela S. Lee, Lisa A. DeStefano, Jacob J. Rowan, Timothy J. Francisco, Lawrence L. Prokop, Mathew A. Zarkin, N. Peter Reeves

PURPOSE/HYPOTHESIS: Therapeutic outcomes of any medical treatment consist of specific and nonspecific effects. Specific effects are the outcomes that result from theoretically derived mechanisms of an intervention. Nonspecific effects are all other outcomes (eg, regression to the mean, placebo, etc). Understanding both effects are important to individualize treatment and maximize the outcomes. Osteopathic manipulative treatment (OMT) is an effective intervention for low back pain (LBP), though the specific mechanisms are unknown. It is also difficult to assess the nonspecific effects of OMT in clinical trials because the perfect sham treatment and double blinding are not possible. Thus, the purpose of this study was to assess the magnitude of nonspecific effects of OMT for LBP using the Credibility and Expectancy questionnaire (CEQ) and Healing Encounters and Attitudes Lists (HEAL).

NUMBER OF SUBJECTS: Forty-six LBP patients (29 women; mean $\pm$ SD age, 44 ± 13 years; BMI, 27.2 ± 3.6 kg/m²; average pain [NPRS], 5.3 ± 1.9 points; disability [ODI], $33\% \pm 19\%$).

MATERIALS AND METHODS: As a part of a larger randomized clinical trial, patients received 4 OMT treatments (2 patients received 3 OMT treatments) delivered over 4 to 6 weeks. Treatment consisted of a mandatory high-velocity, low-amplitude spinal manipulation and any number of the following techniques: soft tissue, muscle energy, myofascial, and articular. NPRS and ODI measures were obtained at baseline and the end of the study. CEQ and HEAL questionnaires were administered at baseline and after the treatment period, respectively. Changes in NPRS and ODI scores were evaluated with the 1-sample t test and were correlated with CEQ and HEAL metrics using Pearson's r . Significantly correlated CEQ and HEAL metrics ($P < .05$), and patients' demographics and baseline outcome values as covariates were entered into a stepwise multiple regression model to assess the variance in outcomes following OMT explained by nonspecific effects.

RESULTS: NPRS and ODI improved significantly ($P < .05$) following OMT by 1.3 ± 2.2 points (range, -4 to 7) and $3\% \pm 9\%$ (range, -14% to 36%), respectively. NPRS change significantly correlated with Spirituality ($r = -0.33$) and Expectancy ($r = -0.37$) scores. ODI change significantly correlated with Spirituality ($r = -0.35$) and Patient-Provider Connection ($r = -0.34$) scores. Aside from the baseline NPRS score, the regression model did not reveal additional metrics of nonspecific effect to be predictive of NPRS change ($R^2 = 0.21$). The regression model for ODI change returned baseline ODI, Spirituality, and Patient-Provider Connection as predictors ($R^2 = 0.36$).

CONCLUSIONS: The magnitude of the treatment effects in this study was consistent with the literature. Higher levels of pain and disability at baseline were associated with larger treatment effects. Greater Spirituality and better Patient-Provider Connection were also associated with better disability outcomes. Together, the nonspecific factors measured in this study accounted for 21% and 36% of the variance in pain and disability outcomes, respectively.

CLINICAL RELEVANCE: These results warrant further investigation into how nonspecific effects of treatment interventions influence outcomes in LBP patients.

OPL7

DOES A PHYSICAL THERAPIST-ADMINISTERED PHYSICAL ACTIVITY INTERVENTION REDUCE SEDENTARY TIME AFTER TOTAL KNEE REPLACEMENT?

Grace Coleman, Daniel Kenta White, Louise Majalap Thoma, Meredith Brunette Christiansen, Dana Rose Mathews, Jason Jakiela, Lauren Neely, Laura Ann Schmitt, Hiral Master

PURPOSE/HYPOTHESIS: People after total knee replacement (TKR) spend little to no time in moderate-to-vigorous physical activity (MVPA) and are sedentary eg spend prolonged time sitting, which are both risk factors for adverse health outcomes. Preliminary findings suggest that adults after TKR who received a physical therapist-administered physical activity (PA) intervention spent 9 to 14 min/d more in MVPA compared to those who did not receive the intervention. Despite improvements in MVPA, it is possible that sedentary time (SED) remains unchanged following intervention (short term) and 1 year later (long term). The purpose of this preliminary study was to investigate the short- and long-term changes in SED following a physical therapist-administered PA intervention in people after TKR.

NUMBER OF SUBJECTS: Forty-one people undergoing outpatient physical therapy (PT) after a unilateral TKR.

MATERIALS AND METHODS: Participants were randomized to either an intervention or a control group. Both groups received standard PT after TKR. The intervention group also received a Fitbit Zip, step goals during PT, and monthly follow-up phone calls to set step goals once they were discharged from PT. SED was quantified using an accelerometer (Actigraph GT3X) worn for >10 hours for >4 days at 3 time points, that is, baseline (IE), discharge (DC) from PT, and 12 months (12M) from PT. SED was defined as time spent in <100 activity counts/min standardized to wear time over 16 waking hours per day [(time in <100 activity counts per minutes/wear time) $\times$ 16 hours]. The outcome, change in SED, was measured from IE to DC (short-term SED change) and IE to 12M (long-term SED change). Positive values indicated a decrease in SED. We compared the short- and long-term changes in SED between control and intervention groups using independent *t* tests.

RESULTS: Of the 41 people enrolled (mean $\pm$ SD age, 66.7 $\pm$ 7.1 years; BMI, 31.8 $\pm$ 5.6 kg/m²; 51% female), 36 participants had data at IE and DC (18 intervention, 18 control) and 27 had data at IE and 12M (12 intervention, 15 control). Short-term SED changes in the intervention and control group were (mean, 91.1 min/d; 95% CI: 54.3, 127.8 min/d and 58.2 min/d; 95% CI: 25.7, 90.7 min/d, respectively). Long-term SED changes in the intervention and control group were 95.6 (95% CI: 58.8, 132.4) min/d and 36.4 (95% CI: -0.8, 73.7) min/d, respectively. The difference in short-term SED change and long-term SED changes were 32.9 (95% CI: -14.4, 80.1) min/d and 59.2 (95% CI: 8.6, 109.7) min/d, respectively, indicating a greater reduction in SED in the intervention group compared to the control group.

CONCLUSIONS: These preliminary results indicate that a physical therapist-administered PA intervention may reduce SED in adults after TKR, and these changes are increased 1 year later.

CLINICAL RELEVANCE: A PA intervention may have substantial short- and long-term effects on reducing SED by approximately 30 to 60 min/d, in addition to improving time in MVPA.

OPL8

GENDER DIFFERENCES IN MOVEMENT DURING SINGLE-LEG TASKS IN PEOPLE WITH HIP-RELATED GROIN PAIN

Riley Cook, G. Kelley Fitzgerald, Stefanie Nicole Foster, Michael Jeffrey Mueller, John C. Clohisy, Marcie Harris-Hayes

PURPOSE/HYPOTHESIS: Determining kinematic differences in the preferred movement patterns of men and women can aid in developing more specific treatment protocols for individuals with hip-related groin pain (HRGP). As part of a parent study, the purpose of this secondary analysis was to compare 2-D frontal plane trunk, pelvic, and hip kinematics between men and women with HRGP during a single-leg squat and single-leg step-down task. Based on previous studies, we hypothesized women would demonstrate more hip adduction and pelvic drop than men, but men and women would demonstrate no differences in trunk lean.

NUMBER OF SUBJECTS: Forty-four participants with HRGP.

MATERIALS AND METHODS: The parent study was a randomized clinical trial

to compare 2 rehabilitation strategies for patients with HRGP. Patients, 15 to 40 years, with chronic HRGP were recruited at 2 sites. Markers were placed on each participant at the sternal notch, bilateral ASIS, and bilateral anterior thigh. A digital video camera was used to capture lower extremity and trunk movement during 2 single-leg tasks, step-down with a heel tap and return (Stpdn) and a single-leg squat (SLSquat). Patients performed 3 trials of each task. For a trial to be valid, the patient had to complete the trial with no loss of balance. Kinovea, a freely available software, was used to complete the measurements. Variables of interest were hip adduction angle (measured at the end of task descent) and frontal plane excursion of the pelvis and trunk (calculated by subtracting the angle at initiation of task descent from the angle at end of task descent). The values of the 3 trials were averaged for each participant and included in the group data, men versus women. Shapiro-Wilk test and Levene's test was used to confirm normality and homogeneity of variance, respectively. Independent *t* tests were used to assess between-group differences.

RESULTS: Forty-six participants were enrolled: 17 men (mean $\pm$ SD age, 30.1 $\pm$ 3.7 years; BMI, 25.6 $\pm$ 4.0 kg/m²) and 29 women (age, 27.8 $\pm$ 5.7 years; BMI, 25.5 $\pm$ 7.4 kg/m²). Data from 2 participants were omitted due to being statistical outliers; with review of their videos, 1 female demonstrated a loss of balance and 1 male demonstrated an exaggerated trunk lean. During the Stpdn, women demonstrated greater hip adduction (24° $\pm$ 8° versus 18° $\pm$ 8°, *P* = .01) and less ipsilateral trunk lean (0° $\pm$ 3° versus 2° $\pm$ 3°, *P* = .02) compared to men. There were no statistical differences in pelvic drop (12° $\pm$ 4° versus 9° $\pm$ 5°, *P* = .06). During the SLSquat, women demonstrated less ipsilateral trunk lean compared to men (2° $\pm$ 3° versus 9° $\pm$ 9°, *P* = .01). There were no differences between women and men in hip adduction (22° $\pm$ 10° versus 20° $\pm$ 7°, *P* = .1) and pelvic drop (-9° $\pm$ 6° versus -11° $\pm$ 5°, *P* = .06).

CONCLUSIONS: Men and women with HRGP move differently during single limb tasks. Men demonstrated greater trunk lean during SLSquat and Stpdn compared to women, however women demonstrate greater hip adduction during Stpdn.

CLINICAL RELEVANCE: These findings suggest that men and women may benefit from different treatment strategies for HRGP.

OPL9

INFLUENCE OF GOAL ATTAINMENT SCALING ON COGNITIVE BEHAVIORAL-BASED PHYSICAL THERAPY OUTCOMES

Rogelio Adrian Coronado, Michael O'Brien, Abigail Henry, Jacquelyn Pennings, Susan W. Vanston, Stephen Wegener, Kristin Archer

PURPOSE/HYPOTHESIS: Patient-centered goal setting is an important component of behavioral interventions for chronic pain. Limited data exist on the relationship between goal attainment during cognitive-behavioral based physical therapy (CBPT) and pain-related outcomes. The purpose of this study was to examine this relationship in a cohort of patients who completed a 6-week telephone-based CBPT intervention after spine surgery. We hypothesized patients who had higher goal attainment would have greater improvements in physical function and reductions in pain at 6 and 12 months after surgery than patients with lower goal attainment.

NUMBER OF SUBJECTS: One hundred eight patients (mean $\pm$ SD age, 63.5 $\pm$ 11.3 years; 54 [50%] female, 92 [85%] white) who completed a CBPT intervention after surgery for a degenerative lumbar spine condition.

MATERIALS AND METHODS: This is a secondary analysis from a randomized trial (*n* = 248) comparing postoperative CBPT and an education program. The primary results of the trial showed superiority of CBPT in an intervention completers only analysis. At each session, CBPT participants used Goal Attainment Scaling (GAS) to set goals and report goal attainment from the previous session. The number and type of goals and percentage of goals met were tracked. A GAS *t* score for achievement of goals across all sessions was computed for each patient. Patients were grouped as high or low goal attainment based on a GAS *t* score of 50, which indicates goals were met as

expected. Six- and 12-month outcomes included physical function (PRO-MIS), pain interference (PROMIS), and back and leg pain intensity (Brief Pain Inventory). Outcome differences between groups were examined using linear regression. Significance was set at $P \leq .05$.

RESULTS: Participants set a median of 3 goals (range, 1-6) at each CBPT session. The most common goals were related to participating in a recreational/physical activity (37%), adopting a cognitive or behavioral strategy (25%), exercising (18%), or performing activities of daily living (12%). Forty-six (43%) participants met criteria for high goal attainment (mean percent goals met, 87% compared to 64% in the low goal attainment group; $P < .001$). There were no baseline characteristic differences between groups ($P > .05$). Greater improvements in the high goal attainment group were observed in physical function at 6 ($\beta = 4.2$, $P < .001$) and 12 months ($\beta = 3.5$, $P = .02$). No other outcome differences were observed ($P > .05$).

CONCLUSIONS: The attainment of personalized goals within a CBPT intervention was an important factor related to improvements in physical functioning after spine surgery.

CLINICAL RELEVANCE: Implementing a structured process for setting personalized goals and tracking goal attainment may be an essential aspect of a psychologically informed physical therapy approach for chronic pain.

OPL10

FEASIBILITY AND ACCEPTABILITY OF A COMPUTER-BASED PAIN SELF-MANAGEMENT PROGRAM FOR ACUTE MUSCULOSKELETAL REHABILITATION

Rogelio Adrian Coronado, Vishvaas Ravikumar, Tricia Kirkhart, Jennifer Haythornthwaite, Stephen Wegener, Kristin Archer

PURPOSE/HYPOTHESIS: Psychologically informed physical therapy (PIPT) has been advocated as a first-line approach for musculoskeletal pain management and has the potential for opioid risk mitigation. PIPT involves integration of psychological strategies within routine PT practice; however, implementation of cognitive behavioral therapy (CBT) strategies requires advanced training and time for optimal delivery. A computer-based self-management (CBSM) program centered on cognitive-behavioral strategies may provide a feasible approach to integrate CBT into PT. The purpose of this study was to examine the feasibility and acceptability of a CBSM program provided in conjunction with PT compared to computer-exposure control and PT in an acute pain population.

NUMBER OF SUBJECTS: One hundred twenty-seven patients (mean $\pm$ SD age, 44.6 $\pm$ 13.7 years; 88 [69%] female, 83 [65%] white) receiving PT for an acute musculoskeletal injury.

MATERIALS AND METHODS: Patients were randomized to receive physical therapy combined with a CBSM program ($n = 66$) or computer-exposure control ($n = 61$). The CBSM program included 7 interactive modules focused on managing pain, improving self-efficacy, and maintaining physical activity. The computer-exposure control included noninteractive modules covering general injury/recovery education. PT was delivered at the discretion of the treating therapist. Outcomes included the number of computer modules completed, number of participants completing program, completion time, and patient satisfaction. Descriptive statistics were used to characterize feasibility and acceptability outcomes.

RESULTS: Data indicated a relatively low rate of utilization (mean $\pm$ SD CBSM modules completed was 3.3 $\pm$ 3.0 and 4.9 $\pm$ 2.1 for control group, $P < .001$) and program completion (35% CBSM participants, 75% controls; $P < .001$). CBSM participants reported high levels of program ease of use (mean $\pm$ SD, 9.1 $\pm$ 2.2) and moderate levels of overall helpfulness (mean $\pm$ SD, 6.3 $\pm$ 2.9). Positive CBSM aspects included content on thinking positive, importance of having fun, balancing activities, and distraction. Negative aspects of CBSM included the lack of relevance to their acute pain and time required to complete the program. Participants also suggested the program could be improved by targeting appropriate patients and including additional pain management strategies.

CONCLUSIONS: A CBSM program is a potential tool for delivering psychological-based strategies within a PIPT model of care. However, additional work is needed to improve dissemination in an acute pain population. Further, methods are needed to improve patient engagement, target patients with greater psychological burden, and enhance integration in physical therapy prior to implementing on a large scale.

CLINICAL RELEVANCE: Successful integration of eHealth CBT strategies within PT will likely require methods for screening and targeting at-risk patients and enhancing patient engagement with these programs. Future work is needed to test whether an integrating eHealth CBT within physical therapy can lead to improved patient outcomes.

OPL11

TENDON MORPHOLOGY AND MECHANICAL PROPERTIES PREDICT SYMPTOM AND FUNCTIONAL RECOVERY FOR PATIENTS WITH ACHILLES TENDINOPATHY

Daniel Patrick Wesley Corrigan, Daniel H. Cortes, Ryan T. Pohlig, Karin Grävare Silbernagel

PURPOSE/HYPOTHESIS: Explore the associations between tendon morphology, mechanical properties, and the recovery of patient symptoms and calf endurance by prospectively following individuals with Achilles tendinopathy for 1 year. We hypothesized that greater tendon thickening, lower shear modulus, and lower viscosity at the initial visit would relate to worse symptoms and calf endurance throughout the year.

NUMBER OF SUBJECTS: Fifty-nine participants (33 male) with mean $\pm$ SD age of 52 $\pm$ 15 years; height, 174 $\pm$ 11 cm; weight, 84 $\pm$ 21 kg, and symptom duration of 25 $\pm$ 58 months were included in this observational study. All participants were diagnosed with Achilles tendinopathy. Participants were excluded if they had Achilles tendon surgery, a comorbidity that affected pain perception, or minimal symptoms at the initial visit (VISA-A > 90). Participants with no follow-up visits or structural evaluation were also excluded.

MATERIALS AND METHODS: Ultrasound imaging and continuous shear wave elastography (cSWE) evaluated Achilles tendon morphology and mechanical properties, including tendon thickening, 5 shear modulus and viscosity, at an initial visit. The Victorian Institute of Sport Assessment-Achilles (VISA-A) questionnaire and the heel-raise endurance test quantified symptom severity and calf endurance at baseline, 6 months and 1 year. The heel-raise endurance test measured the amount of work performed with a linear encoder. Two general linear mixed models analyzed the associations of tendon morphology and mechanical properties with VISA-A scores and heel-raise work.

RESULTS: VISA-A scores significantly increased over time ($P = .016$), with adjusted mean of 54 (95% CI: 50, 60) at the initial visit, 72 (95% CI: 67, 77) at 6 months, and 78 (95% CI: 72, 83) at 1 year. Tendon thickening was significantly associated with VISA-A scores ($P = .001$) while controlling for mechanical properties. A 1-mm increase in thickening was associated with a 4-point decrease in VISA-A scores. Additionally, the relationship of VISA-A scores over time depended on the shear modulus ($P = .009$) while controlling for thickening and viscosity. Higher shear modulus at the initial visit was associated with the higher VISA-A scores by 1 year. There was no change in average heel-raise work over time ($P = .282$). Tendon thickening was significantly associated with heel-raise endurance ($P < .001$) while controlling for mechanical properties. A 1-mm increase in tendon thickening was associated with a 170-J decrease in heel-raise work. Tendon viscosity was also significantly associated with heel-raise work ($P = .001$) while controlling for thickening and shear modulus. A 1-Pa-s decrease in viscosity was associated with a 20-J decrease in heel-raise work.

CONCLUSIONS: For patients with Achilles tendinopathy, the initial amount of Achilles tendon thickening is associated with worse symptoms and calf muscle endurance throughout a year. Achilles tendon shear modulus relates to the recovery of symptoms, while viscosity relates to the recovery of function.

CLINICAL RELEVANCE: Achilles tendon morphology and mechanical properties may be used to predict symptomatic and functional recovery for patients with Achilles tendinopathy, which could allow clinicians to adjust treatment expectations.

OPL12

COMPARISONS OF PATELLAR BONE MINERAL DENSITY BETWEEN INDIVIDUALS WITH AND WITHOUT PATELLOFEMORAL PAIN

Allina Cummins, Chris Khuu, Shane Jeffrey Parker, Steven Shepherd, Kai-Yu Ho

PURPOSE/HYPOTHESIS: It has been reported that individuals with patellofemoral pain (PFP) exhibit increased patellar bone stress injuries compared to controls. In addition, bone stress injuries were found to be more severe within the lateral patella, likely due to patellofemoral joint (PFJ) malalignment (eg, patellar lateral tilt and displacement). While bone remodeling and subsequent increased focal subchondral bone mineral density (BMD) have been documented in response to joint overloading/degeneration, it remains unclear whether persons with PFP exhibit higher regional BMD of the patella. Therefore, the primary purpose of this study was to compare BMD of the patella (lateral, medial, and total regions) between individuals with and without PFP using quantitative computed tomography (QCT). The secondary aim was to examine the associations between patellar regional BMD and PFJ alignment.

NUMBER OF SUBJECTS: Ten individuals with retropatellar pain and 10 sex, age, weight, height, and activity matched pain-free controls participated.

MATERIALS AND METHODS: A calcium hydroxyapatite (CHA) calibration phantom with 4 chambers of specified densities was placed beneath the knee during the QCT scan. From QCT, the average Hounsfield units were measured for each chamber. The values were then plotted against known CHA concentrations. Based on the fitted regression line between Hounsfield unit and CHA concentration, CHA equivalent densities of all bone voxels were determined. Lateral and medial patella regions were manually identified and the average BMD for all regions were calculated. To quantify PFJ alignment, patellar lateral displacement was measured using bisect-offset index (BSO) and patellar lateral tilt was quantified using patellar tilt angle (PTA). A 2-factor repeated-measures ANOVA was used to compare BMD between the 3 regions (lateral, medial, and total) and between the 2 groups (PFP and control). Pearson correlation coefficient analyses were used to evaluate the associations between BMD and PFJ alignment measures of all participants.

RESULTS: ANOVA showed that neither main effect of group nor group-by-region interaction effect was significant ($P \geq .35$). a significant main effect of region on patellar BMD ($P < .01$). The post hoc analyses showed that the patellar BMD was highest within the lateral patella and was lowest within the medial patella (lateral, 0.53 ± 0.08 g/cc; medial, 0.43 ± 0.06 g/cc; total, 0.49 ± 0.07 g/cc; $P < .01$). Pearson correlation coefficient analyses revealed moderate correlations between increased BSO/PTA and increased BMD within lateral ($r = 0.47$ - 0.53 , $P \leq .04$), medial ($r = 0.46$ - 0.51 , $P \leq .04$), and total ($r = 0.47$ - 0.53 , $P \leq .04$) regions.

CONCLUSIONS: While individuals with PFP and pain-free controls had similar patellar BMD, the lateral patellar region exhibited the highest BMD when compared to medial and total regions across both groups. Additionally, higher patellar regional BMD was related to increased patellar lateral displacement and patellar lateral tilt.

CLINICAL RELEVANCE: As patellar malalignment is associated with increased patellar BMD, the PFJ alignment should be considered when treating individuals with PFP.

OPL13

EFFECTIVENESS OF THE TOTAL RANGE EXERCISER IN TOTAL KNEE ARTHROPLASTY REHABILITATION: A RANDOMIZED CONTROLLED TRIAL

Danielle Eustace, Jennifer A. Bunn, Bradley James Myers

PURPOSE/HYPOTHESIS: Total knee arthroplasty (TKA) is a common surgical

procedure for individuals with osteoarthritis leading to considerable surgical and associated rehabilitation costs. The Total Range Exerciser (T-REX) is a medical device intended to reduce the need for physical therapy (PT) services through continuous passive motion, static stretching, and resisted exercise applied within the home to promote range of motion and strength. The purpose of this study was to compare functional and patient reported outcomes for post-TKA rehabilitation for standard care PT versus reduced frequency PT and T-REX.

NUMBER OF SUBJECTS: Seventy potential participants met inclusion criteria and were recruited for participation, 51 elected to enroll in the study and underwent presurgical testing. Eleven participants did not complete post-surgical testing; 40 participants (mean $\pm$ SD age, 55.7 ± 10.8 years; height, 171.4 ± 11.0 cm; weight, 99.3 ± 18.7 kg) completed TKA rehabilitation.

MATERIALS AND METHODS: All surgical and immediate postop care was based upon normal practices. Participants presented to outpatient PT within 3 days of surgery to begin group specific intervention. Standard Care Group (SC) included outpatient PT visits 3 days per week; Experimental Group (EG) included outpatient PT at reduced frequency of 1 day per week. The EG also received in-home use of the T-REX daily for 45 to 60 minutes. Both groups received individualized home exercise programs designed by their treating PT. Outcomes were assessed via Knee injury and Osteoarthritis Outcome Score (KOOS), timed up-and-go (TUG), 6-minute walk test (6MWT), and the 30-second chair-stand test (CST). Measurements were taken prior to surgery and upon discharge from PT.

RESULTS: Repeated-measures MANOVA indicated a statistically significant main effect for time ($P < .001$), but not by group ($P = .571$) or group-by-time interaction ($P = .460$). All outcomes showed a significant improvement with time ($P < .05$). KOOS subscales showed a larger group-by-time improvement favoring SC over EG ($P < .05$) for 3 domains: symptoms (26.0 versus 11.2), pain (38.7 versus 24.3), and ADLs (38.4 versus 26.4). Both groups exceeded minimal detectable change values for TUG, CST, and KOOS; neither group exceeded MDC for 6MWT.

CONCLUSIONS: Post-TKA management yielded meaningful change in both SC and EG however KOOS scores favored SC over EG at discharge from PT.

CLINICAL RELEVANCE: Pressure to control rehabilitation costs continues to mount, especially in post-TKA cases. The use of T-REX with a reduced frequency of PT achieved improvements in functional and patient reported outcomes however the improvements were not equivalent to standard frequency PT.

OPL14

ALTERED NEUROMOTOR CONTROL IN ACHILLES TENDINOPATHY

Abbigail L. Fietzer, Kornelia Kulig

Few studies have examined neuromotor control aspects of Achilles tendinopathy (AT). This study uses the structure of movement variability (uncontrolled manifold analysis, UCM)—as a window into neuromotor control. UCM was conducted for the degree to which variability in foot, shank, and thigh positioning contributed to vertical limb length stabilization across hops. The importance of limb length is demonstrated by its inclusion as a control parameter in the spring-mass model of bouncing gait.

PURPOSE/HYPOTHESIS: To determine whether the structure of movement variability differs between those with and without AT, and if this difference is related to intratendinous structure.

NUMBER OF SUBJECTS: Fourteen currently asymptomatic individuals with unilateral AT and 14 controls matched for age, sex, and sport participated.

MATERIALS AND METHODS: Participants performed ≥ 27 consecutive unipedal hops at 2.0 Hz on a force plate while outfitted for motion capture. Bilateral limbs were tested; limbs were pooled bilaterally for controls. UCM was conducted across the stance phase to measure the degree of limb length stabilization (IMA), limb length-irrelevant variability (VUCM), and limb length-destabilizing variability (VORT). Intratendinous structure was assessed via peak spatial frequency radius (PSFR) on longitudinal ultrasonogram of the

Achilles tendon 2.5 cm proximal to the calcaneal insertion. PSFR has been previously shown to correlate to stiffness of tendinotic tendons and discriminate between those with and without AT, and is thought to represent the degree of collagen bundle density and organization within tendon. One-way ANOVA was run to determine differences among the limb types (tendinopathic [TL], uninvolved contralateral [UL], control [CL]) in PSFR and stance phase totals of UCM measures (IMA, VUCM, VORT). Pearson correlation was conducted to determine the relationship between PSFR and UCM measures.

RESULTS: There were large differences in PSFR among limb types ($P < .001$, $\eta^2 = 0.66$), with $CL > UL > TL$ collagen density and organization ($.001 \leq P \leq .03$). There was a trend toward a difference in IMA among limb types ($P = .09$, $\eta^2 = 0.15$); TL and UL tended to have lesser IMA than CL ($P = .14$). The lesser degree of limb length stabilization was driven by differences in VUCM ($P = .01$, $\eta^2 = 0.24$). TL ($P = .01$) and UL ($P = .02$) had lesser VUCM than CL. All limbs were similar in VORT ($P = .35$, $\eta^2 = 0.06$). PSFR was moderately correlated to VUCM ($P < .001$, $r = 0.57$), but was unrelated to IMA ($P = .35$, $r = 0.16$) or VORT ($P = .75$, $r = 0.06$).

CONCLUSIONS: This study demonstrates neuromotor control differences between those with and without AT. These differences are driven by a failure of the system to employ VUCM variability that promotes slightly different performance from hop to hop without detracting from limb length stabilization. Furthermore, tendon micromorphology explained >32% of the difference in VUCM employed.

CLINICAL RELEVANCE: There is not only localized tissue aberrance in cases of unilateral AT, but overall control system involvement, demonstrated by the bilateral deficit in VUCM in participants with a history of unilateral Achilles tendon symptoms.

OPL15

DO INTERVENTIONS AND RECOMMENDATIONS PROVIDED BY PHYSICAL THERAPISTS AND PHYSICIANS IN THE EMERGENCY DEPARTMENT DIFFER?

Rose Gagnon, Kadija Perreault, Simon Berthelot, Marie-Christine Laroche, Catherine Van Neste, Bertrand Achou, Francois Desmeules, Stéphane Tremblay, Luc J. Hébert

PURPOSE/HYPOTHESIS: In several countries, physiotherapists (PT) have been integrated in emergency departments (ED) for the triage and management of patients with musculoskeletal disorders (MSKD). PT involvement may help reduce the burden of waiting at the ED, emergency physician (EP) overload and unnecessary prescriptions and imaging. However, the benefits of the integration of PTs in EDs are still understudied. The objective of this project was to compare interventions and recommendations used between PTs and EPs for ED patients presenting with an MSKD.

NUMBER OF SUBJECTS: Seventy-eight subjects randomized either in the PT or EP groups.

MATERIALS AND METHODS: We conducted a pilot randomized controlled trial in an academic ED in Quebec City (Canada). We included patients aged 18 to 80 years with a minor MSKD, and excluded those with a major MSKD requiring urgent care, presenting a red flag or an unstable clinical condition, or those coming from a long-term care facility. The intervention group had direct access to a PT in the ED immediately after triage and prior to physician assessment and the control group received usual care by the EP without the intervention of the ED PT. Key variables measured were rate of hospitalizations, consults with another healthcare provider, requests for imaging and types of interventions used (advice, medication, technical aids) and were calculated using descriptive statistics and compared between groups using chi-square tests.

RESULTS: Seventy-eight patients were included either in the PT or EP groups (mean $\pm$ SD age, 40.2 ± 17.6 years; 44% women). Most frequent presenting complaints (traumatic or not) included spinal disorders (44.9%), ankle (15.4%) and knee injuries (15.4%). Regarding manage-

ment, 38% of patients in the PT group had an imaging test compared to 78% in the EP group ($P < .001$). Patients seen by the PT were recommended to consult another healthcare professional more often (85% versus 56%, $P = .005$). No significant differences were found between groups in the hospitalization rate (PT, 0% versus EP, 3%; $P = .289$), frequency of giving advice (83% versus 67%, $P = .184$) and use of technical aids (43% versus 33%, $P = .482$). Patients in the PT group were recommended less prescription medication (eg, opioids) (43% versus 67%, $P = .041$) and more over-the-counter medication (70% versus 11%, $P < .001$).

CONCLUSIONS: Based on our results, certain aspects of management of patients presenting to the ED for MSKD differed between groups. The next step of our study will be to look at the potential impact of these differences on patient clinical outcomes and costs.

CLINICAL RELEVANCE: ED overcrowding causes prolonged lengths of stay, increased rates of patient leaving without being seen, medical errors and mortality among ambulatory and nonambulatory patients and decreased patient satisfaction. This project measured the effects of integrating PTs into the ED in a hospital setting and helped identify ways to improve the current services offered to patients with an MSKD presenting to the ED. Direct access to PT may improve musculoskeletal health outcomes and support positive patient experience.

OPL16

SHORT-TERM OUTCOMES OF DRY NEEDLING FOR PATIENTS WITH MECHANICAL NECK PAIN: RANDOMIZED CLINICAL TRIAL

Eric R. Gattie, Joshua Cleland, Jeevan Jitendra Pandya, Suzanne Snodgrass

PURPOSE/HYPOTHESIS: The aim of this preliminary analysis is to examine the short-term effectiveness of dry needling delivered by a physical therapist on pain, disability, and patient-perceived improvements in patients with mechanical neck pain when added to a multimodal treatment program including manual therapy and exercise. We hypothesize that patients who receive dry needling, manual therapy, and exercise will achieve greater reductions in pain and disability in the short term (4 weeks) compared to those who receive sham dry needling, manual therapy, and exercise.

NUMBER OF SUBJECTS: Seventy-seven participants over the age of 18 with acute or chronic mechanical neck pain referred to physical therapy that satisfied eligibility criteria and agreed to participate in the study.

MATERIALS AND METHODS: Participants were randomized to receive (1) dry needling, manual therapy, and exercise or (2) sham dry needling, manual therapy, and exercise. Participants received 7 physical therapy treatments lasting 45 minutes each over a maximum of 4 weeks. The primary outcome assessed was disability as measured by the Neck Disability Index (NDI). Secondary outcomes include the following: pain measured by the visual analog scale (VAS) and patient-perceived improvement as measured by the global rating of change (GROC). Additionally side effects were recorded. Outcome measures were assessed at 4 weeks by a blinded assessor to determine the short-term treatment effects. Separate ANOVAs (2-way, repeated-measures analysis of variance with treatment group as the between-subjects variable and time as the within-subjects variable) were performed for each of the primary dependent variables: (NDI) and pain (VAS). The hypothesis of interest was the 2-way group by time interaction. An independent t test was performed to determine differences between GROC. An a priori alpha level of .05 was used for all analyses.

RESULTS: Seventy-seven participants with a mean age of 45.2 ± 17.36 years (80.9% female) satisfied the eligibility criteria and agreed to participate in the study. Repeated measure ANOVA did not find a statistically significant interaction between group and time at 4 weeks for disability ($P = .698$), current pain ($P = .932$), or last 24-hour pain ($P = .483$). Additionally the chi-square analysis did not demonstrate a difference between groups for GROC at the 4-week follow-up. Both groups demonstrated a significant improvement over time for all variables.

CONCLUSIONS: The short-term results suggest that dry needling in addition to manual therapy and exercise does not appear to add extra benefit in reducing disability, pain, or patient perceived improvement.

CLINICAL RELEVANCE: Dry needling is frequently used by physical therapists in the treatment of mechanical neck pain, but the evidence to support its utilization is lacking. The short-term results of this randomized clinical trial suggest that the incorporation of dry needling adds no additional benefit to best practice treatment of manual therapy and exercise in a population with mechanical neck pain.

OPL17

BILATERAL COMPARISONS AND ASSOCIATIONS BETWEEN QUADRICEPS STRENGTH, VOLUNTARY ACTIVATION, AND NEURAL EXCITABILITY WITH KNEE OSTEOARTHRITIS

Deborah Lynn Givens, Chris Lane, Richard Faldowski, Hope Davis, Steven Pfeiffer, Brian Pietrosimone

PURPOSE/HYPOTHESIS: Individuals with knee osteoarthritis (KOA) often have quadriceps weakness and voluntary activation deficits. Altered neural excitability may underlie these deficits and locating areas of CNS involvement may inform clinical interventions. The purpose was to examine bilateral differences and associations in the active motor threshold (AMT), a measure of corticospinal excitability, and intracortical facilitation (ICF) and short interval intracortical inhibition (SICI), which measure intracortical excitability. We expected lower quadriceps strength and voluntary activation would be associated with lower quadriceps neural excitability, and the more involved (INV) knee compared to the less involved or “uninvolved” (UN) knee would show lower strength and voluntary activation, higher AMT (lower corticospinal excitability), and lower ICF and SICI (lower facilitation/greater inhibition).

NUMBER OF SUBJECTS: Fourteen (4 male, 10 female; mean $\pm$ SD age, 62.79 $\pm$ 7.55 years; body mass index, 27.65 $\pm$ 3.63 kg/m²).

MATERIALS AND METHODS: Adults (40–75 years) with KOA with primary unilateral symptoms volunteered for this cross-sectional study. Quadriceps strength was recorded as maximum voluntary contraction (MVC) using a HUMAC dynamometer at 70° knee flexion. Central activation ratio (CAR), measuring quadriceps voluntary activation, was recorded with a burst-superimposition protocol. AMT, ICF, and SICI were measured via motor evoked potentials using single- and paired-pulse transcranial magnetic stimulation (TMS) (Magstim BiStim2) over the primary motor cortex. Between-limb differences were examined with 2-tailed Wilcoxon signed rank tests. Between variable associations were estimated with Spearman rank correlations.

RESULTS: Involved-limb MVC (105.75 $\pm$ 50.36 Nm) was less than UN limb (134.60 $\pm$ 50.61 Nm, $P \leq .003$). No differences were found between INV limb CAR (86.52% $\pm$ 8.58%) and UN limb (85.74% $\pm$ 10.67%, $P \leq .27$), INV limb AMT (56.62% $\pm$ 12.28%) and UN limb (54.85% $\pm$ 10.60%, $P \leq .75$), or INV limb ICF (1.85 $\pm$ 1.96 μ V) and UN limb (1.60 $\pm$ 1.12 μ V, $P \leq .55$). INV limb SICI (0.57 $\pm$ 0.24 μ V) was less than UN limb (0.72 $\pm$ 0.31 μ V, $P \leq .023$). Lower INV limb MVC was associated with higher AMT ($r = -0.66$, $P \leq .015$). No associations were found between INV limb MVC and INV limb CAR ($r = 0.26$, $P \leq .42$), ICF ($r = -0.38$, $P \leq .31$), or SICI ($r = -0.55$, $P \leq .125$); or between INV limb CAR and INV limb AMT ($r = 0.12$, $P \leq .72$), ICF ($r = -0.52$, $P \leq .18$), or SICI ($r = 0$, $P \leq .1$).

CONCLUSIONS: Adults with KOA had lower quadriceps strength and greater inhibition of intracortical excitability in INV versus UN knees. Mean CAR of each knee was about 86%, suggesting bilateral voluntary activation deficits compared to healthy controls, which tend to be greater than 90%. As expected, lower strength was associated with lower corticospinal excitability.

CLINICAL RELEVANCE: Individuals with KOA may have lower strength, bilateral activation deficits, and neural excitability differences. Interventions, such as repetitive TMS may alter neural excitability and improve these outcomes, require further study.

OPL18

PATIENT-REPORTED OUTCOME MEASURE COLLECTION FOR MUSCULOSKELETAL PAIN: PRELIMINARY ASSESSMENT ACROSS AN OUTPATIENT DIVISION

Michael Brian Hagist, Jane Crittenden, John Kaperak, Victor DeRienzo, Ann Leinenwever, Jackie Oetjen, Laura Fitzgerald Langer, Jeremy Montz, Jennifer Lynn Hagist, Sara Elizabeth Cristello, Jason M. Beneciuk

PURPOSE/HYPOTHESIS: To describe the process and preliminary assessment of an ongoing quality improvement initiative for enhancing routine collection of patient-reported outcome measures (PROMs) for musculoskeletal pain conditions.

NUMBER OF SUBJECTS: Outpatient rehabilitation clinics ($n = 29$).

MATERIALS AND METHODS: Between June 2017 and April 2019, outpatient clinics as part of a single health system received training to routinely collect PROMs for patients receiving physical therapy for musculoskeletal pain as part of an ongoing quality improvement initiative. PROMs were selected (numeric pain-rating scale [NPRS], Oswestry Disability Index [ODI], Neck Disability Index [NDI], Lower Extremity Functional Scale [LEFS], and QuickDASH) based on focus group meetings with clinician and research stakeholders. Initial 2-hour training emphasized: (1) value associated with outcome measures collection (ie, allows for self-reflection; benchmarking across system; enhanced patient engagement) and (2) PROM collection using iPads at initial visit, every 2 weeks, and at discharge. Routine clinician feedback was used to optimize PROM data collection experience and clinical dashboards were developed to enhance internal dissemination. Approximately one half ($n = 14$, 48.3%) of all outpatient rehabilitation clinics received training by June 2018 and actively contributed quality improvement data to an internal database. Descriptive statistics were used to describe intake and follow-up assessment rates. **RESULTS:** Between June 2018 and May 2019, across trained outpatient clinics, 18 018 orthopaedic physical therapy evaluations were conducted. Intake capture rates improved from 48% to 70% (52% on average), while follow-up rates remained low at 25% to 20% (22% on average).

CONCLUSIONS: Over 12 months, favorable improvements for intake capture rates were observed, however follow-up rates remained low. These findings need to be interpreted with caution as initial phases of this quality improvement initiative were focused on identifying and addressing barriers and facilitators for clinicians to “collect” PROMs, while importance of follow-up capture and sufficiently educating clinicians on how to efficiently use this information in real time clinical practice was not emphasized.

CLINICAL RELEVANCE: These preliminary quality improvement findings indicate collection of PROM data for musculoskeletal pain conditions at initial evaluation can be improved; however, additional mentoring to emphasize value of follow-up assessment for individual physical therapist self-reflection, enhanced patient engagement, and benchmarking across outpatient division of health systems is needed. Longer-term results will inform the iterative quality improvement process to identify and address additional barriers to implementing PROMs to improve clinical outcomes in this health system.

OPL19

HIGHER KINESIOPHOBIA IS PRESENT IN PATIENTS WITH ACHILLES TENDINOPATHY WITH A LONGER DURATION OF SYMPTOMS

Shawn Hanlon, Karin Gräware Silbernagel

PURPOSE/HYPOTHESIS: Tendon pain associated with Achilles tendinopathy can be present for years and remains a clinical challenge. Psychological factors such as kinesiophobia (fear of movement) and pain catastrophizing commonly accompany persistent tendon pain. If the degree of kinesiophobia and pain catastrophizing is related to the length of time a patient has experienced symptoms is not known. However, a better understanding of the relationship between psychological factors, function, symptoms and

symptom duration would be beneficial for improving clinical treatment strategies. Therefore, the purpose of this study was to compare the degree of kinesiophobia, pain catastrophizing, symptom severity, and muscle-tendon performance between patients with short (<6 months) and long (>6 months) duration of symptoms. We hypothesized that patients experiencing symptoms longer will present with higher degrees of kinesiophobia, pain catastrophizing, symptoms and functional deficits.

NUMBER OF SUBJECTS: Ninety-seven subjects (58 men; mean $\pm$ SD age, 51 $\pm$ 16 years) with Achilles tendinopathy, with no history of Achilles surgery or rupture.

MATERIALS AND METHODS: Diagnosis was confirmed by a standardized clinical exam and ultrasonographic imaging. Subjects were dichotomized into 2 groups based on duration of symptoms: short-term (ST) (<6 months) and long-term (LT) (>6 months). The dependent variables were Tampa Scale of Kinesiophobia (TSK), Pain Catastrophizing Scale (PCS), Physical Activity Scale (PAS), Victorian Institute of Sport Assessment-Achilles (VISA-A) score, and the heel rise endurance test. Differences between groups were assessed using Mann-Whitney *U* tests for each variable.

RESULTS: The duration of symptoms reported for LT group (*n* = 60) was a median (IQR) of 15 ($\pm$ 19) months and for the ST group (*n* = 37) of 3 ($\pm$ 2) months. The LT group had significantly higher TSK scores of 40 ($\pm$ 7) compared to ST group of 35 ($\pm$ 9) (*P* = .001). The LT group performed significantly less heel rise work (1096 $\pm$ 1275 J) compared to the ST group (1681 $\pm$ 1264 J, *P* = .01). The LT group reported higher PCS scores of 8 ($\pm$ 11) compared to the ST group of 6 ($\pm$ 8); however, this difference was not statistically significant (*P* = .11). The LT group had significantly lower VISA-A scores of 73 ($\pm$ 29) compared to the ST group of 51 ($\pm$ 35) (*P* = .001). PAS scores, sex, and age did not differ between groups.

CONCLUSIONS: Patients with Achilles tendinopathy who experienced symptoms greater than 6 months had a higher degree of kinesiophobia, greater functional deficit, less symptoms, and similar pain catastrophizing and physical activity levels compared to those with short-term symptoms.

CLINICAL RELEVANCE: When evaluating patients who experience Achilles tendinopathy symptoms lasting greater than 6 months, despite reporting moderate-high physical activity levels. Patients with longer duration symptoms may benefit from pain science education in addition to exercise treatment.

OP120

EVALUATION OF GUIDELINE-ADHERENT EDUCATION FOR THERAPISTS SEEING PATIENTS IN AN OPTIMIZED EARLY PHYSICAL THERAPY PATHWAY

Hank Havlin, Thomas R. Denninger, Adam Daniel Lutz, Ellen Shanley, Michael Kissenberth, Charles Alden Thigpen

PURPOSE/HYPOTHESIS: Guideline adherence is thought to decrease variation in care and in turn deliver improved patient outcomes at a lower cost. However, it is unclear how to disseminate and implement guideline care into practice. Therefore, the purpose of this study is evaluate therapists guideline fidelity relative to the program tenets of guideline care in the preprogram workshop.

NUMBER OF SUBJECTS: One hundred twenty charts of patients with back (*n* = 34), neck (*n* = 24), knee (*n* = 30), and shoulder (*n* = 32) complaints treated by therapists (*n* = 99) who underwent training in guideline adherent care pathways.

MATERIALS AND METHODS: Physical therapists (*n* = 99) completed a standardized 6-hour training across MSK conditions in a staged algorithm for diagnosis and treatment classification. A random sample of their patients (*n* = 120) were selected from all patients (*n* = 592) that participated in a targeted "early physical therapy" program for MSK conditions in 2018. A tool to assess fidelity of symptom irritability and treatment delivered was utilized to assess compliance to training during manual chart review. Each of the 10 items was scored "yes" or "no" based upon adherence to a component of the guideline-based care model based off of patient initial presenting diagnosis, irritability and treatment delivered. Addition-

ally, a composite score summed all yes responses for a maximum possible score of 10. High, moderate, and low fidelity was determined based on cut scores associated with achieving clinically important improvements in patient reported outcomes in a prior study.

RESULTS: Therapists displayed high (18.3%), moderate (66.7%), and low fidelity (15%) fidelity across all body regions. Shoulder (44.4%) and back (33.3%) comprised the majority of low fidelity patient cases across the sample. As the intent of training was to minimize low fidelity treatment, considered to consistent of treatment that was least guideline care. Shoulder cases demonstrated the highest rate of low fidelity treatment, with 25% of patients receiving low fidelity care. Patients with back pain received low fidelity care 17.6% of the time. Knee (10%) and neck (4.2%) received low value care significantly less frequently.

CONCLUSIONS: Our results show lower treatment fidelity for back and shoulder conditions compared to neck and knee. This suggests improvements in educational approach is needed including review the training content, post course follow, and pre-education measures. Future study is required to deliver a sustainable program that decreases unwanted variability in care.

CLINICAL RELEVANCE: There was significant variability in observed levels of treatment fidelity post training across body regions.

OP121

SCORING METHOD OF THE OPTIMAL SCREENING FOR PREDICTION OF REFERRAL AND OUTCOME-YELLOW FLAG TOOL DOES NOT CHANGE PREDICTION OF PAIN REDUCTION AT 12 MONTHS

Maggie Elizabeth Horn, Steven Z. George, Cai Li, Sheng Luo, Trevor Anthony Lentz

PURPOSE/HYPOTHESIS: The overall purpose of this analysis is to investigate the clinical utility of scoring methods for the OSPRO-yellow flag tool. In particular, we are interested in determining what methods of OSPRO-YF tool scoring can be used to enhance clinical decision making and ease of administration. Traditionally, the OSPRO-YF tool is scored by reporting the total number of yellow flags derived from the relative weighted contributions of each item, with the increasing number of yellow flags indicating higher pain associated distress or lower adaptive ability. Alternatively, the simple summary score for the OSPRO-YF tool is a score derived from the raw sum of individual items. The aim of this analysis was to determine if using the simple summary score of the OSPRO-YF tool has similar predictive accuracy for 12-month pain reduction as the OSPRO-YF yellow flag count. In addition to considering scoring method, this analysis also compared the predictive ability of the scoring methods for the 10- and 17-item versions of the OSPRO-YF tool.

NUMBER OF SUBJECTS: This is a secondary analysis from the Optimal Screening for Prediction of Referral and Outcome (OSPRO) validation cohort. Subjects in this cohort were recruited through the Orthopedic Physical Therapy Investigator's Network (OPT-IN) and seeking physical therapy for neck, low back, knee or shoulder pain. This analysis included 440 subjects (62.5% female; mean $\pm$ SD age, 45.1 $\pm$ 17 years) at baseline, with 279 (63.4%) providing follow-up data at 12 months.

MATERIALS AND METHODS: We dichotomized the outcome based on 50% reduction in pain intensity score from baseline to 12 months. We evaluated 4 logistic regression models to examine the relationship between a 50% reduction in pain and simple summary baseline score of (a) 10-item OSPRO-YF and (b) 17-item OSPRO-YF; and baseline yellow flag count for (a) 10-item OSPRO-YF and (b) 17-item OSPRO-YF. In each of the regression models, we included demographic factors and OSPRO-YF change scores at 4 weeks, 6 months and 12 months. The area under the curve (AUC) was used to determine model performance and Akaike Information Criterion (AIC) to determine model quality. All data analyses were preformed using R Version 3.6.0 (Vienna, Austria).

RESULTS: All models for the simple summary score and the yellow flag count for both the OSPRO-10 and OSPRO-17 demonstrated the same

model performance (AUC = 0.78) and similar model quality (AIC = 419.91-420.63).

CONCLUSIONS: Scoring the OSPRO-YF tool by the simple summary score method or yellow flag count yielded similar predictive accuracy and demonstrated good model performance and quality. Furthermore, the 17- and 10-item versions of the tool performed similarly for each scoring method.

CLINICAL RELEVANCE: These findings provide support for flexibility in scoring method used for predicting outcomes with the OSPRO-YF tool. Real-time scoring of the OSPRO-YF can be labor intensive, unless embedded within the EHR. The ability to use either the simple summary score of items or the yellow flag count may promote ease of interpretation and wider adoption of the tool.

OPL22

DOES SPINAL MANIPULATION THERAPY TARGET CENTRAL DRIVERS OF PAIN IN INDIVIDUALS WITH SUBACROMIAL IMPINGEMENT SYNDROME?

Melody Muliawan Hsu, Joseph Rahmon Kardouni, Amy Hegarty, Jean-Sébastien Roy, Lori Michener

PURPOSE/HYPOTHESIS: Both peripheral and central drivers of musculoskeletal pain must be considered to optimize treatments. Thoracic spinal manipulation therapy (SMT), known to target central pathways of pain processing, is an effective treatment tool for individuals with shoulder pain. However, not all patients respond, and mechanisms underlying SMT are not well understood. This study will evaluate the effects of SMT on muscle activity using electromyography (EMG) of shoulder muscles to explore centrally mediated changes in motor control. We hypothesize that muscle activity during arm elevation will increase after SMT, and these changes will be correlated to changes in joint torque.

NUMBER OF SUBJECTS: Fifty-four participants with subacromial pain syndrome (SAPS) were recruited. Inclusion criteria included a positive on 3 out of 5 tests for SAPS, and a numeric pain rating of 2/10 for 6 or more weeks.

MATERIALS AND METHODS: EMG assessment of 6 muscles (upper, middle, and lower trapezius, infraspinatus, serratus anterior, and middle deltoid) during arm elevation were performed similar to previous work before and after SMT (2 manipulations to the lower, middle, and upper thoracic spine) or sham-SMT (same positions as the SMT, but no applied thrust). Participants were randomly assigned to either SMT or sham-SMT. Joint torque, measured using a dynamometer, and EMG were also captured during a maximum voluntary contraction (MVC) with the arm at 90° elevation in the scapular plane. Muscle activity was normalized using peak EMG from baseline MVC. Average EMG activity during elevation (30°-120°) was compared using a linear mixed effects model where time (pre, post), group (SMT, sham-SMT), and time-by-group were included as fixed effects with a subject-specific random intercept ($\alpha = .05$). The relationship between changes across time in EMG and joint torque was evaluated using Pearson's correlation.

RESULTS: Significant main effect of time was found for the upper trapezius, with increased activity after intervention (mean difference, 7.2%; 95% CI: 2.6%, 11.7%; $P = .002$) and no significant time-by-group interactions were found ($P = .107$). Changes in upper trapezius EMG activity during elevation and scapular plane elevation joint torque were positively correlated ($r = 0.29$, $P = .033$).

CONCLUSIONS: The results of this study suggest central effects from both interventions (SMT and sham-SMT) influence changes in motor control. Nonspecific effects such as patient-clinician interaction, touch sensation, and expectation of treatment may contribute not only to pain perception, but also central effects on motor control. We speculate changes in muscle activity were localized to the upper trapezius because of its relative proximity to the location of manipulation/hand placement and its role during the elevation task. Differentiating the mechanisms of both SMT and sham-SMT should be explored in future work.

CLINICAL RELEVANCE: Specific and nonspecific effects of SMT may provide

therapeutic benefit by inducing immediate motor control changes in patients with shoulder pain.

OPL23

LOWER RATES OF OPIOID PRESCRIPTION WITH INCREASED REFERRAL TO PHYSICAL THERAPY BY PHYSICIANS WHO TREAT LOW BACK PAIN

Stephen J. Hunter, Devyn N. Woodfield, Kate Minick, Cara Camiolo Reddy

PURPOSE/HYPOTHESIS: The purpose of this study was to analyze if physicians who refer a higher percentage of patients to physical therapy (PT) prescribe fewer opioid medications in patients with low back pain.

NUMBER OF SUBJECTS: We analyzed 562 physicians who had at least 50 patient encounters experiencing low back pain during the study period. The physicians included were in 3 practice settings; emergency departments, primary care outpatient, and acute care walk-in clinics. For this study we will define all 3 settings as "primary care." We analyzed 71916 patients experiencing low back pain from January 1, 2018 through July 7, 2019. Patients were excluded who had an encounter for low back pain in the previous 6 months, all others were considered to have a "first visit." We define an opioid prescription to be an opioid prescribed during the patient's "first visit" for low back pain, and the patient had no prescribed opioid use in the 6 months leading up to the encounter, which we term as an "opioid naïve" prescription.

MATERIALS AND METHODS: Physician referral rates for PT and opioid prescription of patients with a diagnosis of low back pain were analyzed within a large integrated not-for-profit health care system. A group of 160 ICD-10 codes (used in prior studies) were used to determine those included in the low back pain cohort. A t test was used to determine the statistical significance of the correlation coefficient between opioid prescription rates and PT referral rates.

RESULTS: Of the 71916 patients who had "first visits," 11.83% received an opioid prescription and 8.84% received a referral for PT. The overall correlation for the described population of patients is -0.3313 , which results in a statistically significant P value of less than .0001 by using the t test described above.

CONCLUSIONS: There is a statistically significant correlation with primary care physicians who prescribe PT and make opioid prescription. Those who refer a higher percentage of low back pain patients to PT prescribed significantly less opioid medication. Future research is needed to determine why this correlation was found.

CLINICAL RELEVANCE: With a current focus on reducing opioid prescriptions as an option for relief of low back pain, physical therapy is a low risk, relatively low-cost viable option. The results from this study might influence more physicians to refer patients to physical therapy as an alternative to prescribing opioid medications.

OPL24

HIGH SCHOOL ATHLETE PERFORMANCE TESTING AT RETURN TO PLAY IS LOWER COMPARED TO BASELINE

Edward Raymond Jones, Jessica Jochum, Ellen Hornett, Briana Kaye Leonard, Claire Moorman, Brooke Stevenson, Austin William Kiel, Jacob Roop, Victoria Schaefer

PURPOSE/HYPOTHESIS: Functional performance tests have been used to assess components of sport performance and to determine readiness for return to play following injury. The Y-Balance Test, and single-limb hop tests, are commonly used in this decision. There is little evidence comparing baseline scores on these tests to postinjury scores for return to play decisions across sports with lower extremity injury in the adolescent athletic population. The primary objective of this study is to compare scores from functional performance tests (T test for agility, Y-Balance Test, and single-limb hop tests) at the time of release to return to sport following a lower extremity injury to preseason baseline scores.

NUMBER OF SUBJECTS: Two hundred ninety-five baseline tested; 14 injured were retested.

MATERIALS AND METHODS: This is a prospective repeated-measures study of varsity athletes at 2 Indianapolis-area high schools. Demographic data and score for each of the following tests were recorded during a single testing session prior to the start of the athletic season: T test for agility, Y-Balance Test, and a series of single-leg hop tests (single hop, triple hop, crossover hop). Athletic trainers employed at the schools then conducted injury surveillance during their respective sports season. In those participants sustaining an injury during the season (defined as 5 consecutive missed team events or restriction from participation by a healthcare provider), scores were remeasured at the time of release to return to play. Paired-samples *t* tests were used to evaluate differences between scores recorded in the preseason testing and the scores recorded at the time of release to return to sport for each participant.

RESULTS: Of the 295 athletes with baseline testing, 14 sustained a LE injury meeting criteria (7 knee, 4 ankle, 3 hip). Y-Balance measurements at time of release to return to play were lower in all directions with anterior reach measurements reaching statistical significance ($P = .035$). All hop testing measurements were also lower at time of release to return to play with statistically significant differences noted for single hop ($P = .017$) and crossover hop ($P = .024$) tests. In addition, the limb symmetry indices on all hop tests (single, triple, crossover) were below 90% at time of release for return to play but baseline scores were over 90%. The T test for agility scores were also lower at time of return to play, with cutting to the left having statistically significant difference ($P = .048$) but not cutting to the right ($P = .059$).

CONCLUSIONS: Performance on functional performance testing for athletes is lower than baseline scores when retested at time of return to play which could indicate that these athletes are at greater risk for reinjury. These findings highlight the need for objective data to guide the decision to release high school athletes for participation following a LE injury.

CLINICAL RELEVANCE: These findings could indicate that high school athletes may be at greater risk for lower extremity reinjury when objective data is not used for the decision to return to play.

OPL25

TASK-BASED FUNCTIONAL CONNECTIVITY DURING LUMBOPELVIC MOTOR TASKS: A FUNCTIONAL MAGNETIC RESONANCE IMAGING STUDY IN HEALTHY PARTICIPANTS

Max Jordon, Paul F. Beattie, Sheri P. Silfies, Joel Eric Bialosky, Jill Campbell Stewart

PURPOSE/HYPOTHESIS: Peripheral models do not fully explain the development and persistence of chronic low back pain (cLBP) resulting in a shift in focus toward the role of cortical function. A promising method to study cLBP related changes in cortical function is through functional magnetic resonance imaging (fMRI). However, research into the role of central motor systems and pain processing has primarily relied on the performance of upper extremity motor tasks. Investigations into cLBP necessitate the utilization of lumbopelvic motor tasks. Previous research has shown that during lumbopelvic motor tasks the medial portion of the sensorimotor regions of the brain are active. However, a better understanding of the functional connectivity will give researchers a better understanding of the communication between different brain regions that occur during these motor tasks. Therefore, the purpose of the study was to determine the functional connectivity in the brain that occurs during the performance of lumbopelvic motor tasks in healthy individuals.

NUMBER OF SUBJECTS: Seventeen pain-free participants (10 female; mean $\pm$ SD age, 27.8 ± 5.8 years).

MATERIALS AND METHODS: Participants were trained to perform modified bridging tasks in which they pushed the back of the left knee, right knee, or both knees into a 22-cm bolster while undergoing fMRI of the brain. These tasks were chosen specifically to engage the musculature of the lumbopelvic region and replicate common coordinated activation of movement. Functional connectivity, measured using both region-of-

interest (ROI)-to-ROI and seed-to-voxel approaches, of a constrained motor network (bilateral precentral gyrus (PreCG), bilateral postcentral gyrus (PostCG), and bilateral supplementary motor area (SMA) was measured.

RESULTS: Group-level ROI-to-ROI and seed-to-voxel analysis revealed significant correlations between all ROIs within the constrained motor network except for the left SMA to left PostCG during unilateral bridging tasks. The seed-to-voxel analysis demonstrated significant correlations between the sensorimotor network of the bilateral SMA, PreCG, and PostCG. Additional connections were found between the bilateral PostCG and the left Precuneus and the left PreCG and the left superior frontal gyrus.

CONCLUSIONS: As expected, functional connectivity analyses revealed significant communication within the sensorimotor regions of the SMA, PreCG, and PostCG during the performance of lumbopelvic motor tasks. In addition to these regions, the precuneus was functionally connected to the PostCG and superior frontal gyrus was functionally connected to the PreCG. Together, these regions are capable of planning spatially complex tasks, coordinating movements between multiple motor regions, preparing motor patterns, executing the motor tasks, and receiving sensory feedback to assist with sensorimotor integration and adjusting the motor output as needed.

CLINICAL RELEVANCE: This study lays a foundation for future investigations that examine how this motor network might be altered in individuals who exhibit low back pain.

OPL26

WILL THE PATIENT-REPORTED OUTCOMES MEASUREMENT INFORMATION SYSTEM SELF-EFFICACY SCALE ASSIST PROVIDERS IN MAKING CLINICAL DECISIONS?

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PURPOSE/HYPOTHESIS: To demonstrate that Patient-Reported Outcomes Measurement Information System (PROMIS) Self-Efficacy for Managing Symptoms (SEsx) identifies people with greater needs who are attending an outpatient orthopedic setting. Hypotheses: (1) there would be univariate associations of unacceptable PROMIS SEsx with unacceptable Pain Interference (PI), Physical Function (PF) and Fatigue symptoms; (2) the proportion of patients with combinations of unacceptable PI, PF, and higher Fatigue symptoms would be associated with unacceptable SEsx; and (3) the combination of unacceptable PROMIS scales (SEsx, Fatigue, PF) will predict unacceptable PROMIS PI, demonstrating the importance of using all scales, including SEsx, separately for clinical decisions.

NUMBER OF SUBJECTS: One hundred fifty-six.

MATERIALS AND METHODS: PROMIS computer adaptive tests (PF, PI, Fatigue, SEsx) were administered at initial evaluation for spine (37.2%), lower extremity (32.7%), upper extremity (16.7%), multiple regions (9.0%), and other reasons (4.5%). PROMIS T scores were coded (1, 0) when their score was worse than a patient acceptable symptom state (ie unacceptable low). Unacceptable T scores: PF <40, PI >55, Fatigue >55, SE <45. The proportion of patients with unacceptable SEsx and any combination of other unacceptable symptoms was also determined. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated to examine the associations of unacceptable SEsx with other unacceptable PROMIS symptoms. A logistic regression model including age, gender, unacceptable PROMIS PF, SEsx, and Fatigue was evaluated for ability to independently predict unacceptable PROMIS PI.

RESULTS: Patient age range was 18 to 88 years (average $\pm$ SD, 42.5 ± 19.5 years), with 66% female. The T score average $\pm$ SD for PF was 44.0 ± 8.4 ; PI was 58.8 ± 7.3 ; Fatigue was 53.6 ± 9.1 , and SEsx was 45.8 ± 7.3 . The proportion of patients with unacceptable symptoms were: PF, 30.8%; PI 60.9%; Fatigue, 56.8%, and SEsx, 43.2%. The proportion of patients with any combination of unacceptable symptoms other than SEsx was 70.1%.

A total of 19.4% reported all symptoms at unacceptable levels. Unacceptable SEsx was significantly associated with: unacceptable PI (OR = 12.98; 95% CI: 5.32, 31.66), unacceptable PF (OR = 7.35; 95% CI: 2.0, 16.0), and unacceptable Fatigue (OR = 3.76; 95% CI: 1.92, 7.36), and any combination of unacceptable symptoms (OR = 6.80; 95% CI: 2.8, 16.6). Logistic regression showed that unacceptable PF (OR = 8.20; 95% CI: 2.23, 30.86), unacceptable Fatigue (OR = 3.31; 95% CI: 1.38, 7.96), and unacceptable SEsx (OR = 7.04; 95% CI: 2.69, 18.43) were independent predictors of unacceptable PI. Age was dropped from the model because the OR was close to 1 (OR = 0.966) and gender was not significant.

CONCLUSIONS: Patient confidence (ie, SEsx) in managing their symptoms was a strong independent predictor of common symptoms in orthopedics (pain, physical ability, and fatigue).

CLINICAL RELEVANCE: Providers should consider using PROMIS SEsx as a practical, efficient and meaningful tool to assess patient confidence and engage patients with orthopedics problems.

OPL27

COMPARISON BETWEEN MOVEMENT-PATTERN TRAINING AND STRENGTHENING ON MUSCLE VOLUME AND STRENGTH FOR HIP PAIN

Kristen Koch, Paul K. Commean, Travis J. Hillen, Michael Jeffrey Mueller, John C. Clohisy, Marcie Harris-Hayes

PURPOSE/HYPOTHESIS: Hip abductor weakness exists in patients with Hip-Related Groin Pain (HRGP). We investigated if movement pattern training (MPT) would result in similar muscle volume and strength changes compared to standard strengthening (STND). The purpose of this study was to compare the effects of MPT to STND on muscle volume and strength in patients with HRGP. We hypothesized both groups would have increased muscle volume and strength after treatment, but Stand group would have significantly greater gains.

NUMBER OF SUBJECTS: Twenty-seven.

MATERIALS AND METHODS: This study was a secondary analysis of a randomized control trial. Patients with HRGP, 15 to 40 years, were randomized into MPT (n = 14) or STND (n = 13) groups. Both groups participated in 10 supervised sessions over 12 weeks and a home exercise program performed daily. The goal of MPT was to optimize biomechanics during daily tasks, such as rising from and lowering to a chair, stair ambulation and patient-specific tasks. The goal of STND was to increase lower extremity and trunk strength and increase lower extremity flexibility. Both groups progressed by increasing difficulty or resistance based on patient performance. To assess hip abductor strength, make tests were performed using a handheld dynamometer with the patient in sidelying. Magnetic resonance imaging was used to acquire 3-D images for muscle volume evaluation. Combined measurements of the primary hip abductors (GMed and Gmin) was completed from multiple coronal slices using commercial software. All measurements were completed by a research assistant, blinded to group. Change scores for muscle volume and strength were calculated by subtracting pretreatment from posttreatment values. Shapiro-Wilk test and Levene's test were used to confirm normality and homogeneity of variance, respectively. Independent *t* tests were used to assess between-group differences.

RESULTS: Fourteen participants were randomized to MPT (8 female, 6 male; mean $\pm$ SD age, 27.4 ± 4.9 years; BMI, 23.6 ± 3.2 kg/m²) and 13 were randomized to STD (8 female, 5 male; age, 29.2 ± 5.4 years; BMI, 25.3 ± 6.8 kg/m²). There was a significant between-group difference for muscle volume change; STD demonstrated a significant increase in muscle volume compared to MPT (5.5 ± 4.4 cm³ [2.5%] versus 0.50 ± 0.45 cm³ [0.2%], *P* = .007). Both groups demonstrated an increase in hip abductor strength, however, there were no differences between STND and MPT (13.0 ± 27.0 Nm [11%] versus 13.3 ± 22.4 Nm [12%], *P* = .98). Both groups in the parent study demonstrated improved hip-specific function with increases in all subscales of the Hip disability and Osteoarthritis Outcome Score (reported previously).

CONCLUSIONS: MPT and STND may be equally effective at improving hip abductor strength; however, STND resulted in greater increases in muscle volume. The mechanism underlying the strength changes in MPT is unclear.

CLINICAL RELEVANCE: Movement pattern training and a program of strength/flexibility training may be appropriate options for increasing strength in patients with HRGP, however future research is needed to better understand mechanisms underlying strength changes and correlation with symptom relief.

OPL28

PHYSICAL THERAPY IS ASSOCIATED WITH REDUCED OPIOID UTILIZATION IN PEOPLE WITH KNEE OSTEOARTHRITIS

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PURPOSE/HYPOTHESIS: To investigate the associations of type, dose, and timing of physical therapy (PT) with utilization of opioids in individuals with incident knee osteoarthritis (OA) who had used opioids in the past or were opioid naïve, using data from a large claims database.

NUMBER OF SUBJECTS: There were 32 324 opioid-experienced and 39 302 opioid-naïve individuals with knee OA.

MATERIALS AND METHODS: We used 2000-2014 data from the OptumLabs Data Warehouse (OLDW), a longitudinal, real-world dataset with de-identified administrative claims and electronic health record (EHR) data. Sample included adults ages of 40-plus, who after ≥ 6 months of claims data, had a knee OA diagnosis (ICD9), received PT within 12 months of diagnosis, and had at least 1 year of follow-up after the first PT episode of care (EOC). The first PT EOC was considered to start with an initial PT evaluation followed by at least 1 treatment session, and was considered to end if there was a 4-week period with no PT claim or if a second evaluation was recorded. PT exposures included dose (≤ 5 , 6-12, >12 sessions), timing (<3 , 3- <6 , 6- <9 , 9- <12 months), and type (active, passive). The outcome was any opioid use in the 12 months after the end of the PT EOC. Opioid use was at least 2 filled prescriptions of opioids commonly used for musculoskeletal pain, excluding combinations of opioids with medications commonly used for cough, nasal congestion, and headache. Analyses were stratified by individuals who had ("opioid experienced") and those who had not ("opioid naïve") used opioids prior to PT. Covariates included age, hyperlipidemia, diabetes, and overweight/obesity. Adjusted odds (aOR) of receiving opioids were assessed using logistic regression.

RESULTS: We included 32 324 opioid-experienced (mean $\pm$ SD age, 60.9 ± 10.3 years; 61.5% female) and 39 302 opioid-naïve individuals (age, 62.6 ± 11.2 years; 66.0% female). Overall prevalence of opioid use in the 12 months following the first PT EOC was 58.5% in the opioid experienced group and 15.5% in the opioid naïve group. Compared to 1 to 5 sessions of PT, 6 to 12 and >12 sessions were associated with reduced odds of opioid use among both opioid-experienced (6-12 aOR = 0.65; CI: 0.62, 0.69; >12 aOR = 0.49; CI: 0.47, 0.52) and opioid-naïve (6-12 aOR = 0.79; CI: 0.74, 0.84; >12 aOR = 0.77; CI: 0.70, 0.84) individuals. Compared to receiving PT within <3 months of diagnosis, PT >3 months in opioid-naïve (3- <6 aOR = 1.26; CI: 1.17, 1.37; 6- <9 aOR = 1.14; CI: 1.03, 1.26; 9- <12 aOR = 1.11; CI: 1.00, 1.25) and PT >6 months in opioid-experienced (6- <9 aOR = 1.10; CI: 1.03, 1.17; 9- <12 aOR = 1.20; CI: 1.11, 1.29) was associated with greater odds of opioid use. Receiving active PT (versus passive PT) was associated with reduced odds of further opioid use in opioid experienced (aOR = 0.86; CI: 0.82, 0.91) individuals but not in the opioid naïve group (aOR = 1.00; CI: 0.94, 1.06).

CONCLUSIONS: PT provided earlier after OA diagnosis, more than 5 sessions of PT, and use of active PT interventions may reduce opioid use in people with knee OA.

CLINICAL RELEVANCE: These results provide guidance on optimal dosage,

timing, and type of PT interventions that might be effective at reducing opioid use in this population.

OPL29

DEVELOPMENT OF A CLINICAL PRACTICE GUIDELINE FOR ADULTS AND WORKERS WITH ROTATOR CUFF DISORDERS

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PURPOSE/HYPOTHESIS: Shoulder pain is highly prevalent and is frequently related to rotator cuff (RC) disorders. Currently, clinicians do not have a standardized approach to manage adults and workers with RC disorders. There are few published clinical practice guidelines (CPG) to support clinicians regarding the assessment, treatment and return to work of adults with RC disorders. The published CPGs often rely on very limited evidence and did not use a systematic and transparent development process. The aim of this project was to develop, using established rigorous standards, a CPG to optimize the assessment, conservative and surgical treatments, as well as the return to work processes for adults and workers with a RC disorders.

NUMBER OF SUBJECTS: The CPG was based on available published peer-reviewed literature. Overall, the CPG included and appraised 48 systematic reviews, 7 narrative reviews, 68 randomized control trials, 73 psychometric studies, 2 observational studies and 8 published CPGs.

MATERIALS AND METHODS: The CPG was developed by a research team following the standards of the NICE and AGREE II collaborations. A working group, involving multidisciplinary health professionals, reviewed and commented on the evidence and recommendations at each step. Grading of the initial clinical recommendations was achieved according to the Strength of Recommendation Taxonomy tool (SORT). An extended panel of stakeholders ($n = 51$) reviewed the preliminary recommendations using a three-round Delphi method. Participants were prompted for comments on acceptability, interpretation, clarity, and applicability of the recommendations. Recommendations were revised following these exchanges. The CPG was also externally revised using the AGREE II tool by a group of independent experts ($n = 9$) to assess the methodological quality, content and reporting of the CPG.

RESULTS: The developed CPG includes 73 clinical recommendations on patient assessment ($n = 11$), pharmacological treatments ($n = 20$), rehabilitation interventions ($n = 22$), referral to a specialist's care ($n = 2$), workplace interventions ($n = 3$), surgery ($n = 7$), postsurgical rehabilitation ($n = 1$) and return to work ($n = 7$). Recommendations were modified following input of the participants in the Delphi study (694 commentaries). All recommendations reached consensus. Three flow charts on shoulder assessment, treatment of RC disorders and return to work processes to optimize the management of adults and workers with RC disorders were developed. The external expert committee rated the CPG with a mean overall score of 5.8 ± 0.6 out of 7 on the AGREE II tool.

CONCLUSIONS: The development of this CPG was successful, and its content was accepted by all members. The external evaluation of the CPG reached an excellent score.

CLINICAL RELEVANCE: This CPG proposes 73 clinical recommendations and 3 flow charts that can be used as tools to support clinical decision regarding shoulder assessment, treatments and to optimize return to work processes for workers with RC disorders. Knowledge transfer activities will be necessary to promote its clinical use and evaluation of its impact is warranted.

OPL30

SUPRASPINATUS SHEARWAVE SPEED AS A PREDICTOR OF TEAR CHRONICITY AND PREOPERATIVE SHOULDER FUNCTION

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PURPOSE/HYPOTHESIS: Outcomes after rotator cuff (RC) repair are often unpredictable and retear rates as high as 70% have been reported. Tear chronicity, or the extent to which the RC has degenerated over time, likely has a significant influence on a patient's repair healing and clinical outcomes. Unfortunately, conventional MRI-based measures of tear chronicity (eg, tear size, retraction) do not explicitly assess muscle/tendon quality and therefore may not provide the best information to guide treatment decisions. In contrast, ultrasound shear wave elastography has the potential to provide a more objective assessment of tear chronicity by estimating in vivo tissue stiffness, which is accomplished by quantifying the speed at which sound waves propagate through tissue (ie, shearwave speed [SWS]). However, the relationship between SWS and conventional measures of RC tear chronicity and preoperative shoulder function remains unclear. Thus, the purpose of this preliminary study, which is part of a larger, ongoing investigation, was to assess the extent to which SWS is associated with conventional measures of RC tear chronicity and preoperative shoulder function.

NUMBER OF SUBJECTS: Twenty-seven preoperative patients with full-thickness RC tears (mean $\pm$ SD age, 60 ± 7 years; 75% male).

MATERIALS AND METHODS: Supraspinatus SWS was assessed on each patient's involved shoulder in 3 regions (muscle belly, intramuscular tendon, tendon insertion) under passive and active (ie, isometric) conditions with the shoulder in 30° scapular plane abduction. Mean SWS was calculated from 5 trials for each combination of region and condition using custom software. MRI was used to quantify conventional measures of tear chronicity (ie, tear size, retraction). Also assessed were normalized shoulder strength (Biodex), range of motion (goniometer), and patient-reported pain and function (visual analog scale, Western Ontario Rotator Cuff Index). The relationship between supraspinatus SWS, tear chronicity, and preoperative shoulder function was assessed using correlation coefficients.

RESULTS: Supraspinatus SWS in active muscle was moderately correlated with anterior/posterior tear size ($r = 0.61$, $P < .01$). Additionally, SWS in the passive intramuscular tendon was moderately associated with current pain ($r = 0.52$, $P < .01$) and best pain in the last week ($r = 0.51$, $P < .01$). However, SWS was not correlated with shoulder strength or range of motion.

CONCLUSIONS: Supraspinatus muscle SWS is a moderately strong predictor of tear size in patients with a full-thickness rotator cuff tear. However, SWS is not significantly associated with preoperative shoulder function. The weak relationship between SWS and patient function may not be surprising given the frequent disconnect between tissue integrity and shoulder function.

CLINICAL RELEVANCE: A more objective assessment of RC tear chronicity may improve patient care by providing surgeons with information necessary for better presurgical planning. Furthermore, better information on tissue quality may help physical therapists optimize a patient's postoperative rehab by informing the initiation, pace, intensity, and selection of interventions.

OPL31

TREATMENT MONITORING WITH THE OPTIMAL SCREENING FOR PREDICTION OF REFERRAL AND OUTCOME-YELLOW FLAG TOOL: RECOMMENDATIONS FOR PREDICTION OF 12-MONTH PAIN REDUCTION

Trevor Anthony Lentz, Cai Li, Sheng Luo, Maggie Elizabeth Horn, Steven Z. George

PURPOSE/HYPOTHESIS: The overall purpose of this analysis was to determine the optimal administration parameters for treatment monitoring

using the OSPRO-YF, a multidimensional assessment tool for pain-related psychological distress. Specifically, we were interested in understanding how the timing of OSPRO-YF collection and version used (ie, 10-item versus 17-item simple summary score) influences prediction of 12-month pain intensity reduction.

NUMBER OF SUBJECTS: This is a secondary analysis from the Optimal Screening for Prediction of Referral and Outcome (OSPRO) validation cohort. Subjects in this cohort were recruited through the Orthopedic Physical Therapy Investigator's Network (OPT-IN) and seeking physical therapy for neck, low back, knee or shoulder pain. This analysis included 440 subjects (62.5% female; mean $\pm$ SD age, 45.1 $\pm$ 17 years) at baseline, with 279 (63.4%) providing follow-up data at 12 months.

MATERIALS AND METHODS: The primary outcome was achieving a 50% reduction in pain intensity from baseline to 12 months. We developed logistic regression models to examine the relationship between a 50% reduction in pain intensity and the longitudinal change in the simple summary score for the OSPRO-YF 10-item and OSPRO 17-item versions while controlling for demographics, comorbidities, bodily symptoms and baseline pain intensity. All measures were collected at baseline, with OSPRO-YF also collected at 4-week, 6-month, and 12-month follow-up. OSPRO-YF change scores were calculated for each sequential pair of follow-up time points: baseline to 4 weeks; 4 weeks to 6 months; 6 to 12 months. We compared area under the curve (AUC) and Akaike Information Criterion (AIC) values for each model to determine relative model performance and fit, respectively.

RESULTS: The incremental improvement of the model fit at each time point was statistically significant ($P < .05$) using interval change scores for both versions of the tool. Predictive performance of the models were similar for the 10-item (AUC baseline to 4 weeks = 0.79; AUC 4 weeks to 6 months = 0.80; AUC 6 to 12 months = 0.83) and 17-item OSPRO-YF (AUC = 0.79, 0.80, and 0.84, respectively), with no significant statistical improvement in performance using treatment monitoring intervals beyond baseline to 4 weeks.

CONCLUSIONS: Treatment monitoring using the OSPRO-YF simple summary score can improve prediction of a 50% reduction in pain intensity, but the best model fit statistically (ie, 6-12-month change) may have limited clinical applicability. Models including follow-up intervals beyond 4 weeks perform only marginally better than the 4-week model, and those using the 10-item or 17-item OSPRO-YF performed similarly across all follow-up intervals.

CLINICAL RELEVANCE: There are small, likely clinically insignificant improvements in prediction of 50% pain reduction at 12 months when monitoring change in the OSPRO 10-item or 17-item tools beyond 4 weeks. In this patient population, collection of the 10-item OSPRO-YF at 4 weeks may be sufficient for treatment monitoring purposes related to improving the prediction of change in pain intensity from baseline score.

OPL32

CRITERION VALIDITY, MINIMAL CLINICALLY IMPORTANT DIFFERENCE, AND SUBSTANTIAL CLINICAL BENEFIT CALCULATION FOR THE MODIFIED LOW BACK PAIN DISABILITY QUESTIONNAIRE AND SINGLE ASSESSMENT NUMERIC EVALUATION FOR PATIENTS WITH LOW BACK PAIN

Adam Daniel Lutz, Thomas R. Denninger, Ellen Shanley, Brett Windsor, Charles Alden Thigpen

PURPOSE/HYPOTHESIS: The collection of patient reported outcomes (PROs) is increasingly important as the physical therapy profession moves toward value-based reimbursement. Efficient and appropriate collection of PROs is in the best interest of both physical therapists and patients. The Single Assessment Numeric Evaluation (SANE) is a single-item survey that asks a patient "What percentage of normal is your (body region of interest)?" and has been validated across several body regions. The Modified Low Back Pain Disability Questionnaire (MDQ) is the most commonly used PRO for patients with low back pain (LBP) but only 1 study has examined

its psychometric properties. The purpose of this study was to test criterion validity of the SANE relative to the MDQ and determine an anchor-based minimal clinically important difference (MCID) and substantial clinical benefit (SCB) using the global rating of change (GRoC) for each questionnaire for patients with LBP.

NUMBER OF SUBJECTS: Two hundred six patients seeking physical therapy for LBP through employer-based "early physical therapy" program that met inclusion criteria described below.

MATERIALS AND METHODS: Patient data, including MDQ, SANE, and GRoC, were obtained for a convenience sample of patients seeking care in up-state South Carolina between 2016 and 2018. Patients were considered only if pre/post PROs were present for each (MDQ, SANE) and follow-up PROs (MDQ, SANE, GRoC) were obtained between 2 and 12 weeks of initial PRO. Patients with surgery or injection in the 90 days prior to initial evaluation were excluded. Criterion validity was established using Pearson's correlation for all matching observations of MDQ and SANE (including initial and follow-up observations). Anchor-based MCID and SCB measures were calculated using a ROC curve for each PRO (MDQ, SANE). "Success" for MCID included all patients reporting that symptoms were "moderately improved" or better; while "success" for SCB included only patients reporting that their symptoms were "a great deal better."

RESULTS: The final analytical sample included 206 patients (412 total matching MDQ, SANE outcomes). Pearson correlation across all matched observations was -0.567 ($P < .001$) indicating moderate correlation. Values of 11.2 and 14.2 were calculated for MCID ($n = 157$, 76.2%) and SCB ($n = 103$, 50%) for the MDQ; while like values of 17.0 and 23.9 were identified for the SANE.

CONCLUSIONS: The SANE is moderately correlated with MDQ and therefore demonstrates criterion validity for evaluation of symptoms in patients with LBP. Accordingly, it may be a useful, efficient tool to use for intermediate PRO collection in these patients, providing valuable information on status change that might warrant administration of the more comprehensive MDQ. This study also offers a follow-up MCID calculation for MDQ and introduces calculations of MCID for the SANE and SCB for both SANE and MDQ for patients with LBP.

CLINICAL RELEVANCE: Understanding MCID and SCB values for the MDQ and SANE can inform treatment progression and whether appropriate to complete more comprehensive re-evaluation.

OPL33

EARLY VERSUS DELAYED PHYSICAL THERAPY FOLLOWING AN EMERGENCY DEPARTMENT VISIT FOR LOW BACK PAIN

John Shelton Magel, Jaewhan Kim, Julie M. Fritz, Janet Kues Freburger

PURPOSE/HYPOTHESIS: Low back pain (LBP) is the third most common complaint managed in the emergency department (ED). Data suggest that receipt of physical therapy (PT) earlier during the course of a LBP episode is associated with decreased health care utilization and costs. Little is known about the timing of PT after an ED visit for LBP and whether earlier PT is more beneficial. The aim of this retrospective cohort study was to examine the association between the timing of PT and subsequent healthcare utilization (ie, surgery, advanced imaging, injections, long-term opioid use) and LBP-related health care costs in the 1-year period following a new ED visit for LBP. We hypothesized that early PT would be associated with lower healthcare utilization and costs.

NUMBER OF SUBJECTS: Two hundred sixty-five adults with a new visit to an ED for a primary complaint of LBP and a subsequent PT visit within 90 days of the ED visit.

MATERIALS AND METHODS: Subjects were identified using Utah's All-Payer Claims Database. A new visit to an ED was defined as a visit with a LBP-related ICD-9-CM code preceded by 90 days with no claims with a LBP-related ICD-9-CM code. After the ED visit, patients were catego-

alized as having received early (within 30 days) or delayed (between 31 and 90 days) PT.

We used inverse probability weighting (IPW) to balance baseline covariates between patients who received early or delayed PT. Specifically, we used logistic regression to model the use of early versus late PT as a function of age, sex, insurance type, high-deductible health plan, Elixhauser comorbidity index, comorbid mental health condition, comorbid neck pain, rural versus urban residence, history of lumbar surgery, smoking, obesity, substance abuse disorder and use of pain medications. We then calculated propensity scores and IPWs. Analyses were limited to the area of common support (ie, area of propensity score overlap for early and delayed PT groups).

We used poisson regression weighted with the IPWs to examine the association between timing of PT and subsequent use of lumbar surgery, advanced imaging, epidural steroid injections, and long-term opioid use during the 1-year period follow-up. We used a generalized linear model with a log-link function weighted with the IPWs to examine the association between timing of PT and LBP-related health care costs during the 1-year follow-up.

RESULTS: Two thousand four hundred seventy-three patients had a primary complaint of LBP. Two hundred sixty-nine (11.0%) patients received PT within 90 days of the index visit and 265 of these had common support (early, 94; delay, 171). The mean age of patients was 49 ± 16 years and 45.0% were female. Early PT was associated with a lower risk of receiving lumbar surgery (RR = 0.47; 95% CI: 0.26, 0.86), advanced imaging (RR = 0.72; 95% CI: 0.55, 0.95), and long-term opioid use (RR = 0.45; 95% CI: 0.28, 0.76). Patients who experienced early PT paid less (mean, \$3806; 95% CI: \$1998, \$4184) than those who experienced delayed PT (mean, \$8689; 95% CI: \$4653, \$12727).

CONCLUSIONS: Early PT following an ED visit was associated with reduced risk of health care utilization outcomes and health care costs.

CLINICAL RELEVANCE: Delaying PT for LBP following an ED visit may increase the risk for additional health care use and costs.

OPL34

RECOMMENDING IMAGING IS A COMMON ROLE FOR PHYSICAL THERAPISTS IN CLINICAL PRACTICE

Murray Ernest Maitland, Sean Daniel Rundell, Robert C. Manske, George J. Beneck

PURPOSE/HYPOTHESIS: Published case reports demonstrate the need for physical therapists (PTs) to consider imaging tests during clinical practice for many reasons. The purpose of this survey was to describe PTs' (1) knowledge and attitudes regarding diagnostic imaging in their clinical practice and (2) behaviors regarding ordering and use of diagnostic imaging.

NUMBER OF SUBJECTS: Seven hundred thirty-nine licensed PTs from 48 states and districts.

MATERIALS AND METHODS: An imaging special interest group (SIG) work group developed questions in the following domains: demographic characteristics of participants, attitudes regarding use of common imaging modalities, knowledge of their ability to use and order diagnostic imaging, and behaviors for ordering and recommending diagnostic imaging in clinical practice. The draft survey was pretested by Imaging SIG members. The revised survey was formatted in REDCap and pilot-tested with 24 PTs from a variety of settings. After further revision, the 53-question survey was advertised through sections/academies and chapters. This survey was determined to be exempt from IRB review. Descriptive statistics were used to characterize participants and their responses.

RESULTS: Mean $\pm$ SD age was 43 ± 12 years, with 18 ± 13 years of experience postgraduation. Of those, 394 had DPT degrees; 100 had PhDs; 115 were residency or fellowship trained; 303 were clinical specialists. There were 18 sections represented with most belonging to the Academy of Orthopaedic Physical Therapy (54%) or American Academy of Sports Physical

Therapy (33%). Most respondents worked in orthopaedic clinical practice (67%) and in an outpatient setting (65%). Only 2% of 649 of respondents felt that patients "always" presented with appropriate imaging. The large majority of respondents (92% of 576) recommended imaging tests in the previous 6 months. The median estimated percentage of patients for which imaging was recommended was 10% (interquartile range, 5%-20%). Only 12% of 648 respondents had ever directly ordered imaging. Radiographs and magnetic resonance imaging were most commonly recommended with computed tomography, diagnostic ultrasound and bone scan recommended about one third as often. Cervical, shoulder, lumbar and hip were the most common regions. The most commonly targeted body system was the musculoskeletal system (90%).

CONCLUSIONS: PTs, primarily in orthopaedic practice, reported a frequent clinical role evaluating the appropriateness of diagnostic imaging tests and had a role in recommending imaging. Currently, PTs typically recommend imaging compared to directly ordering imaging.

CLINICAL RELEVANCE: Practicing clinicians should continually update their knowledge on imaging practice guidelines because recommending diagnostic imaging is a common clinical practice. Knowledge of imaging guidelines for differential diagnosis and investigation of red flags will likely facilitate interdisciplinary communication in recommending imaging tests.

OPL35

BIOMECHANICAL WAVEFORM FEATURES DURING GAIT CAN DISCRIMINATE PEOPLE WITH FEMOROACETABULAR IMPINGEMENT SYNDROME FROM MATCHED CONTROLS

Philip J. Malloy, Kyleen Jan, Daniel Wichman, Donald A. Neumann, Shane J. Nho, Kristof Kipp

PURPOSE/HYPOTHESIS: Biomechanical waveform features describe important characteristics of the overall movement pattern during a functional task. These waveform features provide information such as changes in magnitude, differences in the overall pattern of movement, and shifts in the timing of events during the task. Gait studies have used these features to distinguish patients with hip osteoarthritis (OA) from healthy controls. The purpose of this study was to determine if biomechanical waveform features during gait extracted using principal components analysis (PCA) can be used to distinguish people with femoroacetabular impingement (FAI) syndrome from healthy controls.

NUMBER OF SUBJECTS: Forty.

MATERIALS AND METHODS: Twenty patients with FAI syndrome (11 female) and 20 matched controls underwent three-dimensional motion capture using a 14-camera motion capture system (Vicon, London, UK) and 2 force plates (AMTI, Watertown, MA). Hip joint angles and internal moments in all 3 planes were calculated during 5 walking trials. PCA was performed on all hip joint angle and moment waveform data matrices, yielding a total of 6 PCAs. Each waveform data matrix (M) consisted of 197 gait trials by 101 time points in gait cycle. Principal components (PC) were extracted and used to represent movement pattern features. Each waveform of all subjects received a PC score. Paired-samples *t* tests were used to determine between group differences of the PC scores for people with FAI syndrome and controls. The absolute value of the *t* scores, which represents the magnitude of the standardized difference between the groups, were used to rank the most important waveform features. Linear discriminant analysis (LDA) was then performed on the top 10 most important waveform features to determine which combination of these features best distinguished people with FAI syndrome from healthy controls (ie, model specificity). All data and statistical analysis were performed in MATLAB and SPSS. An a priori alpha level of .05 was set to define statistical significance.

RESULTS: The linear discriminant model specificity ranged from 67% to 74% for correctly distinguishing people with FAI syndrome from controls using movement pattern features during gait. The optimal model specificity of 74% used a combination of only 4 movement pattern features. This

movement pattern indicated that during stance phase people with FAI syndrome reach peak internal rotation later in the gait cycle; and during swing phase, people with FAI syndrome demonstrate differences in the overall pattern of sagittal and frontal plane moments during early, mid, and late swing phases of gait.

CONCLUSIONS: Movement pattern features during stance and swing phase of gait can be used to distinguish people with FAI syndrome from healthy controls. Previous studies in people with hip pathology, including FAI syndrome, have shown alterations in movement patterns during gait.

CLINICAL RELEVANCE: Understanding movement pattern differences that distinguish people with FAI syndrome may help to identify treatment targets rehabilitation for these patients.

OPL36

MOVEMENT-PATTERN FEATURES AT THE HIP DURING WALKING DIFFER IN PEOPLE WITH FEMOROACETABULAR IMPINGEMENT SYNDROME

Philip J. Malloy, Shane J. Nho, Donald A. Neumann, Kristof Kipp

PURPOSE/HYPOTHESIS: Previous gait studies in people with femoroacetabular impingement (FAI) syndrome have analyzed only a single discrete time point during the gait cycle; thus leading to a potential loss of important temporal features of the movement pattern. Unlike this snapshot approach, we analyzed hip movement throughout the gait cycle. The purpose of this study was to determine if hip joint movement pattern features extracted using principal components analysis (PCA) can be used to identify differences during gait between patients with FAI syndrome and healthy controls.

NUMBER OF SUBJECTS: Forty.

MATERIALS AND METHODS: Nine females and 11 males diagnosed with FAI syndrome and 20 matched controls underwent 3-dimensional motion capture using a 14-camera motion-capture system (Vicon, London, UK) and 2 force plates (AMTI, Watertown, MA). Hip joint angles and internal moments in all 3 planes were calculated during 5 walking trials. Six PCAs were conducted for each hip joint angle and moment waveform data matrix consisting of 197 gait trials by 101 time points in the gait cycle. The application of multivariate statistical techniques to biomechanical waveforms provides meaningful information about the overall movement pattern during gait. Principal components (PC) were extracted and used to represent movement pattern features. For each retained PC, a subject's waveform received a PC score, which represented how strongly the individual's waveform expresses the PC. A single component waveform reconstruction was used to interpret the movement pattern features in joint angles and moment data. Paired-samples *t* tests were used to determine differences in the PC scores for each group. All data and statistical analysis were performed in MATLAB and SPSS. An a priori alpha level of .05 was set to define statistical significance.

RESULTS: FAI syndrome patients demonstrate greater hip adduction motion (frontal plane angle PC 2, $P < .001$), less internal rotation motion (transverse plane angle PC 1, $P = .001$ and PC 3, $P = .029$) and reach peak hip internal rotation angles later (transverse plane angle PC 4, $P < .001$) than controls during the stance phase of gait. FAI syndrome patients also demonstrate greater external rotation moments (transverse plane moment PC 2, $P = .034$) during stance compared to controls. During swing phase FAI syndrome patients demonstrate differences in the sagittal (sagittal plane moments PC 3, $P < .001$; PC 6, $P < .001$; PC 7, $P < .001$) and frontal plane moment patterns (frontal plane moment PC 4, $P < .001$ and PC 7, $P = .008$). FAI syndrome patients also exhibit differences in transverse plane moment patterns during the early (PC 3, $P = .027$), mid (PC 5, $P = .001$) and late (PC 5, $P = .001$) periods of swing phase.

CONCLUSIONS: There are significant differences in movement throughout the gait cycle in FAI syndrome patients. This contribution is unique in its approach to examining movement throughout the gait cycle as compared to the traditional single time point snapshot approach for gait analysis.

CLINICAL RELEVANCE: Understanding differences in movement patterns during gait in FAI syndrome patients may help identify treatment targets for rehabilitation.

OPL37

DECLINE IN WALKING SPEED DOES NOT PREDICT MORTALITY BEYOND CURRENT WALKING SPEED IN KNEE OSTEOARTHRITIS

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PURPOSE/HYPOTHESIS: Slow walking speed is a risk factor for mortality in older adults and speeds slower than 1.22 m/s are a risk factor for poor health outcomes in people with knee osteoarthritis (OA). With advancing age, walking speed declines, however, the decline in walking speed is not uniform. It is unclear if the rate of decline in walking speed is additionally relevant for mortality risk in knee OA. If so, considering the history of change in addition to present walking speed may be important. The purpose of this study was to investigate whether walking speed at 1 time point, change in walking speed over the past year, or both predict mortality risk over 9 years in knee OA. We hypothesized that irrespective of current walking speed, those adults with knee OA who have meaningful decline in walking speed will have increased risk of mortality.

NUMBER OF SUBJECTS: We used publicly available data from the Osteoarthritis Initiative (OAI) whose purpose was to monitor the progression of knee OA; 4229 people with or at risk of knee OA were used for this study.

MATERIALS AND METHODS: Walking speed was measured from a 20-m walk test at baseline and the 12-month visit. The index date for this analysis is the 12-month visit. Walking < 1.22 m/s represents the inability to cross a street with a timed crosswalk, and change > 0.08 m/s is considered to be a clinically meaningful decline. We classified people into 1 of 4 groups depending on the walking speed at 1 time point (the 12-month visit) and degree of decline over the previous year (from baseline to 12-month visit): (1) < 1.22 m/s and > 0.08 m/s decline, (2) at least ($>$) 1.22 m/s and > 0.08 m/s decline, (3) < 1.22 m/s and < 0.08 m/s decline or (4) > 1.22 m/s and > 0.08 m/s decline. Mortality was assessed up to 9 years of follow-up. We used Kaplan-Meier curves to determine the survival probability for the 4 groups. We examined the association of the 4 groups with mortality using Cox proportional hazards regression, adjusting for potential confounders.

RESULTS: Of 4229 participants in the analytic sample (58% female; mean $\pm$ SD age, 62.3 ± 9.2 years; BMI, 28.5 ± 4.8 kg/m²), 6% ($n = 270$) died over 9 years. Those walking < 1.22 m/s with and without decline had 108% (adjusted HR = 2.08; 95% CI: 1.46, 2.96) and 96% (adjusted HR = 1.96; 95% CI: 1.44, 2.66) greater risk of mortality compared with those walking > 1.22 m/s without meaningful decline over previous year. Those walking ≥ 1.22 m/s with decline had a lower risk (adjusted HR = 0.57; 95% CI: 0.32, 1.01) of mortality than the group walking ≥ 1.22 m/s without meaningful decline in walking speed, likely related to the latter having started with a higher walking speed at baseline.

CONCLUSIONS: Irrespective of history of decline in walking speed, walking slower than 1.22 m/s on a 20-m walk test at 1 time point may identify adults with or risk of knee OA who have an increased risk for all-cause mortality.

CLINICAL RELEVANCE: Our findings indicate that assessing walking speed in the present may be sufficient to gauge mortality risk in adults with or at risk of knee OA rather than tracking the decline in walking speed over the previous year.

OPL38

TIMING OF REHABILITATION FOLLOWING ROTATOR CUFF REPAIR: A COST-UTILITY ANALYSIS

Kate Minick, Julie M. Fritz, Gerard Peter Brennan

PURPOSE/HYPOTHESIS: Although rotator cuff repair (RCR) is a common treatment for rotator cuff tears, conflicting reports exist on the optimal

start time of rehabilitation following surgery to maximize the benefit to pain, range of motion, function, and healing. Health care cost analysis is increasingly becoming a factor in the decision-making process between a patient and the clinician, especially in cases of equivocal clinical outcomes such as this. The purpose of this study is to evaluate the difference in cost-effectiveness of early rehabilitation versus delayed rehabilitation from a payer perspective, using a decision tree cost-utility analysis.

NUMBER OF SUBJECTS: Two thousand one hundred ninety-seven.

MATERIALS AND METHODS: A decision tree model with a 1-year time horizon was constructed from a healthcare payer perspective. The primary effectiveness outcome, quality-adjusted life-years (QALYs), was obtained from the literature. Cost and probability inputs were obtained from a regional not-for-profit health plan serving >800 000 members. All patients who underwent an arthroscopic RCR and subsequently attended rehabilitation between 2005-2015 were included in the model. All shoulder-related costs for 1 year were included, including those related to postoperative care and complications. Patients who attended rehabilitation within the first 28 days following surgery (4 weeks) were considered to have received early rehabilitation, and those beginning 29-plus days received delayed rehabilitation. The decision analysis software package TreeAge Pro was used to conduct the analysis. The primary outcome was the incremental cost-effectiveness ratio (ICER) and probabilistic sensitivity analyses were performed.

RESULTS: Included patients were 59% male, with an average $\pm$ SD age of 53.41 ± 10.08 years. Most patients attended Early Rehabilitation (67.14%). For arthroscopic RCR, Early Rehabilitation is less costly and more effective than Delayed Rehabilitation. Early Rehabilitation resulted in a decreased overall cost of \$465.29 and an increased effectiveness of 0.01 QALY, yielding an ICER of -\$63673 per QALY gained. All variables in the model were robust to altering the input values through Monte Carlo probabilistic sensitivity analysis.

CONCLUSIONS: While the results of previous research have been inconclusive as to the clinical effectiveness of Early versus Delayed Rehabilitation, this cost-utility analysis demonstrates that Early Rehabilitation is both less costly and more effective. At all willingness-to-pay thresholds, Early Rehabilitation is considered a cost-effective procedure from a healthcare payer perspective.

CLINICAL RELEVANCE: Early Rehabilitation is less costly and more effective in terms of QALYs compared to Delayed Rehabilitation at all willingness-to-pay levels, though it is appropriate to consider individual patient factors when determining the ideal start time of rehabilitation. Early Rehabilitation may lead to increased therapy utilization; however, these costs are surpassed by downstream savings by avoiding other shoulder-related care and complications.

OPL39

SURVEY OF WISCONSIN PHYSICAL THERAPIST RADIOGRAPH ORDERING BEHAVIORS AND IMPLEMENTATION: A MIXED-METHODS APPROACH

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PURPOSE/HYPOTHESIS: In 2016, Wisconsin enacted legislation explicitly allowing qualified physical therapists (PT) to sign radiograph orders. The Wisconsin Physical Therapy Association (WPTA) endorsed this authority in August 2017 when rules were promulgated by the PT Examining Board. The purpose of this study was to investigate the implementation of this practice authority by PT members of the WPTA and determine the primary barriers to PT ordered radiographs in Wisconsin.

NUMBER OF SUBJECTS: Membership data from 1725 WPTA PT members was merged with survey responses from 485 members (28.1% yield). 62.1% of the respondents were female, mean $\pm$ SD age of 43.7 ± 11.8 years, 52.8% held a Doctor of Physical Therapy, 54.4% had a primary clinic focus in orthopaedic or sports, and 40.2% worked in a hospital-based outpatient facility. Specialty certification was held by 21.7%.

MATERIALS AND METHODS: A 17-item electronic survey of radiograph ordering authority, ordering frequency, and implementation factors was distributed by WPTA staff in September 2018. Deidentified responses and demographic data were provided for analysis. A grounded theory approach was used to code text responses of feedback PTs received from other providers, payers, patients, and general comments. The framework for the thematic code structure was the R = MC2 heuristic for health innovation implementation. Logistic regression assessed differences in ordering activity while accounting for the survey response probability, estimated from WPTA membership characteristics.

RESULTS: Twenty-one PTs (4.3%) reported ordering radiographs. Limited PT knowledge or confidence was a significant barrier ($OR = 0.19, P = .01$). Qualitative analysis included 886 text responses with 80% pertaining to radiograph-specific innovation capacities and 20% to PT-specific motivation. Text response themes of simple ordering workflows, compatibility with the practice setting, patient cost containment, and colleague support were associated with greater odds of ordering. While not significant in the model, comments described payer noncoverage as a dominant implementation barrier for PT providers and organizations. Respondents (28% of members) were more often practicing in outpatient facilities, in orthopedics, as clinical instructors, with specialty certifications, and with longer APTA membership than nonrespondents in WPTA membership.

CONCLUSIONS: Successful implementation of PT radiograph ordering produces a relative advantage in work efficiency without contributing to overutilization, but many qualified PTs experience restrictive organizational climates or policies. Radiograph ordering is not universally compatible with PT practice and burdensome processes further disincentivize providers.

CLINICAL RELEVANCE: Legislative authority is necessary, but insufficient to produce practice change. Future efforts to increase PT radiograph ordering should target policies, work system efficiency, and service reimbursement at the organizational level.

OPL40

INFLUENCE OF CLINICAL FINDINGS ON PHYSICAL THERAPIST DIAGNOSIS OF SHOULDER INSTABILITY

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PURPOSE/HYPOTHESIS: Rehabilitation is recommended for patients with atraumatic shoulder instability, yet persistent shoulder disability remains at 8-year follow-up. Over 15 classification systems exist for shoulder instability, which may partially explain inconsistent diagnoses. It is unclear how physical therapists (PTs) interpret clinical tests (apprehension, relocation) highly specific for shoulder instability as well as the less specific sulcus sign to inform their diagnosis. Further, secondary findings of subacromial impingement (SAI) in shoulder instability populations could lead to misdiagnosis and impact treatment outcomes. The purpose of this study was to determine (a) which diagnoses PTs apply to patient scenarios with clinical findings consistent of atraumatic shoulder instability, and (b) which findings are important to diagnose instability.

NUMBER OF SUBJECTS: Three hundred seventy-nine PTs.

MATERIALS AND METHODS: A survey was e-mailed to Academies of Orthopaedic and Sports Physical Therapy and American Society of Shoulder and Elbow Therapists members. PTs were asked to diagnose a patient based on 2 scenarios that included the following: 25-year-old male tennis player with no history of significant shoulder trauma, 6-month history of shoulder pain during daily activities, and no relevant bone lesions. Exam findings: normal AROM with painful arc, strong and painful shoulder strength, negative labral tests, positive impingement signs, and positive anterior apprehension and relocation tests. Scenarios 1 and 2 were only differentiated by negative and positive sulcus signs, respectively. PTs chose from 4 diagnoses in each scenario: SAI, UDI (unidirectional instability), MDI (multidirectional instability), and other. PTs also ranked the

importance of 15 clinical findings on a 5-point Likert scale (1, unimportant; 5, crucial) to differentially diagnose UDI/MDI versus SAI.

RESULTS: With a negative sulcus sign in scenario 1, PTs selected SAI (55%) followed by UDI (39%) despite a cluster of positive exam findings highly specific for shoulder instability. With the addition of a positive sulcus sign in scenario 2, the majority of PTs selected MDI (66%), but a few retained SAI (14%). The 3 most important factors to diagnose shoulder instability were: Report of subluxation/"unstable" (89% selected 4 or 5), significant trauma (76%), and repetitive overuse (70%). In scenario 2, PTs selecting MDI ranked the sulcus sign more important than PTs selecting SAI or UDI (mean, 3.6 versus 2.9; $P < .001$).

CONCLUSIONS: Clinical tests with high diagnostic accuracy for shoulder instability did not prevent the majority of PTs from diagnosing patients with SAI when accompanied by positive impingement signs and negative sulcus sign, conflicting with evidence-based practice. However, a positive sulcus sign highly influenced PTs to diagnose patients with MDI. Subluxation is a critical factor to differentially diagnose UDI/MDI from SAI.

CLINICAL RELEVANCE: Decreased PT knowledge of clinical tests recommended to diagnose patients with shoulder instability could lead to suboptimal patient outcomes. Expanded education of clinical practice guidelines to accurately classify shoulder pathologies may improve rehabilitation outcomes for patients with shoulder instability.

OPL41

FRONTAL PLANE MOVEMENT IMPAIRMENTS ARE ASSOCIATED WITH WORSE HIP FUNCTION FOR PERSONS WITH NONARTHRITIC HIP DISEASE

Chase Jed Pendley, Lindsey Brown, Kathryn Reid Martin, Stephanie Di Stasi, W. Kelton Vasileff

PURPOSE/HYPOTHESIS: Nonarthritic hip disease (NAHD) is associated with abnormal movement primarily in the frontal and sagittal planes and may contribute to pain and poor function characteristic of this patient group. Identifying and resolving abnormal movement may be important to reducing symptoms and optimizing loads to promote long-term joint health. The purpose of this study was to investigate the relationship between hip function and the number of sagittal and frontal plane impairments identified during a standardized posture and movement examination of persons with NAHD. We hypothesized that worse hip function would be associated with a greater number of sagittal and frontal plane impairments, indicating worse movement quality.

NUMBER OF SUBJECTS: Thirty-nine participants (mean $\pm$ SD age, 36 ± 10 years; BMI, 30.0 ± 5.7 kg/m²; 72% female) with symptomatic NAHD presented over a 15-month period to a hip preservation clinic.

MATERIALS AND METHODS: Participants were included from a randomized controlled trial to investigate the impact of an interdisciplinary shared decision-making model on treatment planning for NAHD, including femoroacetabular impingement syndrome, borderline hip dysplasia, and labral tear. Only data from participants who received the interdisciplinary evaluation (surgeon and physical therapist) were used in this secondary analysis. The physical therapist identified the presence or absence of sagittal and frontal plane impairments at the trunk, pelvis, hip, and knee during the following 6 movements and postures: sitting, rising from sitting, standing, single-leg stance, single-leg squat, and walking. A maximum of 9 sagittal and 11 frontal plane impairments were possible if all tasks were completed. Self-reported hip function was collected via the 33-item International Hip Outcome Tool (iHOT-33). Spearman rank and Pearson correlations were used to evaluate the relationships between iHOT33 scores and total number of (1) sagittal and (2) frontal plane impairments ($P < .05$).

RESULTS: The average $\pm$ SD iHOT-33 score was 35.0 ± 19.5 . Participants displayed an average of 2.7 ± 1.5 sagittal and 5.1 ± 2.2 frontal plane impairments across the 6 tasks. Single-leg stance and squat revealed the most deficits, and most impairments were observed at the trunk and pelvis across tasks. Increasing number of frontal ($r = -0.37$, $P = .01$), but not sagittal ($\rho = 0.25$, $P = .93$), impairments were significantly associated with worse iHOT-33 scores.

CONCLUSIONS: Participants displayed clinically-observable frontal and sagittal plane movement impairments, though frontal plane impairments were more prevalent (confirm this point). The relationship between a greater number of frontal plane impairments and worse patient-reported hip function is consistent with previous research highlighting excessive frontal plane hip excursion in individuals with chronic, nonarthritic hip joint pain.

CLINICAL RELEVANCE: Patients with NAHD who presented to a hip preservation clinic displayed clinically observable movement impairments during common functional tasks and postures. Evaluation and treatment of movement impairments, specifically in the frontal plane, may have potential to improve hip function and optimize outcomes for these individuals.

OPL42

DO GENERIC AND POPULATION-BASED OUTCOMES TRACK CHANGE AND ACCEPTABLE SYMPTOMS IN OUTPATIENT PHYSICAL THERAPY?

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PURPOSE/HYPOTHESIS: The purpose was to determine the ability of Patient Reported Outcome Measurement Information (PROMIS) pain interference (PI), physical function (PF), fatigue, and self-efficacy of symptom management (SEsx) scales to detect change and outcomes compared to population norms at discharge from an outpatient orthopedic clinic.

NUMBER OF SUBJECTS: Ninety-five of 178 patient data sets were complete.

MATERIALS AND METHODS: PROMIS computer adaptive tests (PF, PI, Fatigue, SEsx) were administered at initial evaluation (IE) and discharge (DC) for spine (44.2%), lower extremity (30.5%), upper extremity (12.6%), multiple regions (10.5%), and other reasons (2.1%) on consecutive patients. Patient average $\pm$ SD age was 43.3 ± 19.8 years, with 68.4% female, and days of treatment (IE to DC) of 4.0 ± 3.1 . Several methods were used to assess change in PROMIS T scores: (1) Effect Size Index (ESI) (all patients and patients with unacceptable IE T scores: PI, >55 ; Fatigue, >55 ; PF, <42 ; and SEsx, <45), (2) proportion improved by more than a minimal clinically important difference (MCID; T score, 5), (3) proportion of patients improved by more than an MCID on any scale, and (4) odds ratio (OR and 95% confidence interval [CI]) of patients being improved to acceptable symptom severity if their symptoms were unacceptable at the IE.

RESULTS: The ESI values for all patients and patients with unacceptably low IE scores were: PI, 0.65 and 0.87; PF, 0.52 and 0.79; Fatigue, 0.54 and 0.78; and SEsx, 0.44 and 0.80, respectively. The proportion improved an MCID: PI, 48.4%; PF, 35.8%; Fatigue, 43.2%; and SEsx, 35.8%. The proportion improved on at least 1 scale by an MCID was 72.6%. The ORs for improving to acceptable symptom severity were: PI = 7.8; 95% CI: 2.6, 22.8; PF = 10.1; 95% CI: 3.1, 32.7; Fatigue = 17.9; 95% CI: 4.9, 66.1; and SEsx = 3.3; 95% CI: 1.3, 8.2.

CONCLUSIONS: The generic PROMIS scales showed the ability to detect change (moderate, 0.5-0.8 ESI or high, >0.8 ESI) across scales. Although 35.8% to 48.4% achieved an MCID improvement on a given scale, approximately 70% achieved MCID improvement on any 1 scale. Patients with unacceptable symptoms at the IE were more likely to achieve acceptable symptoms at DC.

CLINICAL RELEVANCE: Generic health and population norm based outcomes (PROMIS) detect change, determine patient status (acceptable/unacceptable), and assist providers target a patients with unacceptable symptoms when seeking care for orthopedic problems.

OPL43

DIAGNOSTIC UTILITY OF SPECIAL TESTS AND DEMOGRAPHIC INFORMATION FOR DIAGNOSIS OF ATRAUMATIC ROTATOR CUFF TEARS

Adam J. Popchak, Robert Tisherman, Volker Musahl, Richard Debski, James J. Irrgang

PURPOSE/HYPOTHESIS: Shoulder pain and symptoms result in a substantial number of clinical visits each year with rotator cuff tears being 1 of the most common underlying problems. However, despite the regularity

at which this condition is seen, examination and diagnosis of rotator cuff tears, without the use of advanced imaging, remains difficult. Information regarding the diagnostic accuracy of special tests and physical examination procedures can assist the clinician in making accurate diagnoses. The purpose of this study was to investigate the diagnostic accuracy of common special tests of the shoulder and demographic information in identifying chronic rotator cuff tears in a cohort of individuals presenting with shoulder symptoms. We hypothesized that, when positive, a combination of special tests would improve the diagnostic accuracy of the physical examination in the presence of rotator cuff tears.

NUMBER OF SUBJECTS: One hundred eight adults with shoulder pain (mean $\pm$ SD age, 59.6 $\pm$ 10.2 years) enrolled in a prospective observational study examining the outcome of exercise therapy in individuals with isolated supraspinatus tears.

MATERIALS AND METHODS: Participants provided demographic and injury related information and underwent a physical examination and diagnostic ultrasonography to determine the presence of a rotator cuff tear. Demographic information examined included age, sex, BMI, symptom duration, and smoking history. Special tests utilized during the examination included the full can, lag signs at 45° and 90°, lift-off, and drop-arm tests, presence of a painful arc, and resisted external rotation at 0°. A physical therapist or orthopaedic surgery resident performed all physical examinations. Diagnostic ultrasounds were completed by either radiologists in a University Health Care system or an orthopaedic surgery resident. Analysis of diagnostic accuracy, included sensitivity, specificity, and overall accuracy for each special test. An odds ratio was performed to examine the diagnostic utility of having multiple positive special tests.

RESULTS: The average $\pm$ SD duration of symptoms at the time of the examination was 181.5 $\pm$ 120 days, with 36% of subjects reporting a specific injury mechanism. There was a supraspinatus tear in 74% (80/108), an infraspinatus tear in 8% (9/107), and a subscapularis tear in 28% (30/108) of participants. Eighty-four of 108 (78%) of participants had a tear in at least 1 of the rotator cuff muscles. There was no association between any demographic factor and the presence of a rotator cuff tear. The full can test (sensitivity, 0.59; specificity, 0.73; overall accuracy, 62%) and painful arc (sensitivity, 0.78; specificity, 0.50; overall accuracy, 72%) yielded the best combination of diagnostic utility. When both the full can test and the painful arc was positive, 40/44 (91%) of participants were found to have a rotator cuff tear. The odds ratio comparing the odds of having a tear for those with a positive full can test and painful arc to both tests being negative was found to be 8.2 (95% CI: 2.1, 31.7; $P = .002$). Individually, the drop arm test had the highest specificity (0.91) and the painful arc had the highest sensitivity (0.78).

CONCLUSIONS: The results of this study suggest that when used in a population with suspected chronic rotator cuff tears, the full can test and the painful arc provide the best overall diagnostic utility. When used in combination, the presence of positive results for both the full can test and painful arc significantly increase the odds of having a rotator cuff tear. However, secondary to a limited sample size and distribution of rotator cuff tears, additional factors could not be investigated.

CLINICAL RELEVANCE: In the evaluation of chronic shoulder pain in adults, the full can test and the painful arc provide the best overall diagnostic accuracy for identification of a rotator cuff tear. When both tests are positive, there is an 8-fold increase in the odds of a rotator cuff tear. It is recommended that results from multiple tests are utilized in the evaluation process. This data can be used in order to more accurately diagnose rotator cuff tears and direct clinical decision making.

OPL44

ACHILLES TENDINOPATHY PATIENT BELIEFS ON ACTIVITY AVOIDANCE AND SYMPTOM IMPROVEMENT: IMPLICATIONS FOR CLINICAL PRACTICE

Andrew Alexander Post, Ebonie Rio, Karin Grävarer Silbernagel, Kathleen Anne Shuka, Ruth L. Chiment

PURPOSE/HYPOTHESIS: Enhanced patient understanding of their condition allows for better self-management, and use of pain neuroscience education (PNE) improves pain, kinesiophobia, and catastrophizing. Achilles tendinopathy (AT) is a common painful condition of the rearfoot, yet there is a paucity of literature on patient beliefs related to activity avoidance and to minimal clinically important difference (MCID) for magnitude of symptom relief with treatment. To inform the development and utility of AT-specific PNE, the purposes of this study were to (1) examine the proportion of respondents with AT with high kinesiophobia and/or catastrophizing, (2) assess responses related to reluctance to complete activities commonly used in progressive load-based rehabilitation programs for AT, and (3) determine a patient-driven MCID for AT symptom improvement.

NUMBER OF SUBJECTS: A total of 223 respondents (mean $\pm$ SD age, 38.6 $\pm$ 12.6 years; 61% female; BMI, 26.2 $\pm$ 5.0 kg/m²) were analyzed based on inclusion/exclusion criteria.

MATERIALS AND METHODS: A public online survey collected de-identified data on individuals reporting AT for >3 months. Descriptive statistics were used to report percentage of sample who reported high kinesiophobia with the Tampa Scale of Kinesiophobia-11 (TSK11 >24) and catastrophizing with the Pain Catastrophizing Scale-4 (PCS4 >9). Participants reported anticipated pain (VAS; 0-100) with 3 single-limb heel raises and 3 single-leg hops. Participants who chose not to do these activities were asked the primary reason for activity refusal. Patient perspective on MCID was examined by asking participants, "If a treatment was able to decrease your (pain/stiffness) by (Xpoints/minutes), how would you rate this change." Cutoff was defined as >4 (moderately better) on a 9-point scale ranging from 0 (same) to 8 (very great deal better).

RESULTS: Seventy-nine percent reported high kinesiophobia and 67% reported high pain catastrophizing. Participants anticipated moderate pain with heel raises (43.1 $\pm$ 23.9) and hops (49.5 $\pm$ 25.2). Twenty-six percent did not do a heel raise and 36% did not do hops; among these individuals half reported fear of injury from activity (heel raise, 53%; hops, 46%). For pain MCID, a 10-point decrease was the most commonly reported minimum change. For stiffness MCID, a 5-minute decrease was the most commonly reported minimum change.

CONCLUSIONS: The majority of individuals with AT report high fear of movement/injury and pain catastrophizing. Improvements as small as a 10-point decrease in pain with activity and a 5-minute decrease in stiffness duration were commonly reported as meaningful in this sample.

CLINICAL RELEVANCE: High kinesiophobia and pain catastrophizing combined with moderate levels of anticipated pain during activity may contribute to a reluctance to participate in progressive load-based rehabilitation programs for AT. Clinician understanding of patients' beliefs about their pain and rehabilitation expectations may promote additional management strategies to assist with development of collaborative goal setting and clinician-patient communication.

OPL45

REPETITIVE DENTAL HYGIENIST JOB-RELATED TASKS INCREASE THE RISK OF SHOULDER PAIN AND ALTERED SUPRASPINATUS MORPHOLOGY

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PURPOSE/HYPOTHESIS: Repetitive job-related upper extremity tasks are thought to be a risk factor for developing musculoskeletal shoulder pain. Dental hygienists show a high incidence of shoulder pain. This study assessed the association of the incidence of shoulder pain and supraspinatus morphology changes in dental hygienist (DH, at-risk group) and occupational therapist (OT, non-at-risk group) students.

NUMBER OF SUBJECTS: Forty-five DH (8 male; mean $\pm$ SD age, 24.7 $\pm$ 3.9 years) and 50 OT (6 male; age, 24.9 $\pm$ 2.4 years).

MATERIALS AND METHODS: Shoulder pain was measured with a visual an-

alog scale for pain (0-100 VAS; 100 is worst pain). Ultrasound images of the supraspinatus were collected in the longitudinal and cross-sectional views. All measures of the dominant arm were taken at the start of the academic program and 12 months later. The minimal detectable change for the VAS (11 points) was used to identify participants that developed shoulder pain at the 12-month evaluation. Morphological measures of the supraspinatus tendon included both cross-sectional and longitudinal thickness. The amount of the subacromial space occupied by the supraspinatus was calculated (occupation ratio). The change of supraspinatus thickness and occupation ratio was calculated between baseline and 12-month evaluation. Between group comparison on the proportion of individuals that developed shoulder pain was analyzed using the Fisher exact test and likelihood ratio. Across all groups, Pearson correlation assessed the relationship between VAS pain and supraspinatus thickness at 12 months. The 12-month change in supraspinatus tendon thickness and occupation ratio was compared between 3 groups (DH-developed shoulder pain, DH-did not develop shoulder pain, and OT) using a 1-way ANOVA.

RESULTS: Over 12 months, a greater proportion of DH developed shoulder pain compared to OT (22% versus 6%, $P = .03$; positive likelihood ratio = 1.8; 95% CI: 1.2, 2.7). At 12 months, greater supraspinatus thickness was related to greater VAS for shoulder pain ($r = 0.29$, $P < .01$). Significant between-group effects were found for the 12-month change of supraspinatus cross-sectional thickness and occupation ratio ($P < .01$). The DH-developed pain group had greater increase of supraspinatus cross-sectional thickness (1.0 mm; 95% CI: 0.3, 1.6; $P < .01$) and occupation ratio (8.4%; 95% CI: 1.7%, 15.1%; $P < .01$) compared to the OT.

CONCLUSIONS: DH students are at higher risk of developing shoulder pain after 12 months of academic training. Moreover, the development of shoulder pain is associated with an 18% thickening of the supraspinatus tendon. The supraspinatus presence in the subacromial space is more prominent in the DH group that developed shoulder pain. These morphological changes in the supraspinatus are compatible with signs of supraspinatus tendinopathy.

CLINICAL RELEVANCE: Despite the relatively young age, DH students are exposed to repetitive upper extremity tasks during their academic training that may alter the morphology of the supraspinatus and increase the risk of developing shoulder pain.

OPL46

ASSOCIATIONS OF SLEEP DISTURBANCE WITH PAIN, FUNCTION, AND PSYCHOSOCIAL HEALTH IN INDIVIDUALS WITH LIMB AMPUTATIONS

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PURPOSE/HYPOTHESIS: Sleep disturbance encompasses a range of disorders, including difficulty falling asleep, insomnia, and poor quality of sleep. Sleep disturbance has been associated with greater risk for depression and anxiety, impaired function, and heightened pain sensitivity. Individuals with major limb amputations tend to have greater anxiety, decreased physical function, decreased satisfaction with social roles, and increased pain interference compared to the general population. The purpose of this study was to assess sleep disturbance and its associations with pain, physical function, and psychosocial health in individuals with major limb amputations.

NUMBER OF SUBJECTS: A total of 44 individuals with at least 1 major limb amputation were included in this analysis (mean $\pm$ SD age, 35.6 ± 9.0 years; 31 male); 27 had a unilateral lower limb amputation, 8 had bilateral lower limb amputations, 5 had unilateral upper limb amputations, 1 had bilateral upper limb amputations, and 3 had a combination of upper and lower limb amputations. Causes of amputation included both traumatic ($n = 26$) and nontraumatic ($n = 18$) etiologies.

MATERIALS AND METHODS: This was a prospective cross-sectional study. All participants completed a pain body map and indicated average pain intensity for each region of pain using a numeric rating scale (0-10). The

Patient-Reported Outcomes Measurement Information System (PROMIS) short forms for sleep disturbance, pain interference, physical function, anxiety, depression, and ability to participate in social roles were also completed and scored with a T score. Pearson correlations were used to analyze the relationships between the PROMIS short form for sleep disturbance with PROMIS short forms for pain interference, physical function, ability to participate in social roles, anxiety, and depression, the number of pain sites, and maximum average pain intensity.

RESULTS: In this sample, the mean $\pm$ SD T score of the PROMIS short form for sleep disturbance was 48.4 ± 10.1 . Sleep disturbance was shown to have a moderate positive correlation with pain interference ($r = 0.41$, $P < .01$), and the ability to participate in social roles ($r = 0.43$, $P < .01$). There was also a moderate negative correlation between sleep disturbance and physical function ($r = -0.33$, $P = .03$). No significant correlations were observed between sleep disturbance and number of pain sites, maximum average pain intensity, anxiety, or depression ($P > .05$).

CONCLUSIONS: In this study, individuals with major limb amputations reported similar sleep disturbance to the general population; however, greater sleep disturbance was associated with worse pain interference and physical function. Further, greater sleep disturbance was associated with a greater ability to participate in social roles. This observation may be influenced by amputation etiology; a previous study found that individuals with dysvascular amputations reported decreased ability to participate in social roles as compared to individuals with trauma-related amputations. Contrary to previously published literature on US military active duty and veteran populations, no significant correlations were observed between sleep disturbance and anxiety or depression in this sample. Gender may influence these findings, as previous literature supports higher prevalence of sleep disturbance, anxiety, and depression in females as compared to males.

CLINICAL RELEVANCE: The findings from this study support the requisite for emphasis on identification of sleep disturbance, patient education, and interventions focused on addressing sleep disturbance in individuals with major limb amputations. Attention to sleep deficits may yield improvements in pain interference and physical function.

DISCLAIMER: The views expressed herein are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of the Army, Department of Defense, or the US Government.

OPL47

A SURVEY OF PHYSICAL THERAPISTS' ATTITUDES REGARDING DIAGNOSTIC IMAGING

Sean Daniel Rundell, Murray Ernest Maitland, Robert C. Manske, George J. Beneck

PURPOSE/HYPOTHESIS: Physical therapists (PTs) can provide services via direct access. In certain instances, screening by a PT may indicate a need for diagnostic imaging. As states pass laws permitting imaging referral by PTs, the attitudes and knowledge of imaging will likely influence use of these diagnostic tests. The purpose of this survey was to describe PTs' attitudes regarding ordering and use of diagnostic imaging.

NUMBER OF SUBJECTS: Seven hundred thirty-nine respondents, and 658 (89%) completed all questions. The mean $\pm$ SD age was 42.8 ± 12.2 years and 58% ($n = 417$) were female. The most common entry-level degree was a Doctor of Physical Therapy at 43.0% ($n = 309$), and the median years since graduation was 17 (interquartile range, 7-28); 42.4% ($n = 303$) were board certified specialists, 9.5% ($n = 68$) completed a residency, and 6.6% ($n = 47$) completed a fellowship. Most were members of the Academy of Orthopaedic Physical Therapy, 54.3% ($n = 386$).

MATERIALS AND METHODS: Licensed PTs in the United States were recruited to complete a web-based survey. Academies of the APTA and state chapters distributed our survey invitation via email, social media, and newsletters. Recruitment period was from July 2018 to May 2019. The survey was

determined to be exempt by IRB review. Participants were asked about demographics and their perceived knowledge base and skills for recommending and ordering different imaging modalities using a Likert scale. Descriptive statistics were used to characterize the participants' demographics, and their responses to all questions. Bivariate analysis, comparing responses by characteristics of survey participants, was performed using chi-square tests.

RESULTS: Participants' attitudes about their knowledge base and skills for recommending or ordering different imaging modalities were stronger for recommending and ordering plain films compared to any other modalities (Wilcoxon signed-rank tests; $P < .001$). They also reported having a stronger knowledge base and skill for recommending or ordering magnetic resonance imaging (MRI) over other techniques such as computed tomography (CT), diagnostic ultrasound or bone scans. Participants' attitudes on recommending plain films or MRI differed by entry-level education, board-certification status, fellowship completion, and years since graduation. Attitudes on ordering plain films or MRI varied by board-certification status, residency completion, fellowship completion, and years since graduation (chi-square tests; $P < .05$).

CONCLUSIONS: Participating physical therapists believe that they have an adequate knowledge base and skills for recommending and ordering plain films and MRI over CT, diagnostic ultrasound, and bone scans.

CLINICAL RELEVANCE: Increased emphasis may need to be placed on understanding imaging modalities such as CT, diagnostic ultrasound, and bone scans. Better understanding of these valuable imaging modalities will help PTs meet the responsibilities of direct access.

OPL48

MEASUREMENT PROPERTIES OF THE TIMED FUNCTIONAL ARM AND SHOULDER TEST IN PATIENTS WITH SHOULDER PROBLEMS

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PURPOSE/HYPOTHESIS: No widely used performance test of arm and shoulder function currently exists, and functional measures rely on patient self-report. We have developed the Timed Functional Arm and Shoulder Test (TFAST), which has demonstrated good psychometric properties in healthy, asymptomatic individuals in varied age groups. The purpose of this study is to determine the reliability, validity, and responsiveness of the TFAST in patients with shoulder problems.

NUMBER OF SUBJECTS: Data from 73 patients (48 female; mean $\pm$ SD age, 47.5 ± 19.2 years; diagnosis laterality, 25 left) with shoulder problems such as subacromial pain, rotator cuff syndrome, labral tear, and adhesive capsulitis were included. We plan to collect data on 90 patients. Data collection will be completed by February 2020.

MATERIALS AND METHODS: Patients undergoing treatment for shoulder complaints in physical therapy clinics performed 3 timed tasks; hand behind head and back, wall wash, and gallon lift as previously described. The TFAST was performed bilaterally at evaluation (baseline), then only on the affected side at the first follow-up visit (for reliability) and at discharge (for responsiveness). For each task, total repetitions (reps) were recorded and used to calculate the total TFAST score (higher is better). All tasks were represented equally for a 30-second period. The Penn Shoulder Score (PSS) was completed by patients at each time point, while a global rating of change (GROC) was collected at the last 2 time points. The MCID was calculated for patients who reported "gotten moderately better" at discharge.

RESULTS: All patients were able to complete all components of the TFAST safely. The intrarater reliability ($ICC_{2,1}$) was 0.87 (95% CI: 0.75, 0.93) with an MDC_{90} of 21.2 repetitions. The mean $\pm$ SD TFAST repetitions at baseline were 79.8 ± 26.1 and improved to 104.3 ± 22.0 at discharge ($P < .01$). Forty-one patients reported at least "moderately better" at discharge, while 28/51 patients achieved the MCID of 25.6 repetitions. The effect size was 1.0 and standardized response mean (SRM) was 1.45. The

mean PSS scores improved by 26 points and was correlated to the TFAST ($r = 0.51$).

CONCLUSIONS: The TFAST was safe and feasible, while demonstrating adequate reliability. The MDC in this study was similar to that reported for healthy, asymptomatic adults (21.2 versus 18.5). The MCID, effect size, and SRM have demonstrated acceptable responsiveness. As expected, the moderate correlation between TFAST performance and PSS self-report scores indicate that they are capturing different but related constructs.

CLINICAL RELEVANCE: Establishment of the TFAST as a functional performance measure with strong psychometric properties that is appropriate for a wide spectrum of patients will improve clinical decision making and treatment for those with shoulder problems. The inclusion of a functional performance measure, TFAST, to existing self-report questionnaires can provide objective information about a change in shoulder function over time.

OPL49

MAXIMAL ISOMETRIC AND DYNAMIC PLANTAR FLEXOR STRENGTH IN ACHILLES TENDINOPATHY

Lauren Kay Sara, Karis Yang, Meggie Rose Hart, Sandra Hunter

PURPOSE/HYPOTHESIS: Plantar flexor (PF) muscle strength is assumed to be diminished in persons with Achilles tendinopathy (AT). No study has shown such deficits, and none have evaluated maximal isometric versus maximal dynamic PF strength in this population. The aim of this study was to compare the maximal strength of the PF muscles in healthy, age-matched controls and people with AT. We hypothesized that persons with AT would demonstrate weaker PF muscles during maximal isometric, concentric, and eccentric contractions.

NUMBER OF SUBJECTS: Six AT (mean $\pm$ SD age, 26.8 ± 8.9 years), 12 control (age, 21.1 ± 1.75 years).

MATERIALS AND METHODS: PF strength was measured as the maximal voluntary isometric, concentric, and eccentric contractions (MVIC, MVCC, and MVEC, respectively) in a Biodex 3 dynamometer (Biodex Medical, Shirley, NY). Participants first completed a familiarization session, to practice performance of the maximal strength isometric and dynamic contractions. An experimental session was conducted within a week of familiarization and involved performance of 4 MVICs followed by sets of dynamic contractions. The dynamic contractions involved sets of 4 repetitions at 8 velocities (concentric: $30^\circ/s$, $60^\circ/s$, $90^\circ/s$, $120^\circ/s$, $150^\circ/s$; eccentric: $30^\circ/s$, $60^\circ/s$, $90^\circ/s$). Each contraction was separated by at least 1 minute of rest. The average of the 4 contractions at each velocity was used for subsequent analyses. All strength measures were normalized to participant body weight and expressed as mean $\pm$ SD Nm/kg. A priori alpha was set to .05.

RESULTS: Maximal PF strength was significantly less in AT than controls during $60^\circ/s$ MVCC (AT, 0.80 ± 0.44 Nm/kg; control, 1.10 ± 0.32 Nm/kg; $P = .028$) and at $30^\circ/s$ MVEC (AT, 1.14 ± 0.70 Nm/kg; control, 1.55 ± 0.48 Nm/kg; $P = .045$). No differences in maximal PF strength were found at any other velocity, nor were there differences in MVIC in AT (1.50 ± 0.56) compared with healthy controls (1.75 ± 0.41 ; $P = .13$).

CONCLUSIONS: Persons with AT demonstrate similar maximal PF strength to controls both during isometric contractions and during the majority of dynamic contractions (ie, 75% of velocities tested). Only at contractions of $30^\circ/s$ eccentric and $60^\circ/s$ concentric do persons with AT present with diminished PF strength.

CLINICAL RELEVANCE: The results of this study reveal that maximal strength differs only in a minority of dynamic contractions in persons with AT compared to healthy controls. These angular velocities, though relatively slow, could prove functionally relevant during the stance phase of gait, perhaps suggesting a deficit in eccentric control of the advancing shank and concentric initiation of push-off in persons with AT. These findings could prove beneficial when implementing PF strengthening in clinic:

perhaps the key to successful rehabilitation lies in retraining the PF muscles to fire appropriately at specific angular velocities.

OPL50

INFLAMMATORY RESPONSE TO A BOUT OF HIGH-INTENSITY EXERCISE IN FEMALES WITH FIBROMYALGIA

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PURPOSE/HYPOTHESIS: The primary symptom of fibromyalgia (FM) is widespread chronic pain. Past clinical trials have demonstrated that individuals with FM can benefit from moderate to high-intensity exercises (MHIE). However, individuals with FM present exacerbated pain responses post-MHIE impacting their compliance. This study explored a possible physiological mechanism for the exacerbated pain response to MHIE in patients with FM by examining their inflammatory response to a bout of high-intensity exercise (HIE). The main hypothesis was that FM participants would present with an increase in pain intensity and a blunted anti-inflammatory response to the HIE test.

NUMBER OF SUBJECTS: Thirty-five.

MATERIALS AND METHODS: In this prospective study, 26 participants with FM and 9 healthy controls were recruited. The participants were submitted to a bout of HIE on a recumbent cycle ergometer with their blood samples collected at 3 time points (pre-HIE, the peak of HIE, and 1 hour post-HIE). The primary outcomes were serum levels of the proinflammatory cytokines IL-6 and IL-8, and the anti-inflammatory cytokine IL-10 at each of the 3 time points. Pain intensity before HIE and 24 hours post-HIE was also measured.

RESULTS: In comparison to healthy individuals, FM participants presented a blunted anti-inflammatory response to the HIE bout. Changes in the IL-10 level from the pre- to HIE peak were significantly different ($P < .05$) between the 2 groups (FM, -0.2 ± 0.9 pg/mL; HC, 0.5 ± 0.8 pg/mL). Levels of IL-6 and IL-8 were not significantly different between the 2 groups. Contrary to healthy controls, participants with FM reported significantly higher ($P < .01$) levels of widespread muscle pain 24 hours after the exercise, from 6.2 ± 1.7 pre-HIE to 8.3 ± 1.4 24 hours post HIT ($P < .01$) on a 0-to-10-point scale.

CONCLUSIONS: Patients with FM may not be able to produce a sufficient anti-inflammatory response (IL-10) during HIE. Results from the current study support previous findings that patients with FM present exacerbated symptoms after MHIE that may be related to abnormal inflammatory response. Our findings suggest that the exacerbated widespread pain post HIT may be due to a blunted anti-inflammatory response.

CLINICAL RELEVANCE: Low compliance to MHIE programs may be due to exacerbated pain responses experienced by FM individuals postexercise. Results of this study indicate that exacerbated pain post-MHIE may be due to a disruption in the feedback loop between proinflammatory and anti-inflammatory interleukins as shown in a blunted anti-inflammatory response.

OPL51

PSYCHOLOGICALLY INFORMED EDUCATION VIDEO REDUCES MALADAPTIVE BELIEFS IN ADOLESCENTS WITH PATELLOFEMORAL PAIN

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PURPOSE/HYPOTHESIS: Maladaptive psychological beliefs are adversely associated with patellofemoral joint dysfunction, a condition common in active adolescents. As patellofemoral joint dysfunction is largely treated with physical interventions that may not address maladaptive psychological beliefs, an intervention that can efficiently do so is needed. The purpose of this study was to test the hypothesis that a brief educational video can reduce maladaptive psychological beliefs in adolescents with patellofemoral joint dysfunction.

NUMBER OF SUBJECTS: Twenty adolescents with patellofemoral joint dysfunction (mean $\pm$ SD age, 14 ± 1.7 years; 50% female).

MATERIALS AND METHODS: An educational video, specifically targeting fear-avoidance beliefs and pain catastrophizing, was tailored to adolescents with patellofemoral dysfunction and pain. The psychologically informed educational video incorporated concepts of pain neuroscience education and used the "Common Sense Model of Self-Regulation" framework. Adolescents viewed the psychologically informed educational video (8 minutes 30 seconds in length) on a tablet. Psychological beliefs were assessed using the Fear Avoidance Beliefs Questionnaire-physical activity (FABQ-PA) subscale and the Pain Catastrophizing Scale-child (PCS-c). Higher scores on the FABQ-PA (0-24) and PCS-c (0-52) indicate greater maladaptive beliefs. Participants were assessed at baseline (pre-education video intervention), immediately posteducation video intervention, and 2 weeks postbaseline. Significant change in maladaptive beliefs has yet to be established for adolescents with patellofemoral joint dysfunction, but based on other populations, a 25% change in the FABQ-PA and PCS-c were considered meaningful. Data Analysis: repeated-measures analysis of variance evaluated change in the FABQ-PA and PCS-c over time.

RESULTS: Adolescents with patellofemoral joint dysfunction presented at baseline with a mean functional ability of 77 ± 13 on the Anterior Knee Pain Scale and a reported pain of 4 ± 2 on the numeric pain rating scale. The baseline FABQ-PA score was 12.0 ± 5 , and the PCS-c was 14.3 ± 8 . Immediate reductions in FABQ-PA (7.9 ± 5 , 32% reduction) and PCS-c (10.7 ± 8 , 26% reduction) were observed immediately posteducation video intervention ($P \leq .01$). At 2 weeks, the maladaptive beliefs remained lowered for FABQ-PA (5.5 ± 4.5 , 54% reduction) and PCS-C (7.8 ± 7.3 , 45% reduction) compared to baseline ($P \leq .01$).

CONCLUSIONS: This study provides preliminary evidence that incorporating a brief one-time education video into standard physical therapy care can significantly reduce maladaptive psychological beliefs in adolescents with patellofemoral joint dysfunction. Continued psychosocial intervention may likely be necessary, particularly among adolescents with chronic pain or excessively elevated maladaptive psychological beliefs.

CLINICAL RELEVANCE: Brief psychologically informed video education can reduce maladaptive beliefs among adolescent with patellofemoral joint dysfunction.

OPL52

DANCERS WITH FLEXOR HALLUCIS LONGUS TENDINOPATHY MAINTAIN PERFORMANCE DESPITE ALTERED LOWER EXTREMITY DYNAMICS

Hai-Jung Shih, K. Michael Rowley, Kornelia Kulig

PURPOSE/HYPOTHESIS: Extreme range of motion and excessive demand on the toes are thought to contribute to flexor hallucis longus (FHL) tendinopathy in dancers. Biomechanical factors, such as rate of vertical ground reaction force (GRF) development and joint torsional stiffness have been associated with both injury and athletic performance. Therefore, the purpose of this study was to compare lower extremity dynamics during take-off of a dance split leap (saut de chat) between dancers with and without FHL tendinopathy.

NUMBER OF SUBJECTS: Nineteen.

MATERIALS AND METHODS: Eleven uninjured dancers and 8 dancers with FHL tendinopathy, carefully diagnosed by expert clinicians and ultrasound imaging, enrolled in the study. In a motion capture laboratory, dancers were fitted with full body reflective markers and performed 3 trials of saut de chat taking off of a force plate. GRF data and marker coordinates were low pass filtered at 50 Hz and 20 Hz, respectively. Net joint moments of the metatarsophalangeal (MTP), ankle, and knee joint were calculated using inverse dynamics. Moment impulse was calculated as the area under the moment-time curve. Joint torsional stiffness was calculated as the change in joint moment over the change in joint excursion during loading response (joint moment from onset to peak). Jump height performance, GRF measures, and joint dynamics and stiffness were com-

pared between groups with independent t tests, with $\alpha = .05$. To facilitate interpretation, the leap takeoff was divided into weight acceptance and propulsion phases based on peak vertical GRF.

RESULTS: Dancers with FHL tendinopathy demonstrated a decreased rate of force development ($P = .004$) driven by decreased peak vertical GRF ($P = .012$) and increased weight acceptance time ($P = .027$) during saut de chat takeoff. Surprisingly, no difference was found between groups regarding MTP, ankle, or knee joint moment impulse, representing similar overall loads on the joints. However, ankle ($P = .038$) and knee ($P = .044$) joint excursion during weight acceptance was greater in dancers with FHL tendinopathy. Increased joint excursion may, in part, be driving the decreased joint torsional stiffness during loading response of the MTP ($P = .011$), ankle ($P = .007$), and knee ($P = .039$) seen in dancers with FHL tendinopathy. Despite altered lower extremity dynamics, dancers with FHL tendinopathy did not differ from uninjured dancers in jump height performance ($P = .727$).

CONCLUSIONS: Our findings showed a decreased rate of force development and torsional stiffness across the lower extremity joints in dancers with FHL tendinopathy, although dancers were still able to maintain jump performance. Whether these changes were the result of neuromuscular adaptation to an injured tendon, or are contributing to tendon injury through decreased joint stiffness and increased joint excursions remains unclear.

CLINICAL RELEVANCE: Joint excursion of a leap takeoff may provide insight into joint torsional stiffness, as an optimal amount of stiffness is required for low-risk performance. We recommend that physical therapists evaluate lower extremity joint excursions during functional movements in dancers presenting with FHL tendinopathy.

OPL53

PEAK PLANTAR PRESSURES IN PROGRESSIVE STAGES OF CHRONIC KIDNEY DISEASE-MINERAL BONE DISORDER

David R. Sinacore

PURPOSE/HYPOTHESIS: Chronic kidney disease-mineral bone disorder (CKD-MBD) is a systemic disorder of mineral bone metabolism due to a progressive decline in renal function. CKD-MBD is characterized by 5 progressive stages based on the estimated glomerular filtration rate (eGFR). While the relationship between diabetic neuropathic foot disease (ulceration and amputation) in end-stage renal disease (ESRD, stage 5) is well documented, it is not known if progressive decline in renal function (eGFR) alters dynamic foot function, specifically the stress (peak plantar pressure or PPP) in the diabetic, neuropathic foot. The purpose of this study is to determine the dynamic foot function in participants with diabetes mellitus (DM), peripheral neuropathy (PN) across all 5 stages of CKD-MBD.

NUMBER OF SUBJECTS: Ninety-three.

MATERIALS AND METHODS: This is a cross-sectional cohort analysis of 93 participants (41% women) with DMPN assessing percent glycosylated hemoglobin (HbA1c) levels and serum creatinine (Cr) concentrations to estimate glomerular filtration rate (eGFR) and classify participants into 5 stages of CKD-MBD. All participants performed 3 walking trials on each foot over an Emed ST pressure platform (Novel, USA) using a 3-step method. The foot progression angle (FPA) from each pressure map and PPP in 5 masks of the left foot ie, hind foot, medial and lateral mid foot; medial and lateral forefoot was assessed using Novel software. GFR, HbA1c, FPA and PPPs were compared across stages of CKD-MBD using 1-way ANOVA.

RESULTS: Mean $\pm$ SD age of DMPN participants was 56 ± 9 years; weight, 104 ± 24 kg; BMI, 34 ± 7 kg/m². Based on Cr concentrations and estimates of GFR, 30 participants (32%) were classified in stage 1; 24 (26%) in stage 2; 24 (26%) in stage 3 and 15 (16%) in stages 4 and 5 combined. HbA1c did not differ across stages of CKD-MBD ($P > .05$). External FPA increased from $13^\circ \pm 7^\circ$ in stage 1 to $16^\circ \pm 5^\circ$ in stage 4 and 5. The mean medial mid foot PPP in stage 1, stage 2 and stage 4 and 5 participants increased progressively from 15 to 17 to 23 N/cm², respectively ($P < .05$) and

the mean PPP in the medial forefoot increased from 57 N/cm² in stage 1, 50 N/cm² in stage 2 to 75 N/cm² in stage 4 and 5 participants.

CONCLUSIONS: A progressive decline in renal function (evidenced by increasing serum Cr and decreasing eGFR), is paralleled by an increase in FPA and stress (PPP) specifically in the medial mid foot and forefoot masks during walking. Increases in PPP along the medial column of the foot may likely be due to an increasing external FPA, a progressive deterioration in bony architecture with a decreased medial longitudinal arch and poor windlass function during walking.

CLINICAL RELEVANCE: Progressive CKD-MBD is associated with an increasing external FPA and PPP along the medial column of the diabetic neuropathic foot. Physical therapists should assess dynamic foot function in patients with DMPN to recognize progressive pedal impairments in all stages of CKD-MBD since the risk for ulceration and subsequent LEA is increased.

OPL54

DO CLINICAL STIFFNESS ASSESSMENTS CORRELATE TO MECHANICALLY MEASURED SPINAL STIFFNESS?

Sarah Kalmes Spivey, Joshua Dean Kuest, Gabriel Arthur Lawrence, Kristen Levesque, David Samuel Owens, Jeremy Prisby, Liana Michele Tennant, Jack P. Callaghan, Erika Jo Nelson-Wong

PURPOSE/HYPOTHESIS: Clinical tests of lumbar spinal stiffness include posterior-anterior spring (PA) and passive intervertebral motion (PIVM). These tests assess segmental hypo/hypermobility and contribute to plan of care. Mechanical stiffness can be quantified in vivo through passive moment-angle relationships. The aim of this study was to investigate relationships between experimentally derived mechanical stiffness and clinical tests of spinal stiffness. We expected clinical and mechanical stiffness measures to be correlated.

NUMBER OF SUBJECTS: Fifty-nine healthy adults (29 men; mean $\pm$ SD age, 26 ± 7.7 years).

MATERIALS AND METHODS: Electrodes were placed over lumbar extensors for EMG. Prone extension was used for reference voluntary contraction (RVC). EMG provided biofeedback to ensure relaxed extensors during testing with upper threshold of 2% RVC. Reflective markers were placed at T12 and S2 for kinematics obtained with video camera. Participants were secured in sidelying with lower body fixed, torso on a near-frictionless moveable cradle, then pulled through a flexion motion via cable instrumented with a linear force transducer. Kinematics were used to calculate trunk angle and moment arm from axis of rotation and pulling point. Moment-angle curves were plotted, and slopes used to quantify lumbar spinal stiffness (LSS). PA and PIVM were tested at L3-L4 and rated as hypomobile, normal, or hypermobile by 2 examiners, blind to each other's rating. Upon disagreement, a third examiner performed a tiebreak. Participants were excluded from analysis if no 2 examiners agreed on mobility rating. Kendall's tau was calculated for each variable pairing ($\alpha < .05$) (SAS Studio Version 3.6).

RESULTS: Mean LSS was 2.3 ± 1.3 Nm/°. PA testing identified 19 hypomobile, 28 normal, and 7 hypermobile participants. 5 participants were excluded due to rater disagreement. PIVM testing identified 12 hypomobile, 35 normal, and 12 hypermobile participants. There were no significant correlations between PA-LSS ($r = -0.06$, $P = .57$) or PIVM-LSS ($r = 0.18$, $P = .07$).

CONCLUSIONS: These findings suggest clinical measures of PA and PIVM may not provide information about mechanical spinal stiffness. While not statistically significant, PIVM was moderately correlated to mechanical stiffness obtained through the jig, which might be expected due to the test position/motion similarity. PIVM tests were only assessed at L3-L4 where LSS included all lumbar segments. It is possible these measures would be significantly correlated if all segments were included in clinical tests. Clinical tests of the lumbar spine might provide information about segmental

mobility rather than stiffness. The clinical concept of 'stiffness' may differ from actual mechanical stiffness.

CLINICAL RELEVANCE: Clinical descriptions of PA and PIVM findings using a conceptual framework of "stiffness" may not be accurate as these tests do not correlate with measured mechanical stiffness; it may be time to re-evaluate the use of this terminology. Using overall clinical presentation as well as PA and PIVM tests may determine the best plan of care but these tests do not necessarily correspond to the mechanical stiffness of the lumbar spine.

OPL55

ALTERATIONS IN TENDON STRUCTURE MAY RELATE TO SYMPTOM SEVERITY AND FUNCTIONAL DEFICITS IN PATELLAR TENDINOPATHY

Andrew Lynn Sprague, Karin Grävare Silbernagel

PURPOSE/HYPOTHESIS: Tendon structure (morphology and mechanical properties) is altered in patellar tendinopathy. The clinical relevance of these structural changes has been debated, since symptoms and functional impairments typically resolve prior to changes in tendon structure. The purpose of this study was to explore relationships between degree of altered tendon structure, symptom severity, and deficits in lower extremity function.

NUMBER OF SUBJECTS: Fourteen (7 female) subjects with a mean $\pm$ SD age of 26 ± 8 years, height of 174 ± 11 cm, weight of 75 ± 13 kg, symptom duration of 13 ± 17 months, and a diagnosis of unilateral patellar tendinopathy were recruited.

MATERIALS AND METHODS: Diagnosis was confirmed by a standardized clinical exam. Symptom severity was assessed using the Victorian Institute of Sport Assessment-Patellar Tendon (VISA-P) questionnaire. Tendon thickness and cross-sectional area (CSA) were recorded at 1 cm distal to the inferior pole of the patella using B-mode ultrasound imaging. Tendon mechanical properties (shear modulus and viscosity) were assessed using continuous shear wave elastography (cSWE). The counter-movement jump (CMJ) and drop CMJ tests were used to evaluate function. Paired *t* tests were used to examine differences between symptomatic and asymptomatic limbs for tendon structural measures and jump height on the CMJ and drop CMJ tests. Side-to-side differences (symptomatic – asymptomatic) were calculated for thickness, CSA, shear modulus, viscosity, and CMJ and drop CMJ height for use in relationship analysis. Pearson correlation coefficients were used to explore relationships between degree of altered tendon structure, and symptom severity and lower extremity functional deficits.

RESULTS: The mean $\pm$ SD VISA-P score was 57 ± 16 points. Shear modulus, thickness, and CSA were significantly higher on the symptomatic limb (shear modulus: Sym, 70 ± 12 kPa; Asym, 56 ± 9 kPa; $P = .002$; thickness: Sym, 4.9 ± 2.0 mm; Asym, 3.8 ± 1.5 mm; $P = .03$; CSA: Sym, 111 ± 40 mm²; Asym, 89 ± 30 mm²; $P = .03$). Viscosity did not differ between limbs (Sym, 27 ± 7 Pa·s; Asym, 24 ± 7 Pa·s; $P = .12$). Average height in the CMJ and drop CMJ tests were significantly lower on the symptomatic limb (CMJ: Sym, 9.0 ± 4.0 cm; Asym, 10.5 ± 4.0 cm; $P = .02$; Drop CMJ: Sym, 10.3 ± 4.4 cm; Asym, 12.0 ± 4.5 cm; $P = .004$). Moderate positive relationships were observed between side-to-side differences in viscosity and VISA-P scores (0.429) and CMJ height (0.491), and shear modulus and drop CMJ height (0.446) but did not reach statistical significance ($P = .075-.126$). All other relationships were not close to significance ($P > .16$).

CONCLUSIONS: Patients with unilateral patellar tendinopathy have a larger tendon, higher shear modulus and worse lower extremity function on their symptomatic limb. Alterations in tendon mechanical properties may relate to symptom severity and deficits in lower extremity function but further study with a larger sample size is needed.

CLINICAL RELEVANCE: Altered tendon structure is present with patellar tendinopathy and may contribute to symptom severity and deficits in lower extremity function. Utilizing treatments that improve tendon structure may be of importance in achieving tendon health.

OPL56

RESTRICTING ACTIVITY TO EVADE KNEE SYMPTOMS IS ASSOCIATED WITH WORSE PHYSICAL FUNCTION AND RADIOGRAPHIC OSTEOARTHRITIS

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PURPOSE/HYPOTHESIS: Activity restriction is a common strategy to reduce knee symptoms. Knee symptoms may be indicative of knee osteoarthritis (OA), thus are a common reason people seek health care services, such as physical therapy. It is unclear if activity restriction may indicate deteriorating physical function and development of OA, even if the knee remains asymptomatic. The purpose of this analysis was to examine the associations of activity restriction and knee symptoms with physical function and radiographic OA (ROA) in adults with or at risk for knee OA. We hypothesized that asymptomatic people who report activity restriction would have worse physical function and have higher odds ROA compared to those without symptoms or activity restriction.

NUMBER OF SUBJECTS: Four thousand seven hundred ninety-six (58% women; mean $\pm$ SD age, 61 ± 9 years; BMI, 28.6 ± 4.8 kg/m²).

MATERIALS AND METHODS: We conducted a cross-sectional analysis using baseline data from the Osteoarthritis Initiative, a cohort study of individuals with or at risk for knee OA. We defined people using activity restriction if they reported they "avoid/reduce pain, aching, or stiffness by changing or cutting back on normal activities" in the past 30 days, and people with knee symptoms as those reporting "knee pain, aching, or stiffness on more than half of the past 30 days." We created a 4-category exposure by combining the answers to activity restriction (yes/no) and knee symptoms (yes/no). Outcomes were physical function and ROA. Physical function was assessed with the Short Form-12 Physical Component Score (SF-12 PCS), Western Ontario and McMaster Universities Osteoarthritis Index for physical function (WOMAC-PF), and gait speed (meters per second) from the 20-m walk test. ROA was defined as KL grade ≥ 2 in either limb. To examine the association of the exposure groups with the outcomes, we used general linear models to calculate effect estimates (for physical function) and binomial logistic regression to calculate odds ratios (for ROA) with 95% confidence intervals, adjusting for potential confounders.

RESULTS: Of the full sample, 45% reported no activity restriction or knee symptoms, 12% reported activity restriction only, 17% reported knee symptoms only, and 25% reported both activity restriction and knee symptoms. Compared to people reporting no activity restriction or knee symptoms, those who reported activity restriction and/or knee symptoms had worse SF-12 PCS (mean differences, 2.3–9.0 points; $P < .001$), worse WOMAC-PF (mean differences, 5.7–14.8 points; $P < .001$), and slower gait speed (mean differences, 0.02–0.07 m/s; $P < .001$). Similarly, those reporting activity restriction and/or knee symptoms had 1.3 to 1.9 times the odds of ROA compared to those reporting neither.

CONCLUSIONS: People who restrict normal activities to avoid knee symptoms, or have knee symptoms, have worse physical function and higher odds of ROA compared to those who have neither.

CLINICAL RELEVANCE: In addition to knee symptoms, activity restriction to avoid knee symptoms may also be an indication for referral to physical therapy, since activity restriction is associated with functional deficits.

OPL57

IMPORTANCE OF EARLY IMPROVEMENT IN THE TREATMENT OF LOW BACK PAIN WITH PHYSICAL THERAPY

Zachary Everett Walston, Cheryl McLester

PURPOSE/HYPOTHESIS: To assess the time course of functional outcome improvements during a physical therapy (PT) plan of care for patients with low back pain (LBP). In addition, assess the impact of patient variables, such as symptom duration, on the time course of functional outcome improvements.

NUMBER OF SUBJECTS: Eleven thousand nine hundred forty-five patients.

MATERIALS AND METHODS: Data from a sample of convenience, consisting of patients with lumbar impairments within the FOTO database from 122 outpatient PT clinics across 13 states collected between January 1, 2017 and December 31, 2018, were examined. The authors retrieved data on April 22, 2019 from FOTO Inc (Knoxville, TN). No follow-up data were collected. Inclusion criteria include "body part regions" of lumbar spine, completed episode of care, recorded duration of symptoms, and recorded duration of care. The primary outcome tool assessing functional status outcomes at discharge from PT services was the FOTO Low Back FS PROM, which assesses the patients' perceived physical abilities for patients experiencing LBP impairments. Intake Function Status (FS), FS change at discharge, predicted FS change at discharge, FS change at first progress report (FS1), duration of symptoms prior to treatment, and duration of physical therapy episode of care were assessed. Pearson correlation analysis was used to assess correlation between collected variables and FS change.

RESULTS: The mean FS change at discharge was 16.995, mean at FS1 was 12.024, duration at discharge was 63.591, and duration at FS1 was 28.969, indicating 70.72% of FS change occurred in the first 45.45% of the episode of care. When breaking down by symptom duration, the FS change varied significantly from 13.934 (6+ months) to 28.114 (0-7 days). Correlation analysis demonstrated change at FS1 had the greatest correlation to FS change at discharge. A strong correlation ($r > 0.7$) was demonstrated in all symptom duration categories ranging from 0.741 to 0.805.

CONCLUSIONS: The results of this study yield further support for the importance of rapid functional improvements during a PT plan of care. Patients demonstrated roughly two thirds of their improvement in the first 40% of visits regardless of their symptom duration. This highlights the expectation that patients should demonstrate significant improvement in the first month of care, regardless of the duration of their symptoms. It should be noted that the level of improvement at FS1 is relative to the final outcome. While the percentage of improvement is similar across symptom durations, the magnitude of improvement is statistically and clinically different.

CLINICAL RELEVANCE: This study may help clinicians identify when modification to a plan of care may be needed. Significant improvements should be achieved in the first 3 weeks of care, regardless of the chronicity of symptoms. These results may help therapists educate patients on expected improvements throughout a plan of care.

OPL58

IMPACT OF LOW BACK PAIN CHRONICITY ON PATIENT OUTCOMES FOR THOSE TREATED IN OUTPATIENT PHYSICAL THERAPY

Zachary Everett Walston, Cherilyn McLester, John McLester

PURPOSE/HYPOTHESIS: The purpose of this study is to report on the potential relationship between chronicity of symptoms prior to onset of physical therapy intervention and functional status (FS) outcomes in patients treated for low back pain in outpatient physical therapy settings. Additionally, the study will report on the differences in dosage (number of visits and total duration of the episode of care) for each stage of symptom chronicity to assess the potential relationship.

NUMBER OF SUBJECTS: Eleven thousand nine hundred forty-one patients with LBP provided physical therapy services and discharged from care between January 1, 2017 to December 31, 2018.

MATERIALS AND METHODS: Data from a sample of convenience, consisting of patients with lumbar impairments within the FOTO database from 122 outpatient PT clinics across 13 states collected between January 1, 2017 and December 31, 2018, were examined. The authors retrieved data on April 22, 2019 from FOTO Inc (Knoxville, TN). No follow-up data were collected. Inclusion criteria include 'body part regions' of lumbar spine, completed episode of care, recorded duration of symptoms, and recorded duration of care. The primary outcome tool assessing functional sta-

tus outcomes at discharge from PT services was the FOTO Low Back FS PROM, which assesses the patients' perceived physical abilities for patients experiencing LBP impairments. Repeated-measures analysis of variance (ANOVA) was used to determine any differences between variables across chronicity categories. Variables included age, gender, intake FS (0-100), initial pain rating, body mass index (BMI), number comorbidities, and exercise frequency. Pearson correlation analysis was used to assess correlation between collected variables and FS change (difference in intake FS score and discharge FS score, MCID is 5). Regression covariates included intake FS, chronicity, number of comorbidities, number of visits, age, duration of care, exercise frequency outside PT, initial pain rating, and BMI. All analyses were set at an alpha level of .05.

RESULTS: The mean FS change was 16.997 ($n = 11941$). Patients with chronic symptoms (>90 -day duration) had an FS change of 15.920 ($n = 7261$). Patients with subacute symptoms (15-90 days) had an FS change of 21.66 ($n = 3630$). Patients with acute symptoms (0-14 days) had an FS change of 29.32 ($n = 1050$). Acute patients received 13.66 visits, subacute patients received 14.05 visits, and chronic patients received 14.63 visits on average. Stepwise regression analysis revealed a significant beta for chronicity (-4.155) with all models. Intake FS had the greatest correlation with FS change ($r = -0.393$) across all patients.

CONCLUSIONS: Overall, this study shows patients experiencing shorter duration of LBP symptoms prior to starting a physical therapy episode of care experience significantly better outcomes than patients who waited. The greatest FS change was seen in patients treated within 15 days of the onset of LBP symptoms. Additionally, the number of sessions provided for each chronicity group differed little. This is potentially a result of fewer tissue and behavioral changes occurring compared to patients with chronic symptoms. With respect to regression analysis of all included variables, chronicity had the greatest predictive value. Intake FS has a moderate negative correlation with FS change which may be impacted by a ceiling effect as a lower starting score has more potential improvement.

CLINICAL RELEVANCE: Physical therapists should consider the chronicity of a patient's symptoms when developing a plan of care. With similar dosage of care, represented by duration and number of visits, worsening functional status improvement may occur as symptom chronicity increases. Physical therapists may need to increase the dosage of care provided and change interventional strategies when treating patients with chronic pain.

OPL59

QUADRICEPS MUSCLE ATROPHY AND HETEROGENEOUS RECOVERY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A LONGITUDINAL MAGNETIC RESONANCE IMAGING EVALUATION

Grace Marie White, Emma Madison Davis, Macie Michelle Sims, Mallory Anne Law, Madeleine Louise O'Callaghan, Olivia Marie Hoey, Abigail Kathryn Woodard, John Michael Popovich, Liang-Ching Tsai

PURPOSE/HYPOTHESIS: Quadriceps strength deficits are commonly observed after anterior cruciate ligament reconstruction (ACLR), yet the restoration of individual quadriceps muscles and their contributions to strength recovery over time remain unknown. Using magnetic resonance imaging (MRI), we examined the variation in atrophy among the 4 quadriceps muscles longitudinally and assessed the association of muscle hypertrophy with strength recovery after ACLR.

NUMBER OF SUBJECTS: Nine subjects with unilateral ACLR (6 women; mean $\pm$ SD age, 24.6 ± 8.2 years; BMI, 23.7 ± 3.1 kg/m²).

MATERIALS AND METHODS: Subjects underwent axial MRI scans and isokinetic (60°/s) strength testing of bilateral quadriceps muscles at approximately 6 (5.4 ± 1.6) and 12 (11.6 ± 3.1) months post ACLR. Individual muscle volume was calculated as the cross-sectional areas measured on all MRI images multiplied by the slice thickness. Atrophy was defined as the difference in muscle volume between the ACLR and uninjured legs normalized to the uninjured leg's volume (ie, percent change of the uninjured

leg). Differences in atrophy among the 4 muscles and across 2 time points were evaluated using a 2-way (muscle-by-time) repeated-measures ANOVA. Pearson correlation was used to examine the association of the change in overall quadriceps volume with the change in peak isokinetic strength over the 2 time points.

RESULTS: A significant muscle-by-time interaction was identified when comparing atrophy among muscles over 2 post-ACLR time points ($P = .04$). Follow-up simple main effect analyses revealed that the vastus medialis (VM) had greater atrophy than the vastus intermedius (VI, $P = .02$) and rectus femoris (RF, $P < .01$) only at 6 months post-ACLR. However, atrophy of the vastus lateralis (VL) was greater than that of the VI and RF at both 6- and 12-month time points (all, $P \leq .05$). A significant reduction in atrophy across the 2 time points was observed for the VL, VM, and VI (all, $P \leq .04$), but not in the RF ($P = .33$). Though significant recovery of the isokinetic strength and overall quadriceps volume over time were observed in the ACLR legs (by $23\% \pm 16\%$ and $7\% \pm 7\%$, respectively; $P \leq .02$), the ACLR legs still had weaker and smaller quadriceps muscles than the uninjured legs at both time points (all, $P \leq .02$). There was no significant association between strength and volume recovery ($r = 0.33$, $P = .39$).

CONCLUSIONS: Heterogeneous recovery in morphology is evident among quadriceps muscles post ACLR. Greater atrophy was noted in the VM and VL at 6 months. Though subsequent recovery occurred faster in the VM, atrophy of the VL persisted at 12 months post ACLR (ie, return to sport timeframe). The relatively small recovery of the quadriceps muscle size may not be a main determinant of strength gains from 6 to 12 months post ACLR.

CLINICAL RELEVANCE: While variations in atrophy occur, preferential strengthening of specific muscles (eg, VM and/or VL) may depend on the time post ACLR. The lack of association between quadriceps hypertrophy and strength gains indicates the need for continued rigorous quadriceps strengthening after discharge. Interventions developed to achieve uniform recovery and enhance quadriceps hypertrophy may help reduce the persistent weakness post ACLR.

OPL60

RELIABILITY AND VALIDITY OF A NEW ACTIVE MOVEMENT SCREEN FOR WORKPLACE HEALTH

Rick Wickstrom, Inga Wang, Rose L. Smith

PURPOSE/HYPOTHESIS: One strategy to improve workplace wellness is to identify and reduce musculoskeletal risks that limit participation in suitable physical activity. The purpose of this study was to investigate the intrarater reliability, test-retest reliability, and concurrent validity for a new Active Movement Screen (AMS).

NUMBER OF SUBJECTS: Two hundred forty-eight.

MATERIALS AND METHODS: Two hundred forty-eight nondisabled volunteers (138 male, 110 female) of working age (mean $\pm$ SD age, 38.2 ± 14.6 years) were assessed for Physical Activity Rating (PAR), BMI, waist to height (WtH), AMS and best of 3 functional mobility trials on the 2-Square Agility Test (TSAT) and Maximum Step Length Test (MSL). The AMS consists of 5 upper-body movements in sitting and 8 lower-body movements in standing. Each movement is rated based on observational criteria from 4 (normal) to 0 (unable). An AMS Total score was derived from percent of all numbered ratings out of 100 total points. An AMS Upper Body subscore was derived from the percent of upper body ratings out of 40 points and a Lower Body AMS subscore was derived from the percent of lower body ratings out of 60 points. Out of 248 subjects, 44 subjects were rated by 2 examiners on the AMS for interrater reliability during the first session, and 78 subjects returned for a second session a week later to be reassessed for test-retest reliability by the same rater, using intraclass correlation coefficient (ICC) model 2,1. Pearson correlations (r) were used to assess concurrent validity for AMS with body size, recent physical activity, and functional mobility measures.

RESULTS: Mean $\pm$ SD performances for 248 subjects were: AMS total, $96 \pm$

6.3 ; AMS lower body, 95.7 ± 8.3 ; and AMS upper body, 96.6 ± 5.7 . Interrater reliability was good to excellent for AMS upper body (ICC = 0.82), AMS lower body (ICC = 0.93), and AMS total (ICC = 0.94). Test-retest reliability was good for AMS upper body (ICC = 0.77), lower body (ICC = 0.82), and AMS total (ICC = 0.85). Lower-body AMS was significantly correlated with TSAT ($r = -0.57$), WtH ($r = -0.49$), BMI ($r = -0.42$), PAR ($r = 0.41$), and MSL ($r = 0.40$). AMS upper body was significantly correlated with TSAT ($r = -0.34$), WtH ($r = -0.32$), BMI ($r = -0.25$), PAR ($r = 0.31$), and MSL ($r = 0.20$).

CONCLUSIONS: Our results for this preliminary study demonstrated good to excellent reliability for all AMS measures in working age, nondisabled subjects. AMS Lower Body had more substantial validity correlations with body size and functional mobility measures. There was a substantial ceiling effect identified for the AMS in this sample of nondisabled volunteers. Therefore, the AMS should be supplemented with other functional performance measures such as the TSAT and MSL tasks that don't have ceiling effects in workers that are physically fit.

CLINICAL RELEVANCE: Among workplace wellness participants, AMS may be useful to screen for abnormal movements for triage to suitable physical activity or follow-up consultation. Establishing a preinjury baseline of movement performance supports worker transitions between wellness and treatment programs.

OPL61

THE RELATIONSHIP BETWEEN MASSAGE HYPOALGESIA AND CONDITIONED PAIN MODULATION: RANDOMIZED CONTROLLED TRIAL IN HEALTHY PARTICIPANTS

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PURPOSE/HYPOTHESIS: Conditioned pain modulation (CPM) is a response in which a secondary painful conditioning stimulus inhibits a primary painful testing stimulus. Painful massage lessens pain sensitivity more than pain free massage suggesting a mechanism dependent on CPM. The primary aim of this research was to determine if pain induced by massage or a cold pressor task (immersion in 10°C water) could elicit comparable experimental pain sensitivity changes in healthy participants, suggesting a shared underlying mechanism of CPM. A secondary aim of this research was to determine if baseline CPM efficiency (efficient, increase in pressure pain threshold following the conditioning stimulus) could stratify a hypoalgesic response to massage in healthy participants. The hypothesis was that individuals with efficient CPM at baseline would show greater increases in pressure pain thresholds in response to a pain inducing massage than individuals with less efficient baseline CPM.

NUMBER OF SUBJECTS: Sixty healthy participants (mean $\pm$ SD age, 22.45 ± 4.82 years; 67% female).

MATERIALS AND METHODS: Individuals underwent a CPM paradigm at baseline to determine CPM efficiency. Each participant was then randomly assigned to either a moderately painful massage to the neck ($n = 20$), a pain free massage to the neck ($n = 20$), or a cold pressor task to the hand ($n = 20$). Participants in each group received their assigned intervention as a conditioning stimulus for 1 minute, 4 times with assessment of the testing stimulus of pressure pain threshold at the foot between each time interval. A repeated measures ANCOVA with baseline pressure pain threshold as a covariate determined between group changes in pain sensitivity. Individuals receiving the massage interventions were then stratified according to baseline CPM efficiency and a dependent t test was conducted to examine mean difference in pressure pain threshold immediately following 4 minutes of pain free and pain inducing massage.

RESULTS: Pain inducing massage resulted in comparable experimental pain sensitivity changes as a cold pressor task across all time points ($P < .05$) and both demonstrated larger changes than pain free massage. Individuals with an efficient CPM at baseline who received the pain in-

ducing massage displayed greater increases in pressure pain threshold (mean difference, -20.33 ; 95% CI: $-75.39, 34.74$) compared to individuals with an inefficient CPM (mean difference, -4.90 ; 95% CI: $-75.07, 65.27$). Individuals who received the pain-free massage displayed similar changes in pressure pain threshold regardless of CPM efficiency.

CONCLUSIONS: These findings support a mechanism of pain inducing massage comparable to CPM. Individuals with an efficient CPM demonstrated greater hypoalgesia than those with inefficient CPM in response to a pain inducing massage suggesting a mechanistic based treatment stratification method.

CLINICAL RELEVANCE: Understanding the mechanisms of interventions for individuals in pain can facilitate mechanistic based treatment approaches and greater personalization of care. The results of this study provide preliminary evidence for the utility of stratifying rehabilitation interventions by underlying mechanism necessitating replication in individuals with pain conditions.

OPL62

BLOOD PRESSURE-RELATED HYPOALGESIA AND COMPARATIVE SYMPATHOINHIBITION DURING MOBILIZATIONS IN NECK PAIN: CONCURRENT ANALYSES FROM A RANDOMIZED CONTROLLED TRIAL

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PURPOSE/HYPOTHESIS: Blood pressure (BP)-related hypoalgesia exists whereby higher resting BP is related to reduced (acute) pain perception-an inverse relationship well-established in the normotensive population ($n = 10371$). Yet, this BP-related hypoalgesia mechanism, is little known in neurophysiologic models of how joint mobilization works. Historically, sympatho-excitatory effects is the popular paradigm presumably related to neurophysiologic models. Yet, only 1 study formally related hypoalgesia with sympatho-excitation using lateral glide (LAT) mobilization, dosed at 3×30 seconds. Conversely, posterior (AP) mobilization decreased systolic BP (SBP), suggesting sympathoinhibitory effects, in pain-free adults when uniquely dosed at 5×10 seconds. Therefore, it seems helpful to explore if either AP or LAT mobilization decreases pain and BP, related to borderline normotensive individuals whereby a further BP increase may be worrisome. (1) To evaluate the relationship of resting/baseline BP with pain response 2 days postintervention and (2) to evaluate the cardiovascular effects of AP and LAT mobilization.

NUMBER OF SUBJECTS: Forty-three (23 female) participants with nonchronic mechanical neck pain (baseline mean $\pm$ SD heart rate, 61.34 ± 8.70 bpm; SBP, 114.16 ± 13.84 mmHg; DBP, 71.23 ± 6.95 mmHg; average numeric pain-rating scale [NPRS] at rest, 2.92 ± 1.25 ; Neck Disability Index, 7.74 ± 3.41) randomly received either technique, dosed at 5×10 seconds (on/off).

MATERIALS AND METHODS: Research assistants determined cardiovascular variables before, during, and after the intervention and neck NPRS (average, current, best, worst) before and 2 days post intervention. A linear regression model was used to evaluate the relationship between independent variables and average NPRS reduction in a univariate manner. Subsequently, multivariate regression models were fitted to the data using a stepwise variable selection approach to identify independent predictors of outcomes while controlling for confounders. Mean differences between groups on cardiovascular variables were compared using multilevel mixed-effect modeling for repeated measures, adjusting for baseline characteristics by entering treatment, time, and baseline values (age, gender, and BMI) as covariates.

RESULTS: Baseline SBP was significantly related to average NPRS reduction 2 days post intervention on univariate and multivariate analyses (coefficients, -0.029 ± 0.013 ; $P = .036$ and -0.026 ± 0.012 ; $P = .032$, respectively). Average NPRS decreased for both groups (from 2.92 ± 1.25 to 1.90 ± 1.26 ; $P < .001$). There were no between-group differences in average

NPRS reduction and cardiovascular changes. Mixed-effect model ANOVA revealed a significant change in SBP over time (estimate, -1.94 ± 0.70 mmHg; $P = .016$), from baseline to during-intervention.

CONCLUSIONS: Our study was the first to relate baseline SBP with NPRS reduction, explaining SBP-related hypoalgesia. Each 10-mmHg higher baseline SBP was related to a 0.29-unit average NPRS decrease 2 days post intervention. When uniquely dosed, both mobilizations decreased sbp during the intervention, suggesting sympathoinhibition, a related important finding with promising helpful effects.

CLINICAL RELEVANCE: Given a baseline 3/10 average NPRS as our cohort: patient A hypothetical baseline SBP is 138 mmHg while patient B has 98 mmHg. Evaluating this 40-mmHg difference (-0.029×40), patient A NPRS may improve by 1.16/10, resulting in a clinically insignificant value of 1.84/10. Further, the study adds new knowledge and clinical value, offering a useful alternative treatment option for some patients who present with neck pain and have a borderline resting BP (eg, 138/90 mmHg). Relatedly, performing either technique with the novel dose used in this study would likely not increase the BP toward the hypertensive range, and thus adding an important safety value to the clinical reasoning process.

OPL63

INFERIOR TENDON MECHANICAL PROPERTIES IN THE PRESENCE OF DIABETES IN INDIVIDUALS WITH ACHILLES TENDINOPATHY

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PURPOSE/HYPOTHESIS: Diabetes (DM) is associated with a 3-fold greater risk of developing tendinopathy. Increased Achilles tendon thickness, decreased stiffness, and calcifications on ultrasound have been reported in asymptomatic individuals with DM, however, little is known in humans about tendon injury and healing in the context of DM. The purpose of this study was to compare Achilles tendon structural characteristics in tendinopathic individuals with and without DM.

NUMBER OF SUBJECTS: Individuals with Achilles tendinopathy were included in this study. Individuals with a self-report of DM (DM group: $n = 8$; 5 male; mean $\pm$ SD age, 69 ± 4 years; BMI, 32 ± 9 kg/m²) were matched for sex, age (± 5 years), BMI (± 5 kg/m²), and smoking status (in all but 1 case) to an individual without diabetes (non-DM group: $n = 8$; 5 male; age, 67 ± 3 years; BMI, 30 ± 2 kg/m²). Participants were excluded if they had Achilles tendon surgery or rupture.

MATERIALS AND METHODS: This is a retrospective analysis of prospectively collected data. Tendon viscosity and shear modulus, which relate to tendon tensile behavior, were assessed bilaterally using continuous shear wave elastography. Achilles tendon length from calcaneus to gastrocnemius and cross sectional area were assessed using B-mode ultrasound. Self-reported symptoms and function were assessed using the VISA-A and FAOS quality of life subscale along with pain on tendon palpation via a numeric rating scale. Between-group differences were assessed using paired t tests.

RESULTS: On the symptomatic side, the DM group had lower tendon viscosity (DM, 42.7 ± 11.0 Pa-s; non-DM, 58.2 ± 10.4 Pa-s; $P = .04$) and group differences in shear modulus exceeded measurement error but were not statistically significant (DM, 114.6 ± 16.4 kPa; non-DM, 93.4 ± 12.1 kPa). There were no significant differences in viscosity or shear modulus on the uninjured side. There were no differences between groups in symptomatic tendon length (DM, 19.6 ± 3.0 cm; non-DM, 20.5 ± 3.3 cm) or cross-sectional area (DM, 1.25 ± 0.65 cm²; non-DM, 1.06 ± 0.46 cm²). There were no differences in tendon morphology on the uninjured side. There were no differences in VISA-A score (DM, 43 ± 16 ; non-DM, 39 ± 16), FAOS quality of life subscale (DM, 41 ± 15 ; non-DM, 40 ± 7), or pain on palpation (DM, 4 ± 3 ; non-DM, 5 ± 2).

CONCLUSIONS: Individuals with DM and symptomatic Achilles tendinopathy have lower rate-dependent resistance to shearing forces on the symptomatic

side. This may suggest greater tendon structure disorganization and deterioration. There were no differences observed in tendon morphology on the symptomatic side or any tendon structural parameter on the contralateral side, suggesting no systemic changes associated with DM.

CLINICAL RELEVANCE: Individuals with Achilles tendinopathy and comorbid DM exhibit a greater degree of tendon structural disruption or impaired ability for the tendon to remodel compared to individuals without DM, despite similar symptom severity. Intervention timelines and prognosis may be altered as a result.

OPL64

INTERRATER RELIABILITY OF A NOVEL TREATMENT FIDELITY TOOL EXAMINING GUIDELINE ADHERENCE OF PHYSICAL THERAPISTS

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PURPOSE/HYPOTHESIS: Fidelity to guideline care recommendations is thought to decrease unwanted variability in care and optimize physical therapy outcomes. Having a standardized measure to evaluate the delivery of physical therapy services is key as value-based reimbursement models become standard. This fidelity tool was designed to examine utilization of guideline adherent care as it is reflected in current best practice recommendations. The purpose of this study was to examine interrater reliability of the fidelity tool between 2 clinician-examiners across a random sample of 25 patients enrolled in an optimized PT-first program.

NUMBER OF SUBJECTS: Charts review of a random sample of 25 patients enrolled in an optimized PT-first program.

MATERIALS AND METHODS: Two independent clinician-examiners were trained in the administration of a 10-item fidelity tool. Each of the 10 items was scored "yes" or "no" based upon adherence to a component of the guideline

based care model based off of patient initial presenting irritability; a composite score summed all "yes" responses for a maximum possible score of 10. Interrater reliability was calculated for each item using an unweighted kappa statistic; while a weighted kappa statistic was used to assess interrater reliability for the composite score. Strength of agreement was classified using the initial cut points recommended by Cohen.

RESULTS: Of the 10 items, a kappa statistic could not be calculated for the item evaluating the review of patient goals due to uniform responses by 1 reviewer. Of the remaining 9 items, 2 were deemed to have poor agreement (review of prognosis, $\kappa = -0.19$); appropriate manual therapy for reported irritability ($\kappa = -0.10$), 3 demonstrated fair agreement (appropriate strengthening for reported irritability ($\kappa = 0.20$); appropriate modalities for reported irritability ($\kappa = 0.26$); treatment time 60 to 75 min per session ($\kappa = 0.28$), 2 demonstrated moderate agreement (appropriate scheduling at initial evaluation ($\kappa = 0.41$); appropriate actual visits attended ($\kappa = 0.51$), 1 demonstrated substantial agreement (diagnosis matches documented patient presentation ($\kappa = 0.65$), and 1 demonstrated almost perfect agreement (appropriate mobility exercises for reported irritability ($\kappa = 0.82$). The composite score demonstrated moderate agreement ($\kappa = 0.48$).

CONCLUSIONS: Analysis of appropriate treatment patterns that is adherent to best practice recommendations is crucial to translational research that reviews more detail than financial coding. Overall the tool suggests moderate interrater reliability between 2 clinician-examiners. Out of 9 items available for calculation, 4 items were found with either moderate or better agreement and 5 were found with fair or worse agreement. This preliminary evaluation provides important information to refine the tool and training to ensure consistent interpretation of items in the tool.

CLINICAL RELEVANCE: With further refinement and testing, the fidelity tool may prove useful in determining adherence to evidence-based care guidelines for physical therapists.

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SPL1

ASSOCIATION OF QUADRICEPS STRENGTH SYMMETRY WITH CLINICAL OSTEOARTHRITIS 5 YEARS AFTER ANTERIOR CRUCIATE LIGAMENT RUPTURE

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PURPOSE/HYPOTHESIS: After anterior cruciate ligament (ACL) rupture, the chances of developing posttraumatic osteoarthritis (OA) are 60% to 90%, with 50% of individuals developing OA within a decade of ACL reconstruction. Posttraumatic OA is associated with reduced sports and recreational participation, pain, and decreased self-reported quality of life. Several factors are associated with the development of OA, including altered gait mechanics, changes in joint loading and decreased muscle strength surrounding the knee joint. The relationship between clinical outcomes at 5 years after ACL injury and the development of OA is unknown. The purpose of this study was to examine the association of quadriceps strength with presence of early knee OA symptoms 5 years after ACL rupture.

NUMBER OF SUBJECTS: Two hundred four athletes 5 years after ACL rupture or reconstruction (mean $\pm$ SD age, 33 ± 10 years; body mass index [BMI], 25 ± 4 kg/m²).

MATERIALS AND METHODS: This is a secondary analysis of a prospective cohort study. Participants were enrolled if they were participating in level I (eg, soccer, basketball) or level II (eg, racket sports, baseball) sports at the time of ACL rupture. Participants were excluded if they had symptomatic grade III ligamentous injury, articular cartilage lesions >1 cm² or previous history of ACL injury. For this analysis, we included participants who returned for the 5-year follow-up visit. Quadriceps strength was measured with an electromechanical dynamometer and reported as a limb symmetry index (involved limb maximal volitional isometric contraction (MVIC) divided by uninvolved limb MVIC expressed as a percentage). The Knee injury and Osteoarthritis Outcome Score (KOOS), a patient-reported outcome of knee function, was administered to all participants. We identified individuals with symptoms consistent with early clinical knee OA based on a proposed classification criteria. The criteria require that 2 out of 4 KOOS subscales (pain, symptoms, function, and knee-related quality of life) are $\leq 85\%$. To examine the association between quadriceps strength and early knee OA, we calculated odds ratios (ORs) and 95% confidence intervals (CIs) using logistic regression, adjusted for sex, age, and BMI.

RESULTS: At the 5-year follow-up, 20% (41/204) of participants met the

Luyten KOOS criteria for clinical knee OA. Better quadriceps strength symmetry was associated with lower odds of clinical knee OA symptoms (adjusted OR = 0.96; 95% CI: 0.93, 0.99). Specifically, for every 1% increase in quadriceps strength limb symmetry index, there was 4% lower odds of clinical OA symptoms.

CONCLUSIONS: Higher quadriceps strength LSI 5 years after ACLR is associated with lower odds of clinical knee OA. Future work should examine the association of quadriceps strength with the development of radiographic OA.

CLINICAL RELEVANCE: Maintaining higher quadriceps limb symmetry at 5 years after ACL rupture or reconstruction may decrease odds of clinical knee OA symptoms.

SPL2

SUCCESSFUL NONOPERATIVE MANAGEMENT OF A COLLEGIATE WRESTLER WITH AN ACUTE ANTERIOR CRUCIATE LIGAMENT INJURY

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Lynn Snyder-Mackler*

BACKGROUND AND PURPOSE: Following an ACL injury, conventional treatment for athletes is often reconstruction; yet, current outcomes demonstrate that rates of return to prior level of play are lower than believed. In a study comparing immediate surgical treatment, delayed surgical treatment, or nonoperative treatment of ACL tears; no significant difference in patient reported outcomes were found. Nonoperative management has been shown to be a viable option following a treatment algorithm. In a 10-year prospective study of this algorithm, athletes who met nonoperative screening criteria (potential copers or PC) demonstrated a 72% successful return to preinjury level of sports participation. The algorithm provides criteria for a temporary return to sport (RTS) protocol, initially focusing on impairment resolution including full range of motion (ROM) of the knee, $>70\%$ quad strength index (QI), trace or less effusion, pain-free hopping, and no repairable meniscus tear. Screening includes: ≤ 1 episode of giving way, $>80\%$ on timed hop test, $>80\%$ Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADLS), and $>60\%$ Global Rating Scale (GRS). If met, progressive physical therapy is initiated, including 10 visits of perturbation training and sports specific skills. The purpose of this case report is to describe the successful nonoperative treatment of a collegiate wrestler using an ACL injury treatment algorithm for temporary RTS.

CASE DESCRIPTION: A 21-year-old male collegiate wrestler sustained a complete ACL tear in preseason. The patient was seen for evaluation 2 weeks

after his injury displaying full knee ROM, trace effusion, and QI of 92.3% (without stimulation) and 85.6% (with stimulation) via burst superimposition testing. Using the ACL injury treatment algorithm, the patient was screened for potential temporary RTS. Results included: ≤ 1 episode of giving away, hop testing LSI all $>90\%$, KOS-ADLs 87% and GRS 95% indicating patient was a PC. The patient began a plan of care consisting of 10 treatments of progressive perturbation training, strength training, and sport-specific activities.

OUTCOMES: Throughout treatment, the patient's knee effusion remained at trace or less without any episodes of instability. Discharge findings included Burst testing QI of 95.5% (without stimulation) and 107.6% (with stimulation), all hop testing LSI of $>90\%$, KOS-ADL of 100% and GRS of 90%. The patient returned to wrestling practice 2 months after his injury, competing a few weeks later, and finishing fourth in the division III NCAA tournament.

DISCUSSION: After meeting screening criteria and following a progressive rehabilitation program the patient was able to meet all functional testing criteria for return to sport and had a successful collegiate season without any instability. The outcomes of this case report support the use of an ACL injury treatment algorithm to guide clinical decision making for athletes with an ACL tear who want to delay surgery and return to play in the short term.

SPL3

INTRAOPERATIVE PLATELET-RICH PLASMA DOES NOT IMPROVE PATIENT FUNCTION FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A MATCHED CASE-CONTROL STUDY

Lane Bailey, Jacquelyn Lee Kleihege, Kyle Lauck, Matthew Weldon, Walter R. Lowe

PURPOSE/HYPOTHESIS: Platelet-rich plasma (PRP) contains various growth factors that positively effect biological healing, unfortunately few existing clinical studies are available to determine the risks and benefits of these therapies and their relevance on patient recovery. Therefore, the purpose of this study was to determine the influence of intraoperative PRP on postoperative knee function out to 2 years following ACL reconstruction with meniscus repair.

NUMBER OF SUBJECTS: Three hundred twenty-four patients following ACL reconstruction.

MATERIALS AND METHODS: A matched case-control study was conducted using a single surgeon database of 673 patients undergoing ACL reconstruction with concomitant meniscus repair resulting in 324 patients (PRP, $n = 162$) versus matched-control ($n = 162$) who met the study criteria. Patients were matched on age, gender, graft type, and meniscus tear size and location. The single assessment numeric evaluation (SANE) was administered at 2 years and served as the primary outcome measure. Secondary outcomes included the time to return-to-activity (months), self-reported knee function (International Knee Disability Committee [IKDC]), objective functional testing (knee ROM, single-leg balance, single leg-hopping, agility testing), and postoperative complications (graft failure, infection, loss of motion, venous thrombosis, etc). Univariate models were used for between groups comparisons and alpha was set at .05 for all analyses.

RESULTS: There were no differences in SANE knee function scores between the PRP and matched-control groups at 2 years, respectively (91.6 ± 11.2 versus 92.4 ± 10.6 , $P = .599$). Additionally, no differences were observed between groups for self-reported function (IKDC score, 87.6 ± 13.3 versus 88.1 ± 12.6 ; $P = .952$), objective functional testing ($P > .05$), and timing of return-to-activity (7.8 ± 1.9 versus 8.0 ± 1.9 , $P = .765$). The PRP group demonstrated a higher rate of postoperative knee motion loss complications when compared to the control group (13.5% versus 4.9%, $P < .001$). No other differences were observed in postoperative complications ($P > .05$).

CONCLUSIONS: The added use of intraoperative PRP did not improve self-reported knee function, objective functional testing, and timing of return-

to-activity for patients undergoing ACL reconstruction with concomitant meniscus repair. Furthermore, the use of PRP may have negative consequences for regaining knee ROM after surgery.

CLINICAL RELEVANCE: Based on these data, patients and surgeons should cautiously consider the application of PRP when surgical planning for intra-articular injuries of the knee.

SPL4

THE RELATIONSHIP BETWEEN TRUNK ENDURANCE AND RUNNING KINEMATICS IN ADOLESCENT LONG-DISTANCE RUNNERS

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PURPOSE/HYPOTHESIS: The trunk plays a crucial role in optimizing athletic performance by generating and controlling forces through the integration of upper and lower extremities. In recreationally active adults, fatigue of the trunk and paraspinal musculature has been linked to lower back pain and deficits in lower extremity and postural control. While positive relationships have been reported between trunk endurance and trunk and pelvic tilt range of motion (ROM) in adolescent male runners, the relationship between trunk endurance and running kinematics in adolescent runners is sparse. The physiologic and somatic development process in children is complex, with maturational stages resulting in varying rates of strength and neurodevelopment in youth athletes. Therefore, the purpose of this study was to compare running patterns between adolescent long-distance runners with high and low trunk endurance.

NUMBER OF SUBJECTS: One hundred two.

MATERIALS AND METHODS: One hundred two uninjured adolescents who participated in long-distance running activities participated in the study (43 male, 59 female; mean $\pm$ SD age, 13.4 ± 2.9 years). Participants held a prone forward plank until they could no longer maintain the position. Subjects were then instrumented with reflective markers and underwent 3-D motion analysis while running at a self-selected speed. Trunk endurance was measured as the duration of the plank hold and normalized to body weight. Participants were stratified by trunk endurance and participants below the 25th percentile were classified as LOW (11 male, 14 female; mean $\pm$ SD age, 13.7 ± 3.0 years) and participants above the 75th percentile were classified as HIGH (11 male, 15 female; mean $\pm$ SD age, 13.5 ± 3.0 years). Stride length and running velocity were nondimensionalized to remove the effect of limb length. Differences in triplanar joint ROM and temporal-spatial measures were assessed between LOW and HIGH runners using multivariate ANCOVA with running velocity used as a covariate ($P = .05$).

RESULTS: HIGH runners had a faster nondimensionalized running speed, longer nondimensionalized stride length, and shorter stance duration than LOW runners. Compared to LOW runners, HIGH runners also demonstrated greater sagittal plane ROM at the trunk, pelvis, and hips, as well as coronal plane pelvis and hip motion. No significant differences were measured in age or the remaining motions.

CONCLUSIONS: This study demonstrated runners with HIGH trunk endurance ran faster and took a longer stride than runners with LOW trunk endurance. HIGH runners also demonstrated greater stance phase hip ROM, which is likely related to the longer stride length. Prior literature has reported faster 5-km running times in adults who underwent a core strength training program. Further study is warranted to determine if increasing an adolescent runner's trunk endurance is related to improved running performance.

CLINICAL RELEVANCE: This study has identified a relationship between greater trunk muscle endurance and the biomechanics of the trunk and lower extremities, as well as a relationship with faster self-selected running speeds. As running continues to grow in popularity among adolescents, further understanding of the relationship between trunk endurance and running kinematics is important to provide therapists, coaches, and athletes advice on optimizing training and performance.

SPL5

EFFECTS OF STATIC POSTURAL CONTROL PERFORMANCE AND HEARING STATUS ON ATHLETE DYNAMIC POSTURAL CONTROL PERFORMANCE

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PURPOSE/HYPOTHESIS: Postural control is often evaluated to quantify an athlete's balance performance, which is influenced by visual, somatosensory, and vestibular stimuli. Due to the relationship between the cochlea and the vestibular system, postural control performance may differ between athletes who are deaf or hard-of-hearing (D/HoH) and athletes who are hearing. The purpose of this study was to determine the effects of athletes' hearing status and static postural control performance on dynamic postural control performance.

NUMBER OF SUBJECTS: Fifty-one NCAA Division III athletes who are D/HoH (33 male; mean $\pm$ SD age, 20.65 $\pm$ 1.82 years; height, 1.76 $\pm$ 0.08 m; weight, 78.16 $\pm$ 14.09 kg) and 61 collegiate club athletes who are hearing (50 male; age, 20.02 $\pm$ 1.47 years; height, 1.78 $\pm$ 0.09 m; weight, 81.21 $\pm$ 11.44 kg) participated.

MATERIALS AND METHODS: Participants completed single-leg (SL) stance trials on a triaxial force plate. Center-of-pressure (CoP) parameters were calculated to quantify static postural control. Participants then stood on the force plate under a height measuring device (HMD) and performed a bilateral-foot take-off jump to 50% to 55% of their maximum jump height. Instructions were given to land on the dominant leg and maintain stability. Time-to-stabilization (TTS) was calculated as the time when vertical ground reaction force stayed within 5% of the participant's body weight for at least 500 milliseconds following landing. Generalized linear mixed models were performed to test the effects of hearing status and static postural control performance on TTS. Significance was determined a priori at $P \leq .05$.

RESULTS: Anteroposterior (AP) excursion, sway area, and hearing status were included in the overall model as estimators of TTS ($R^2 = 0.50$, $P < .01$). Athletes who were D/HoH took 0.02 seconds longer for TTS than athletes who are hearing (95% CI: -0.26, 0.31). For each 1-cm increase in AP excursion during SL stance, TTS was 0.06 seconds longer (95% CI: 0.04, 0.07). For every 1-cm² increase in sway area, TTS was 0.06 seconds shorter (95% CI: -0.10, -0.02).

CONCLUSIONS: Static postural control performance significantly estimated dynamic postural control performance when controlling for hearing status. Though previous work has suggested static postural control differences between athletes who are D/HoH and athletes who are hearing, dynamic postural control may not be sensitive enough to detect differences between groups due to the availability of all sensory systems during the TTS assessment. If athletes who are D/HoH have underlying sensory deficits, they may compensate with the other sensory systems. Further research is warranted to understand the role of degree of hearing loss and the etiology of hearing loss on dynamic postural control performance.

CLINICAL RELEVANCE: Understanding dynamic postural control performance will assist clinicians in optimizing rehabilitation and return-to-play decisions of athletes who are D/HoH.

SPL6

BLOOD FLOW RESTRICTION TRAINING FOR THE ROTATOR CUFF: A RANDOMIZED CONTROLLED TRIAL

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PURPOSE/HYPOTHESIS: Blood flow restriction (BFR) training utilizes a tourniquet, applied to the proximal portion of 1 or more extremities, to occlude blood flow during exercise. Prior research has demonstrated that low-load exercise can be performed with BFR and achieve gains in strength and muscular cross-sectional area (CSA) similar to the gains experienced by training at a higher intensity. Prior research has also demonstrated that significant gains in strength and CSA can be achieved in

muscles proximal to BFR cuff application. This finding holds promise for patients with rotator cuff pathology; especially for patients who are not able to train with a heavy load due to symptom reproduction. However, the benefits of applying BFR to the proximal upper extremity (UE) when performing an exercise for the rotator cuff is unknown. The purpose of this study was to compare strength gains of the supraspinatus and the external rotators of the shoulder and changes in tendon size of the supraspinatus in subjects who performed the sidelying external rotation (ER) exercise with or without BFR.

NUMBER OF SUBJECTS: Forty-six healthy subjects (mean $\pm$ SD age, 25.0 $\pm$ 2.2 years).

MATERIALS AND METHODS: Subjects were excluded from study participation if they had medical treatment for the upper quadrant region during the prior 6 months or if there were contraindications for BFR training. Subjects were randomized to a BFR + ER exercise ($n = 24$) or an ER exercise only group ($n = 22$) by a random number generator. Pre- and post-test measures of strength and tendon size were collected and the 1RM for the ER exercise was estimated using the following formula: 1RM = (0.033 reps)RepWt + RepWt. A Co-PI, blinded to group allocation, performed all manual muscle tests utilizing a hand held dynamometer (MicroFET 2, Hogan Scientific, Salt Lake City, UT). The test-retest reliability (ICC_{3,3}) of strength measures were established a priori: 0.985 (0.932, 0.997) for the supraspinatus and 0.942 (0.742, 0.987) for the external rotators. A different Co-PI, blinded to group allocation, collected all sonographic images of the supraspinatus. An Affinity 50G ultrasound (Phillips Healthcare, Andover, MA) fitted with a 50-mm linear array probe was used at a depth of 4.0 cm for all images. All subjects performed 4 sets (30/15/15/15 reps; 30 seconds of rest between sets) of the ER exercise 2 times per week for 8 weeks at 30% of 1RM with their dominant UE. Subjects were allowed to continue their current exercise programs; however, they were required to not perform any exercises specific for the external rotators. A 2-way ANOVA was used for statistical comparisons.

RESULTS: Subjects in both groups experienced significant strength gains in the supraspinatus and the shoulder external rotators ($P < .0001$). However, there was no difference in strength gains between groups for the supraspinatus ($P = .750$) or the external rotators ($P = .708$). Subjects in both groups experienced significant increases in supraspinatus tendon thickness (BFR + ER, $P = .041$; ER only, $P = .011$). However, there was no difference between groups ($P = .610$).

CONCLUSIONS: Subjects in both groups experienced significant gains in rotator cuff strength and tendon size after performing the ER exercise for 8 weeks. The use of BFR on the proximal UE did not augment these effects. The trial was registered at www.clinicaltrials.gov (NCT03815760).

CLINICAL RELEVANCE: Rotator cuff strength and tendon size significantly increased in response to a low-load 8-week training program. Future research should investigate the benefits of BFR application to the lower extremity combined with rotator cuff training programs.

SPL7

REACTIVE STRENGTH INDEX SCORES IN VOLLEYBALL PLAYERS ARE ASSOCIATED WITH INJURY RISK AND GAME PERFORMANCE

Ruel Jason Brumitt, Robin Dorociak

PURPOSE/HYPOTHESIS: The drop vertical jump (DVJ) test is frequently used by physical therapists to evaluate an athlete's risk for an anterior cruciate ligament (ACL) injury. However, the rate of ACL injury during sport is low when compared to other injuries (eg, the rate of ACL injury in women's collegiate volleyball is 0.06 per 1000 athletic exposures [AE] whereas the rate of ankle sprains is 0.83 practices to 1.06 games per 1000 AE). Therefore, it is likely that hundreds would need to be screened to identify a small number of athletes who may be at risk for an ACL injury. There is another measure, the reactive strength index (RSI), that can be calculated based on one's DVJ performance. The RSI is a measure used by strength coaches to quantify an athlete's explosiveness. It has also been used by re-

habilitation professionals to evaluate recovery after injury. The RSI score is calculated based on one's DVJ performance by dividing jump height by the contact time on the ground ($RSI = \text{jump height/contact time}$). The RSI score may provide physical therapists with additional data to determine one's risk of injury. The RSI score may also provide coaches with data that may influence training and personnel decisions. The purpose of this study was twofold. The first purpose was to evaluate the ability of preseason RSI scores to discriminate injury risk in female collegiate volleyball (VB) players. The second purpose was to evaluate correlations between preseason RSI scores and game performance.

NUMBER OF SUBJECTS: One hundred seventeen female collegiate VB players representing 3 levels of competition.

MATERIALS AND METHODS: Each athlete completed a 5-minute dynamic warm-up prior to testing. Reflective markers were applied to the pelvis and the lower extremities. Athletes performed 3 DVJ from a 30.48-cm box. The primary investigator demonstrated a DVJ and provided test performance instructions to each athlete prior to testing. Subjects were instructed to drop off the box, land with 1 foot on each force plate (BP 600600 force plate, ATMI, Watertown, MA), and then immediately upon landing jump as high as possible. Reflective marker and force data were collected simultaneously with an 11-camera Qualisys motion system (Gothenburg, Sweden) at 100 Hz for the 3-D marker data and 1000 Hz for the force plates. Visual3D (C-Motion, Germantown, MD) was used to create the kinematics and kinetics. Each team's athletic trainer collected injury information throughout the season. Game statistics were acquired at the end of the season. A receiver operating characteristic curve was constructed to identify a cutoff score for subsequent risk analysis. Relative risk was calculated to determine the difference in injury risk between 2 groups based on cutoff score dichotomization. The Pearson product-moment correlation coefficient was calculated to determine the relationship between preseason RSI scores and game statistics.

RESULTS: Mean $\pm$ SD preseason RSI score was 0.88 ± 0.31 m/s. Athletes with a lower preseason RSI score (0.9125 m/s or less) were 4 times more likely (relative risk = 4.4; 95% CI: 1.0, 18.4; $P = .022$) to experience a non-contact time-loss injury to the low back or lower extremities during the season. There was a significant correlation between preseason RSI score and kills/set ($r = 0.369$, $P < .001$) and points/set ($r = 0.360$, $P < .001$).

CONCLUSIONS: The RSI measure should be collected as part of a preseason screening clinic to identify female collegiate VB players at risk for a non-contact time-loss injury to the low back or lower extremities. The RSI score could also be used by VB coaches when evaluating current and future athletes.

CLINICAL RELEVANCE: Physical therapists who screen female collegiate VB players with the DVJ should also calculate the RSI.

SPL8

RETURNING IN-SEASON AFTER ACUTE HAMSTRING INJURY IS ASSOCIATED WITH GREATER REINJURY, DESPITE NORMAL CLINICAL ASSESSMENT

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PURPOSE/HYPOTHESIS: Hamstring strain injuries (HSI) have recurrence rates over 25%, with a history of HSI being a strong predictor of future HSI. Strength, range of motion, and patient reported outcomes (PRO) are often assessed throughout rehabilitation following HSI to assess readiness for return to sport (RTS) and minimize reinjury risk. However, sport demands, such as being in or out of the competitive season, can influence RTS timing and therefore impact both clinical outcomes at RTS as well as HSI recurrence. The purpose of this study was to assess the influence of previous HSI history (pHx) and RTS timing (in versus out-of-season) on clinical measures and reinjury rates.

NUMBER OF SUBJECTS: Forty-nine.

MATERIALS AND METHODS: Forty-nine Division I athletes sustaining an acute, unilateral HSI participated. Following an initial HSI, pHx was as-

sessed via medical record review and self-report. At time of injury (TOI), athletes underwent magnetic resonance imaging (MRI) to assess presence of edema. At RTS, athletes completed testing including: PROs (TSK-11, global rating of change, and Single Assessment Numerical Evaluation), active knee extension test (AKET), and Nordic curl exercise for eccentric strength assessment. Timing of RTS (ie, in versus out-of-season) was noted and athletes were followed for reinjury of either limb for 12 months after the primary injury. RTS measures were compared between pHx and RTS groups using a 2-by-2 ANOVA. Reinjury and presence of edema on MRI were also compared between pHx and RTS groups.

RESULTS: Athletes with a pHx who RTS in-season showed the greatest proportion of reinjury (8/14, 57.1%). Disregarding pHx, those who RTS in-season showed 2-fold greater proportion of reinjury (12/30, 42.9%) than those who RTS out-of-season (4/19, 21.1%). A significant interaction between pHx and RTS time was observed for days to RTS ($P = .012$); athletes with a pHx of HSI who RTS out-of-season demonstrated greater days to RTS (40.6 versus 19.4-21.8 days). No significant interactions or main effects were observed for pHx status or RTS time for AKET or any PROs. Though nonsignificant ($P = .13$), greater eccentric hamstring strength asymmetry was observed among those who RTS in-season (11.0%) compared to out-of-season (7.8%). There were no differences in the proportion of athletes showing edema at TOI between pHx or RTS time ($P \geq .68$).

CONCLUSIONS: Despite similar MRI findings at TOI and clinical measures and PROs at RTS, athletes who RTS in-season appear to be at greater risk of reinjury than those who RTS out-of-season. Athletes with a pHx of HSI who RTS during their competitive season may be at the greatest risk for reinjury.

CLINICAL RELEVANCE: Current assessments of function at RTS following an HSI are inadequate for identifying who may go on to sustain a secondary HSI. Given the lack of differences in clinical measures, it is likely that factors motivating RTS timing may be influenced by nonclinical factors when returning in-season. Unfortunately, this may predispose these athletes to higher reinjury rates. Potential value may exist in adding more advanced measures to guide RTS decision making such as repeat MRI.

SPL9

QUALITY OF LIFE AND SELF-EFFICACY AFTER AN EXERCISE PROGRAM FOR INDIVIDUALS WITH PHYSICAL DISABILITY

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PURPOSE/HYPOTHESIS: Individuals with physical disabilities (PD) are less active and have barriers to physical activity (PA), which can result in poor health. Higher levels of social support, self-efficacy (SE), as well as customized activity programs correlate with higher PA levels. The purpose of this pilot study was to evaluate the effectiveness of adapting a popular exercise program and compare the results between individuals with PD and an able-bodied group. We hypothesized that measures of health related quality of life (QOL) and exercise SE would improve equally in both groups.

NUMBER OF SUBJECTS: A convenience sample of 14 participants was enrolled. PD group: 7 males, 5 with spinal cord injury (SCI), aged 24 to 60 years, BMI of 17 to 28 kg/m². Able-bodied group (AB) was significant others or friends of the PD group: 4 males, 3 females, aged 24 to 57 years, BMI of 22 to 24 kg/m².

MATERIALS AND METHODS: Ninety-minute sessions including flexibility, progressive strengthening, and moderate to high intensity interval cardiovascular exercises were performed twice a week for 12 weeks. Scores for WHOQOL-BREF, Barriers Self-Efficacy Scale (BARSE), and SCI Exercise Self-Efficacy Scale (ESES), were collected prior to and after the program, and at 12-week follow-up. Nonparametric comparisons were made between time points utilizing the Kruskal-Wallis 1-way ANOVA, $P < .05$.

Focus groups were performed after the intervention. A qualitative framework analysis was used to identify and code themes.

RESULTS: The following positive trends were observed: improved satisfaction with health postprogram (WHOQOL-BREF: PD ($\chi^2 = 2.2$, $P = .33$), AB ($\chi^2 = 4.8$, $P = .09$); increasing scores on the WHOQOL-BREF Physical Health domain in the PD group ($\chi^2 = 3.2$, $P = .20$); and higher postprogram and follow-up scores on the Social Relationships domain compared to baseline for the PD group ($\chi^2 = 5.9$, $P = .05$). There was a significant main effect in the Social Relationships domain for the AB group ($\chi^2 = 7.0$, $P = .03$), but post hoc pairwise comparisons were not significant ($Z = 1.82$, $P = .07$), likely due to small sample size. For individuals with SCI, SCI ESES scores trended up from baseline to postprogram ($\chi^2 = 3.1$, $P = .21$). Focus group data revealed participants valued exercise personalization, trained staff, social benefits, and improvements in daily function for the PD group, including transfers and sitting balance. Participants wished strategies would have been suggested for maintaining gains following program completion.

CONCLUSIONS: Trends toward improved social relationships, function, and satisfaction with health were found following an exercise program with modifications for individuals with PD.

CLINICAL RELEVANCE: Popular moderate to high intensity exercise programs adapted for individuals with physical disabilities utilizing commonly found fitness equipment are feasible and valued. Such programs may improve quality of life and health satisfaction; however, trainers must be familiar with the needs and risks for individuals with various physical disabilities.

SPL10

BIOMECHANICAL RISK FACTORS FOR RUNNING-RELATED INJURY DIFFER BY SAMPLE POPULATION: A SYSTEMATIC REVIEW AND META-ANALYSIS

Charles Nathan Vannatta, Becky Lynn Heinert, Thomas Kernozek

PURPOSE/HYPOTHESIS: Biomechanical factors of running gait have been hypothesized as important to the etiology of running-related injury (RRI). Numerous cross-sectional studies have attempted to identify specific factors that may be important in the development of RRI. However, due to the retrospective nature of these studies, determining how these biomechanical factors result in a specific injury mechanism are not possible. Further, previous systematic reviews have been limited in their ability to synthesize results due to study heterogeneity. Thus, this study aimed to identify only prospective studies that have investigated the role of biomechanical factors in the development of RRI and provide pooled analyses when possible in specific running samples and evaluate differences in etiological factors between samples.

NUMBER OF SUBJECTS: Seven hundred ninety-eight.

MATERIALS AND METHODS: A systematic review was completed in January 2019 using MEDLINE, CINAHL, and PubMed. Inclusion criteria included a prospective study design, human subjects that were currently completing a regular running program, and a minimum 12-week follow-up period. Articles were excluded if no biomechanical data were reported, participants were beginning runners or military recruits, or if any intervention was provided to participants. Article quality was assessed using the modified Black and Downs criteria. Biomechanical variables from studies were extracted and assigned levels of evidence. Pooled analyses were completed if 2 or more studies were available with study samples that investigated the same sex and competitive level and had similar controls on foot-strike patterns. Qualitative synthesis was completed when pooled analysis was not possible. Differences in findings on specific biomechanical factors between running samples were noted.

RESULTS: Thirteen studies met these inclusion and exclusion criteria. Five unique running samples were identified and allowed for pooled analyses of variables in mixed-sex collegiate runners (foot-strike pattern uncontrolled) and female recreational runners (rearfoot-strike pattern). Moder-

ate evidence exists for increased loading rates and hip adduction and reduced peak rearfoot eversion as risk factors for RRI in female recreational runners. Limited evidence exists for increased medial plantar pressure and knee abduction impulse in male recreational runners. In mixed-sex samples, only increased external knee adduction moment and knee stiffness and decreased step rate were identified as risk factors for RRI with each variable specific to different levels of competition.

CONCLUSIONS: Sex, competitive level, and footstrike pattern may affect biomechanical factors and their relationship to the development of RRI. Loading rates, hip adduction, and rearfoot eversion may be important factors related to RRI in female recreational runners who utilize a rearfoot-strike pattern.

CLINICAL RELEVANCE: A runner's sex, competitive level, and foot-strike pattern should be considered when evaluating biomechanical factors pertaining to RRI as these may be important factors in preventative and rehabilitative efforts.

SPL11

CLINICAL MEASURES TO PREDICT QUADRICEPS INHIBITION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Following anterior cruciate ligament reconstruction (ACL-R) quadriceps inhibition limits the ability to increase quadriceps strength, but quadriceps inhibition is difficult to quantify in clinical settings. Electromyography (EMG) biofeedback is often used as a clinical intervention to improve quadriceps strength and activation, but it is not known if EMG could be used to determine the presence of quadriceps inhibition in the early postoperative period following ACL-R. The purpose of this study was to determine the relationship between quadriceps activation and peak EMG of the vastus lateralis in individuals following ACL-R.

NUMBER OF SUBJECTS: Thirty individuals with a history of ACLR-R (21 female, 9 male; mean $\pm$ SD age, 20.4 ± 5.9 years; height, 172.9 ± 6.5 cm; mass, 69.8 ± 11.3 kg; time since surgery, 3.3 ± 0.9 months) volunteered for this study.

MATERIALS AND METHODS: Quadriceps percent activation was quantified using the interpolated twitch technique while performing a maximum isometric contraction of the quadriceps on an isokinetic dynamometer. Peak EMG amplitude of the vastus lateralis was determined using surface electrodes during the maximum isometric contraction. Pearson correlation was used to calculate the relationship between percent quadriceps activation of the involved limb and the limb symmetry index (LSI = involved/uninvolved) of peak EMG amplitude. Bland-Altman plots with limits of agreement (LOA) calculations were used to quantify systematic bias between the 2 measurement techniques.

RESULTS: There was a significant correlation between percent quadriceps activation of the involved limb and the peak EMG LSI ($r = 0.579$, $P < .01$). Bland-Altman plot LOA indicated that the peak EMG amplitude ratio tended to overestimate quadriceps activation ($12.3\% \pm 21.8\%$).

CONCLUSIONS: Peak EMG amplitude LSI and percent quadriceps activation following ACL-R showed a significant correlation. However, when examining the Bland-Altman plots and LOAs it was determined this relationship was not clinically relevant. There was a lack of consistency in the EMG results which diminishes clinical applicability. Electrical stimulation to augment a voluntary quadriceps contraction remains the gold standard for quantifying quadriceps activation measures.

CLINICAL RELEVANCE: Despite the statistically significant correlation between quadriceps percent activation and peak EMG amplitude LSI, this relationship is not clinically relevant. The results demonstrated that EMG cannot accurately identify the presence of quadriceps inhibition. Even though electrical stimulation remains the gold standard, EMG can still be used in clinics as a form of biofeedback during the rehabilitation process.

SPL12

THE INFLUENCE OF CONCOMITANT INJURY AT THE TIME OF ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION ON LANDING MECHANICS

Caroline Lewis Brunst, Staci Thomas, Mark Vincent Paterno, Laura C. Schmitt

PURPOSE/HYPOTHESIS: Our previous work indicates concomitant meniscal (MEN) or articular cartilage (AC) pathology at the time of anterior cruciate ligament (ACL) injury contributes to worse self-reported function at 2 years post ACL reconstruction (ACLR) and return to sports (RTS). In this study, we tested the hypothesis that athletes with concomitant MEN or AC pathology would demonstrate greater asymmetry during landing tasks and quadriceps femoris (QF) strength testing at RTS and 2 years post RTS (RTS+2) compared to athletes with isolated ACL injury.

NUMBER OF SUBJECTS: Ninety athletes after primary, unilateral ACLR were evaluated at time of RTS (70% female; mean $\pm$ SD age, 17.0 ± 2.3 years). A subgroup ($n = 40$) was evaluated at RTS+2 (78% female; age, 17.3 ± 2.1 years).

MATERIALS AND METHODS: Concomitant MEN or AC pathology were identified via preoperative imaging or operative note. Participants were grouped as: ACLonly, ACL+MENorAC, or ACL+MEN+AC. At RTS and RTS+2, landing mechanics during a drop vertical jump (DVJ) and single-leg drop landing (SLL) were assessed using 3-dimensional motion analysis techniques. Landing variables of interest included peak knee flexion angle and excursion (degrees), peak trunk flexion angle (degrees) (SLL only), peak internal knee extension moment (Newton meters per kilogram), and peak vertical ground reaction force (Newtons per kilogram). Strength was measured using isokinetic dynamometry at $180^\circ/\text{s}$ (Newton meters per kilogram). Limb symmetry index (LSI [percent]) was calculated [(involved/uninvolved) $\times 100\%$]. Group differences were evaluated with 1-way ANOVA (post hoc testing as appropriate) at RTS and independent-samples t tests at RTS+2 ($\alpha \leq .05$).

RESULTS: A majority of participants had at least 1 concomitant injury with no demographic differences at RTS or RTS+2 between groups (ACLonly ($n = 17/7$), ACL+MENorAC ($n = 50/22$), ACL+MEN+AC ($n = 23/11$)). At RTS, the involved limb of the ACLonly group demonstrated lower knee flexion excursion during SLL (ACLonly, $38.9^\circ \pm 7.0^\circ$; ACL+MENorAC, $46.2^\circ \pm 10.2^\circ$; ACL+MEN+AC, $45.8^\circ \pm 8.9^\circ$) and lower QF strength (ACLonly, 1.4 ± 0.3 Nm/kg; ACL+MENorAC, 1.5 ± 0.3 Nm/kg; ACL+MEN+AC group, 1.7 ± 0.3 Nm/kg) compared to both other groups. The ACLonly group was removed from RTS+2 analysis due to small sample size. During the DVJ landing, the ACL+MEN+AC group landed with less knee flexion ($76.2^\circ \pm 6.3^\circ$) compared to the ACL+MENorAC group ($83.1^\circ \pm 9.1^\circ$), but was not significant ($P = .07$).

CONCLUSIONS: Concomitant MEN or AC pathology did not grossly impact sagittal plane landing mechanics at RTS or RTS+2 in patients after ACLR. Contrary to our hypothesis, at RTS the ACLonly group demonstrated less knee flexion excursion during landing, which may be related to QF weakness. At RTS+2, a trend for reduced knee flexion during SLL was observed in those with both concomitant MEN and AC pathology, warranting further investigation.

CLINICAL RELEVANCE: Athletes with concomitant injury are at high risk for posttraumatic knee osteoarthritis, which may be due to altered knee mechanics. At RTS+2, a trend for reduced knee flexion during SLL was observed in those with both concomitant MEN and AC pathology. In our previous work, patients in this group (ACL+MEN+AC) reported worse function at the same time point. Patients with concomitant pathology at the time of ACLR may benefit from postoperative surveillance of function and movement mechanics.

SPL13

RELIABILITY AND CONCURRENT VALIDITY OF A COMMERCIAL INERTIAL MEASUREMENT UNIT USED TO ANALYZE RUNNING KINEMATICS

Robert Aaron Wayner, Joseph Michael Wisniewski

PURPOSE/HYPOTHESIS: A runner's mechanics have been associated with risk of injury and have been proposed to affect cumulative load. Many commercial devices are available to analyze a runner's mechanics but the reliability and validity for some of these devices is still unknown. The primary purpose of this study was to determine the concurrent validity of a commercial inertial measurement unit (RunScribe) used to measure cadence, ground contact time, impact acceleration, and pronation excursion compared to laboratory collected kinematic data. The secondary purpose of the study was to examine the reliability of the RunScribe device between running on the treadmill versus outside on level ground.

NUMBER OF SUBJECTS: Fifteen healthy recreational runners (8 male, 7 female; mean $\pm$ SD age, 27 ± 6 years).

MATERIALS AND METHODS: Participants completed 2 testing sessions within 72 hours. For each session, runners were asked to run at their preferred pace for 4 minutes following a 3-minute walking warm-up. During the laboratory testing session the subjects were prepared for data collection using a 3-D motion capture system (Vicon, Oxford, UK) and ran on an instrumented treadmill (Bertec Corporation, Columbus, OH). Impact acceleration and pronation excursion data were sampled at 250 Hz. A 20-N threshold on the treadmill was used to identify stance phase of gait and used to obtain cadence and ground contact data. A commercial inertial measurement unit (Runscribe, San Francisco, CA) sampling at 500 Hz was adhered to the dorsum of the foot during both testing sessions. The average of 15 steps were used for analysis from both devices. Concurrent validity between the IMU and lab collected data were examined using a 1-sample t test with an expected difference between IMU and lab of zero. In cases where there was no significant difference Bland-Altman plots were constructed to check for proportional bias between the 2 measures. Second, the agreement between treadmill and outdoor running was examined using intraclass correlation coefficients ($\text{ICC}_{3,k}$).

RESULTS: There were no significant differences in treadmill versus overground running speed ($P = .205$) or heart rate ($P = .118$). There were no significant differences between the 2 measurement systems for impact acceleration ($P = .357$), pronation excursion ($P = .427$), and cadence ($P = .602$). Bland-Altman plots did not reveal any proportional bias between the 2 measures. There was a significant difference in GCT ($P \leq .001$). ICCs between treadmill and overground running ranged from 0.815 to 0.912 indicating good to excellent agreement.

CONCLUSIONS: The RunScribe unit is a valid and reliable tool for measurement of impact acceleration, pronation excursion and cadence compared to laboratory derived values.

CLINICAL RELEVANCE: Clinicians can use the RunScribe unit to provide reliable and valid kinematic data in their analysis of running gait. This data could be used to assist in clinical decision making, tracking progress with gait retraining, and monitoring training loads.

SPL14

THE DIFFERENCES OF FUNCTIONAL PERFORMANCE IN OVERHEAD ATHLETES WITH AND WITHOUT SYMPTOMS

Hsiao-Chen Wei, Jiu-Jenq Lin, Yuan-Hung Chao

PURPOSE/HYPOTHESIS: Overhead athletes often suffer from shoulder injuries because of the demand of the repetitive and high speed overhead arm movements. After injury, returning to play (RTP) on the same sport or even performance become a critical issue. Nevertheless, previous studies have showed that the decision making of RTP is too complicated to provide standardized, objective criteria for RTP after upper extremity injuries. As the result of that, athletes especially amateur players usually RTP without medical clearance which leads to potential functional impairment afterward. Functional performance assessments (FPAs) may provide objective information in differentiating symptomatic athletes from health ones. Thus, the main purpose of this study was to differentiate symptomatic and healthy overhead athletes through function performance assessments (FPAs). To be specific, we investigated 2 hypotheses:

(1) to investigate the difference in FPAs and self-reported outcomes between overhead athletes with and without shoulder symptoms; (2) to investigate the discriminant validity of the FPAs and self-reported outcomes as diagnostic tools in overhead athletes with and without symptoms.

NUMBER OF SUBJECTS: Forty-four.

MATERIALS AND METHODS: Forty-four active, amateur volleyball players, 22 for the symptomatic group (mean $\pm$ SD age, 28.1 ± 4.4 years) and 22 for the healthy group (age, 24.6 ± 3.3 years) performed assessments, including Kerlan-Jobe Orthopaedic Clinic shoulder and elbow questionnaire (KJOC), Functional Movement Screen (FMS), Y-Balance Test-upper quarter (YBT-UQ), closed kinetic chain upper extremity stability test (CKCUEST), unilateral seated shotput test (USSP) and push-up test (PU), were assessed in both groups. Differences between 2 groups, receiver operating characteristic (ROC), area under curve (AUC), and predictive accuracy were analyzed.

RESULTS: The symptomatic overhead athletes showed significant worse scores and performance on KJOC scores and FPAs. Among FPAs, all 3 directions for YBT-UQ in dominate side, CKCUEST and FMS are significant lower in symptomatic group. The overall AUCs for KJOC scores, YBT-UQ medial, YBT-UQ anterolateral, YBT-UQ posterolateral, CKCUEST, and FMS were 1.000, 0.738, 0.788, 0.800, 0.748, and 0.702, respectively. In addition, for diagnostic accuracy, KJOC provided both perfect sensitivity and specificity (1.000 for both), YBT-UQ medial, CKCUEST and FMS had higher specificity (0.864, 0.909, and 0.909, respectively), and YBT-UQ anterolateral and YBT-UQ posterolateral had higher sensitivity (0.857 and 0.952, respectively).

CONCLUSIONS: The results are consistent with the hypothesis that overhead athletes with symptom showed significant worse performance on FPAs and self-reported outcomes. Additionally, KJOC, YBT-UQ, CKCUEST and FMS showed good diagnostic validity in differentiating symptomatic and healthy overhead athletes.

CLINICAL RELEVANCE: This study provides an objective value of FPAs in determining the appropriate level of stability and agility of the upper extremity and FMS scores in overhead athletes with symptom. Since most of the symptomatic athletes RTP without standardized criteria, the risk of reinjury remains. The result of this study established cutoff point in FPAs, these tools can help us rule out/in potential injury factors in particular athletes, also, find weak point of the athletes which enables further training to be more specific to their deficiency. This information can be applied on functional impairment screening and forming training strategy.

SPL15

IDENTIFYING NEURAL ACTIVITY ASSOCIATED WITH ELEVATED KINESIOPHOBIA AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Return to activity after anterior cruciate ligament reconstruction (ACLR) can be limited due to psychological factors such as kinesiophobia (fear of movement/reinjury). Behaviorally, kinesiophobia after ACLR is associated with asymmetric knee kinematics during gait and single-leg landings. However, the link between kinesiophobia and sensorimotor control is unclear as the neural processes governing movement in those with elevated kinesiophobia is poorly understood. Understanding the sensorimotor neural activity associated with kinesiophobia after ACLR may provide new therapeutic insights. Therefore, the purpose was to correlate scores on the Tampa Scale of Kinesiophobia (TSK) with brain activity during a hip-knee movement task in those with ACLR. We hypothesized that higher TSK scores would be associated with altered sensorimotor neural activity during the movement task.

NUMBER OF SUBJECTS: Ten patients with left-knee ACLR (6 female, 4 male; mean $\pm$ SD age, 20.3 ± 2.00 years; height, 1.72 ± 0.11 m; weight,

68.72 ± 14.79 kg; 29.1 ± 25.7 months from injury; all returned to activity).

MATERIALS AND METHODS: Patients participated in a single test session. TSK (17–68 points, high scores are greater kinesiophobia) was completed prior to neuroimaging on a 3-T Siemens Magnetom scanner with a 16-channel head coil. Functional neuroimaging was completed during 4 repeated 30-second cycles of left knee and hip extension/flexion (similar to a heel slide movement). Brain activation patterns during movement were contrasted with an interspersed rest condition, with each participant's data averaged across trials. Results were reported as z scores, with higher scores indicating greater likelihood of activation and P value indicating the probability of finding activation when there was none. The correlation of the TSK and brain activity was completed with a general linear model second-level mixed-effects a priori threshold at $z = 3.1$ and alpha level of less than .05 cluster corrected for multiple comparisons.

RESULTS: Mean TSK score was 31.3 ± 3.65 (range, 26–37). Higher TSK scores were positively correlated with 3 clusters. Cluster 1 included the left thalamus ($z = 5.41$, $P < .001$). Cluster 2 included the left corticospinal tract ($z = 6.12$, $P < .001$). Cluster 3 included the right corticospinal tract ($z = 5.93$, $P < .001$).

CONCLUSIONS: Elevated kinesiophobia after ACLR is associated with increased corticospinal and thalamic activation during a hip-knee movement task.

CLINICAL RELEVANCE: The altered sensorimotor brain activation pattern in patients with elevated kinesiophobia may have implications for addressing movement patterns associated with kinesiophobia during therapy. Potential modifications to therapy that facilitate decreased thalamic and/or corticospinal activity include: engaging in implicit motor learning strategies or using external focus feedback and/or virtual reality to reduce attentional focus on the injured joint.

SPL16

PREDICTORS OF PATIENT SATISFACTION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Patient's satisfaction after anterior cruciate ligament reconstruction (ACLR) is a key component representing the importance of surgical and rehabilitation interventions. However, the rate and predictors of patient's satisfaction after ACLR are not well studied. The purpose of this study was to determine the rate and predictors of patient's satisfaction after ACLR.

NUMBER OF SUBJECTS: One hundred ten athletes (2 females), 1 to 5 years after primary ACLR.

MATERIALS AND METHODS: Patients answered 2 questions to determine their satisfaction after ACLR: "Taking into account all the activity you have during your daily life, the level of pain and also your activity limitations and participation restrictions, do you consider the current state of your knee satisfactory?" (Patients' Acceptable Symptom State [feeling well]), and "If you had to spend the rest of your life with the symptoms you have now, how would you feel about it?" (feeling better). Predictors of patients' satisfaction included preinjury level of activity (competitive versus recreational), injury profile (mechanism of injury, concomitant knee injuries), surgical factors (time from injury to surgery, graft type), and time to start running and cutting-pivoting activities, episodes of knee giving way, second injuries to ipsilateral and contralateral knee, and return to preinjury level of sports after ACLR. Predictors were evaluated using univariate and multivariate logistic regressions.

RESULTS: Sixty-eight (62%) and 63 (57%) patients reported feeling well and feeling better after ACLR respectively. Univariate analysis for feeling well and feeling better showed that time from injury to surgery (<6 months), no episodes of knee giving-way, and no second injury to ipsilateral knee after ACLR predicted more patients' satisfaction ($P < .05$).

Start running ≤ 4 months ($P = .029$) and no contralateral knee injury after ACLR ($P = .049$) predicted also feeling well. Multivariate analysis indicated that no episodes of giving-way after ACLR was the only predictor for feeling well (OR = 4.4; 95% CI: 1.7, 11.4; $P = .002$), and time from injury to surgery < 6 months (OR = 3.7; 95% CI: 1.4, 10.4; $P = .011$) was the only predictor for feeling better.

CONCLUSIONS: Almost two thirds of patients were satisfied with their knee state and symptoms after ACLR. Having surgery < 6 months, dynamic knee stability, being able to run early, and having no knee injuries after ACLR were associated with being satisfied. Patients with dynamic knee stability were 4.4 times more likely to be satisfied with their knee current state, while patients who had the surgery prior to 6 months were almost 4 times more likely to be satisfied with their current knee symptoms.

CLINICAL RELEVANCE: Performing the ACL reconstructive surgery within 6 months from the initial injury and addressing dynamic knee stability, early resuming sport-related activity, and preventing second injuries would result with more patient's satisfaction after ACLR.

SPL17

QUADRICEPS STRENGTH SYMMETRY AND SUFFICIENCY ARE ASSOCIATED WITH LANDING BIOMECHANICS AMONG YOUNG ATHLETES AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Return-to-sport (RTS) decision making following anterior cruciate ligament reconstruction (ACLR) frequently involves strength limb symmetry calculations without measures of absolute performance or limb sufficiency. The purpose of this study was to test the hypothesis that young athletes who are unable to achieve both quadriceps strength symmetry (SYMM) and sufficiency (SUFF) at time of RTS after ACLR would demonstrate altered single-leg mechanics compared to athletes who achieve both SYMM and SUFF and to uninjured individuals.

NUMBER OF SUBJECTS: One hundred fifty young athletes (56 uninjured controls (CTRL) (mean $\pm$ SD age, 17.2 ± 2.5 years; 69% female) and 94 after ACLR (age, 17.2 ± 3.4 years; 73% female) were included in this cross-sectional analysis from a larger cohort study. Athletes after ACLR were enrolled within 4 weeks of clearance to RTS.

MATERIALS AND METHODS: All participants completed bilateral isometric quadriceps strength testing, from which quadriceps index (QI) was calculated [(involved peak torque/uninvolved peak torque) $\times$ 100%]. SYMM was defined as QI = 100% $\pm$ 10%. SUFF was defined as normalized peak torque < 1 SD from the mean normalized peak torque of CTRL, established from previous work in our lab. SYMM and SUFF scores were used to divide ACLR participants into those who achieved both (MET group) and those who were deficient in either or both (DEF group). Kinematic and kinetic sagittal plane variables of interest (knee flexion excursion (degrees) (KFE), peak internal knee extension moment (Newton meters per kilogram) (PIKEM), and peak trunk flexion angle (degrees) (PTFA) were collected with 3-D motion analysis during weight acceptance phase of a single-leg drop-landing task. For each variable of interest, limb values and limb symmetry indices (LSI) were calculated. One-way ANOVAs (with Bonferroni correction, as appropriate) were used to detect demographic and biomechanical differences between MET, DEF, and CTRL groups ($\alpha < .05$).

RESULTS: Within the ACLR group, 43% ($n = 40$) were in classified in the MET group and 57% ($n = 54$) were classified in the DEF group. No differences in age, height, or weight were found among the groups ($P = .08$ – 1.0). The CTRL group demonstrated greater symmetry compared to the DEF group in KFE LSI (DEF, 88.6%; MET, 95.8%; CTRL, 99.3%; $P = .001$). The MET and DEF groups both demonstrated greater PTFA (21.8° and 21.7° , respectively) compared to the CTRL group (13.5°) ($P < .001$). There were no differences in PIKEM found among the groups ($P = .112$).

CONCLUSIONS: Partially supporting our hypothesis, the DEF group demonstrated greater sagittal plane asymmetries at the knee and trunk during a single-limb drop-landing task compared to the CTRL group, but not the MET group. Both the DEF and MET groups demonstrated increased PTKA compared to the CTRL group.

CLINICAL RELEVANCE: Achievement of quadriceps strength symmetry and sufficiency at time of RTS following ACLR among young athletes may be associated with more symmetric landing mechanics. However, further study of other influencing factors is warranted as those who met symmetry and sufficiency also demonstrated trunk asymmetries during landing compared to uninjured controls.

SPL18

THE RELATIONSHIP BETWEEN BASEBALL PARTICIPATION, HEALTH, AND WELL-BEING: A SYSTEMATIC SCOPING REVIEW

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PURPOSE/HYPOTHESIS: Participation in sports such as baseball may have health and wellbeing benefits. However, baseball has a high injury incidence, and there are potential negative psychological consequences of baseball participation. There is currently uncertainty concerning the relationship between baseball participation, health and wellbeing. The purpose of this scoping review was to investigate the relationship between baseball participation, health, and wellbeing at all ages and competition levels, and identify research gaps in the existing literature.

NUMBER OF SUBJECTS: Current and former baseball participants.

MATERIALS AND METHODS: A systematic scoping literature search was performed with the assistance of a medical librarian. Databases including MEDLINE, CINAHL, Embase, Scopus, PsycINFO, SPORTDiscus, Cochrane Library, EBSCO, Web of Science and PEDro, and grey literature sources including Google Scholar, Clinicaltrials.gov, ISRCTN Registry and Proquest Dissertation and Theses were searched from inception to November 2018. All studies that investigated constructs related to health or wellbeing in current or former baseball participants were included. Data were extracted for thematic summaries relating to key themes: musculoskeletal health, general health, and wellbeing.

RESULTS: A total of 10 574 titles/abstracts were screened, with 678 studies included in this review. Ninety percent of articles included only baseballers playing in the United States, 34% of articles investigated professional baseballers and 11% studied college baseballers. Five hundred eighty-three (86%) studies investigated musculoskeletal health, 77 (11%) physical health, and 18 (3%) well-being. Injury incidence ranged from 0.7 to 3.6 injuries per 1000 athlete exposures (AE) in professional, 4.7 to 5.8 injuries per 1000 AE in college and from 0.8 to 4.0 injuries per 1000 AE in high school baseball. Five studies investigated injury prevention strategies, and only 1 study investigated weighted ball training. Thirty-one percent to 50% of baseballers reported regular tobacco use, and alcohol and drug use was more prevalent in baseball participants compared to the general population. Baseballers had increased longevity and reduced cardiovascular risk compared to the general population. There was a scarcity of research investigating wellbeing in current or former baseball players. Only 1 study investigated the long-term impacts of baseball participation on health and found that 1 in 5 retired baseballers had osteoarthritis.

CONCLUSIONS: Despite 523 studies investigating baseball injury, only 5 studies investigated injury prevention strategies. Baseball players have high tobacco, alcohol, and drug use compared to the general population, which may have negative health outcomes. Little is understood about the long-term health and wellbeing of baseballers.

CLINICAL RELEVANCE: Baseball injury prevention programs are effective, but require organization wide implementation at all levels. Gaps in the literature in need of further research include wellbeing in current and former baseballers from all standards of play, and long-term health outcomes of baseball participation.

SPL19

KNEE KINETICS ARE MORE ASYMMETRICAL DURING RUNNING THAN JUMPING 6 TO 12 MONTHS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN COLLEGIATE ATHLETES*Daniel Garrett Cobian, Matthew Bjork,**Mikel Renee Stiffler-Joachim, Bryan C. Heiderscheit*

PURPOSE/HYPOTHESIS: Running and jumping movements are primary components of most sporting activities. Anterior cruciate ligament (ACL) injury and surgical reconstruction (ACLR) contributes to abnormal movement biomechanics that can impair sports performance and increase injury risk. It is unclear how task-specific mechanics recover post-ACLR, which is important for developing targeted rehabilitation strategies and establishing patient expectations. The purpose of this study was to compare lower extremity (LE) kinetics during running and jumping at 2 important intervals post-ACLR in collegiate athletes. We hypothesized that athletes would present with greater between-limb kinetic asymmetries during running than jumping at both 6 and 12 months post ACLR.

NUMBER OF SUBJECTS: Sixteen Division I collegiate athletes (mean $\pm$ SD age, 20.8 ± 1.1 years; BMI, 25.2 ± 3.3 kg/m²; 9 female).

MATERIALS AND METHODS: Subjects performed maximal countermovement jumps (CMJ) and ran at a maximally comfortable speed on an instrumented treadmill at 6.1 ± 0.4 and 12.5 ± 1.0 months post ACLR while 3-D kinematics and ground reaction forces were recorded. Sagittal plane peak knee joint moments, knee extensor moment rates, knee extensor impulses, and knee joint work were computed during the stance phase of running and the concentric (CON), landing (LAND), and eccentric (ECC) phases of the CMJ. Limb symmetry indices (LSI) were computed for all variables and effect sizes (ES) were calculated. LSIs within and across tasks were evaluated using Wilcoxon signed-rank tests at both intervals.

RESULTS: Involved limb knee kinetics were significantly reduced compared to uninjured limb kinetics during running at both intervals (6 months: LSI = 39%-65%, $P < .001$; ES, 0.62; 12 months: LSI = 60%-79%, $P < .002$; ES, 0.56-0.62) and during all CMJ phases at 6 months post surgery (LSI = 62%-78%, $P < .003$; ES, 0.54-0.62). At 12 months, ECC and CON kinetics were significantly different across limbs (LSI = 81%-92%, $P < .005$; ES, 0.51-0.58) but LAND knee extensor impulse (LSI = 93.6%, $P = .127$) and knee extensor moment rate (LSI = 95.3%, $P = .06$) were similar between limbs. Comparing across tasks, running knee kinetic LSIs were significantly less than CMJ LSIs at both 6 and 12 months ($P < .004$; ES, 0.52-0.62), except for knee extensor moment rates during ECC ($P = .32$) and LAND ($P = .18$) at 6 months and ECC knee extensor moment rate at 12 months ($P = .57$).

CONCLUSIONS: Despite excellent surgical care and high volumes of rehabilitation, collegiate athletes present with significant between-limb asymmetries in sagittal plane knee joint kinetics during both running and jumping at 6 and 12 months post surgery. After ACLR, knee kinetic asymmetries during running are more pronounced than during the CMJ.

CLINICAL RELEVANCE: Following ACLR, knee mechanics during running appear to take longer to normalize than jumping. Asymmetrical knee joint loading is present 1 year post ACLR during both running and jumping activities in elite collegiate athletes, which may increase injury risk and impair sports performance. Targeted interventions are required to assist in normalizing running and CMJ mechanics to facilitate successful recovery and return to sport.

SPL20

RATE OF TORQUE DEVELOPMENT, NOT STRENGTH OR TIME, IS ASSOCIATED WITH RUNNING KNEE LOADS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION*Daniel Garrett Cobian, Sarah A. Gamillo,**Mikel Renee Stiffler-Joachim, Jennifer L. Sanfilippo,**Stephanie Kliethermes, Bryan C. Heiderscheit*

PURPOSE/HYPOTHESIS: Anterior cruciate ligament injury and reconstruction (ACLR) contributes to abnormal and asymmetrical running mechan-

ics that can persist for years postsurgery. Altered knee joint loading during running may lead to joint degeneration and increase future injury risk. Quadriceps dysfunction after ACLR is universal and contributes to abnormal running mechanics. Peak quadriceps strength is often assessed clinically but time-dependent measures of muscle output such as rate of torque development may be more functionally relevant, particularly to sporting activities. The purpose of this study was to determine the relationships between quadriceps strength, rate of torque development, time from surgery, and knee joint kinetics during running in collegiate athletes up to 2 years post ACLR.

NUMBER OF SUBJECTS: Twenty-seven Division I collegiate athletes (mean $\pm$ SD age, 20.3 ± 1.3 years; BMI, 25.8 ± 3.4 kg/m²; 15 female).

MATERIALS AND METHODS: At prespecified intervals post-ACLR, subjects ran at a maximally comfortable speed on an instrumented treadmill and performed maximal and rapid voluntary isometric knee extension contractions at 90° of knee flexion. Three-dimensional kinematics and ground reaction forces were recorded during running, and stance phase sagittal plane knee extensor impulses (KEIMP) were computed. Knee extensor peak torque (KEPT) and rate of torque development from 20% to 80% of peak torque (KERTD20-80) were obtained from isometric knee extension efforts. Limb symmetry indices (LSI) were computed for all variables and clinically relevant cutoffs of 90% LSI KEPT and KERTD20-80 were investigated. To account for repeated measurements, a mixed effects model was used to assess the relationships of KEPT, KERTD20-80, and time from surgery with KEIMP, and all possible pairwise interactions were tested.

RESULTS: Among 27 unique athletes, 75 tests were completed 4 to 24 months postsurgery. There was a significant association ($P < .001$) between KERTD20-80 LSI and KEIMP LSI. After adjusting for both time from surgery and KEPT, individuals with $\geq 90\%$ KERTD20-80 LSI had an average of 31.5% greater KEIMP symmetry than those with $< 90\%$ KERTD20-80 LSI. No association ($P = .157$) between KEPT LSI and KEIMP LSI was detected, after adjusting for time from surgery and KERTD20-80. No significant pairwise interactions between KEPT, KERTD20-80, and time from surgery were detected. Of the 23 incidences of KEPT LSI $> 90\%$, median KEIMP LSI was 63.6%, compared to 84.2% for the 15 instances of KERTD20-80 LSI $> 90\%$. There were 24 assessments completed > 1 year post surgery, of which the median KEIMP LSI was 63.6%. Conversely, of the 12 instances in which KEIMP LSI was $> 80\%$, median KERTD20-80 was 94.0%.

CONCLUSIONS: KERTD20-80 is a stronger indicator of symmetrical sagittal plane knee kinetics during the stance phase of running than peak torque. Running knee kinetic asymmetries do not appear to resolve over time independent from quadriceps function.

CLINICAL RELEVANCE: Maximizing rapid quadriceps torque capacity appears to be an important step in re-establishing symmetrical running mechanics post-ACLR. Clinicians should prescribe appropriately dosed quadriceps exercises to facilitate resolution of running gait abnormalities.

SPL21

QUANTIFYING HAMSTRING ENDURANCE WITH A NOVEL SUSTAINED KNEE FLEXOR TASK VERSUS REPEATED-EFFORT ISOMETRIC CONTRACTIONS*Daniel Garrett Cobian, Zachary Lentini,**Mikel Renee Stiffler-Joachim, Grant Thomas,**Benjamin Davis, Bryan C. Heiderscheit*

PURPOSE/HYPOTHESIS: Hamstring strain injuries (HSI) are common, with screening and postinjury assessments often focusing on peak muscle strength. High rates of HSI recurrence suggest other aspects of muscle function, such as endurance, should be considered. The purpose of this study was to compare hamstring strength and endurance between a novel test of unilateral, sustained isometric knee flexor endurance (END) and repeated effort isometric dynamometry (REID), considered the gold standard method.

NUMBER OF SUBJECTS: Twenty-five healthy, active volunteers (mean $\pm$ SD age, 23.0 ± 3.7 years; BMI, 24.3 ± 2.9 kg/m²; 13 female).

MATERIALS AND METHODS: Subjects completed the END test using the NordBord device (Vald Performance, Queensland, Australia) and the REID (Biodex System 4, Shirley, NY) with ≥ 7 days rest between sessions. Both tests were performed unilaterally and the right limb was used for analysis. For the END test, subjects knelt in 60° of knee flexion, shoulders flexed, and hands on an inclined platform. Subjects performed maximal isometric knee flexion while maintaining this position for as long as possible. Peak isometric force (ENDPF) and time to reach a 25% decrement in force (ENDTIME) were computed. For REID, peak torque was established (REIDPT) and subjects repeated 8-second bouts of maximal isometric knee flexion at 60° separated by 20-second rest intervals. REID performance was quantified as repetitions completed before failure to reach 75% of REIDPT (REIDREPS). Subjective discomfort following each test was assessed by Visual Analogue Scale (VAS). Surface electromyography (EMG) of the biceps femoris (BF), medial hamstrings (MH), and medial gastrocnemius (MG) was collected during all trials. Root mean square (RMS) values of the first 5 seconds of the initial and final 2 repetitions (REID) or first and last 5 seconds of the continuous trial (END) were calculated and compared using the Wilcoxon signed-ranks test. Spearman rank correlations assessed the relationships between REID and END performance.

RESULTS: There was a strong correlation between ENDPF and REIDPT ($r = 0.613$ – 0.696 , $P = .001$), but no correlation between ENDTIME and REIDREPS ($r = 0.119$ – 0.248). VAS scores for the END test were lower relative to the REID ($P = .010$). Both BFRMS and MHRMS were significantly reduced following the END and REID protocols ($P < .004$). MGRMS was significantly lower following REID ($P = .001$), but not after END ($P = .126$). The difference between initial and final MGRMS was significantly greater after REID than END ($P = .027$).

CONCLUSIONS: Maximal isometric knee flexor output was comparable between a sustained kneeling task and a seated assessment, but endurance varied across tasks. BF and MH activations were similar between END and REID, but the REID task involved greater MG contribution.

CLINICAL RELEVANCE: The novel END test is a valid measure of unilateral isometric strength; however, there is a lack of agreement in endurance performance between the END and REID. Isometric knee flexion in a kneeling position may require unique functional demands compared to sitting, which limits the utility of comparisons across tasks. Future investigations will explore the relationships between HSI and knee flexor performance across tasks.

SPL22

HAMSTRING PERFORMANCE TESTING: NORDBORD NORDIC HAMSTRING EXERCISE VERSUS ISOKINETIC DYNAMOMETRY: WHAT'S THE DIFFERENCE?

Joseph Cuellar, Susan S. Levy, Michael Rosenthal

PURPOSE/HYPOTHESIS: The purpose of this study was to compare hamstring muscle performance and posterior chain muscle activation during isolated knee flexion (IKF) assessed with isokinetic dynamometry (ID) versus the Nordic hamstring exercise (NHE) assessed with the NordBord (NB).

NUMBER OF SUBJECTS: Forty-nine healthy adults (25 women).

MATERIALS AND METHODS: A controlled laboratory study was performed. Testing order was randomized and participants performed both tests on the same day within 10 days of completing a familiarization session. Peak (PT) and average (AT) knee flexion torque along with surface EMG activity of 7 posterior chain muscles were assessed during 5 repetitions of both the NHE and ID (Biodex) IKF at 60°/s. EMG activity, analyzed as a percent of maximal voluntary isometric contraction, was measured from the right (RM) and left (LM) multifidi, gluteus maximus (GM), semitendinosus (ST), biceps femoris-long head (BF), and medial (MG) and lateral (LG) heads of the gastrocnemius. A 2-by-2 (gender by instrument) mixed-design repeated-measures of analysis of variance with repeated measures

on the second factor was performed to assess PT and AT. NB NHE versus ID IKF PT, AT and normalized PT and AT were further examined using Bland-Altman plots to assess validity using ID IKF as the gold standard. Differences in muscle activation of the posterior chain muscles were examined using a 2-by-2 multivariate analysis of variance (MANOVA).

RESULTS: Significant ($P < .01$) main effects for instrument (NHE>ID) and gender (male>female) were present for PT, AT and bodyweight normalized PT and AT. No significant instrument by gender interaction was present for PT or AT. While NHE values were higher in all knee flexion PT and AT measures, Bland-Altman plots indicated that when PT and AT were normalized to bodyweight, there was no proportional bias between the 2 instruments. MANOVA assessment of EMG activity yielded significant main effects ($P < .001$) for instrument. Greater EMG activity of the ST, BF, and LG was present with ID IKF while greater EMG activity was present in the LM, RM, and GM during the NB NHE. Both the NHE and ID IKF testing produced EMG activity near or >100% of MVIC in the knee flexor muscles and >60% for the multifidi. No significant main effect for gender or interaction between gender and instrument was present for EMG activity.

CONCLUSIONS: Performance bias is present with NB NHE testing demonstrating significantly higher (PT and AT) values than ID IKF testing. Greater activation of the knee flexors was present during ID IKF than the NHE. Proximal posterior chain muscles demonstrated greater activation during the NB NHE than ID IKF.

CLINICAL RELEVANCE: NB NHE and ID IKF PT and AT results should not be used interchangeably. Both exercises produce high levels of hamstring, gastrocnemius and multifidi activation. These findings may influence health professionals' exercise selection when developing rehabilitation programs and testing for return to sport decision making in athletes.

SPL23

ATHLETE TRAINING PROFILE AND PERFORMANCE AT THE EUROPEAN ADAPTIVE SURFING CHAMPIONSHIP

Heather Marie Scott David, Gonçalo Cruz, Maureen Johnson, Renato Bentes, Bruno Silva

PURPOSE/HYPOTHESIS: Surfing will debut at the 2020 Olympics with Para-Surfing targeting inclusion in the Paralympics. Surfing requires strength, balance, and agility in unpredictable ocean environments. Motor learning research is clear about the importance of task-specific training to learn and refine motor skills. Well developed sport-specific motor skills may enable a surfer to paddle more efficiently, catch more waves and execute more surfing maneuvers. To participate in adaptive surfing, athletes must overcome environmental and accessibility barriers. Challenges include traversing sand, transporting surfboard, entering and exiting water, transferring on and off surfboard, and navigating through ocean currents. In-water training may be limited for adaptive surfers as they often require assistance. No published research examines training habits of competitive adaptive surfers and correlation to scores. The purpose of this study was to examine training habits and look for correlations between in-water surfing time and out-of-water training time and scores at the European Adaptive Surfing Championship.

NUMBER OF SUBJECTS: Thirty.

MATERIALS AND METHODS: Participants (9 female, 21 male; mean age, 36.8 years) completed a survey on frequency and duration of in-water surfing, number of people required to assist in the water, out-of-water training activities including strength, cardio, swimming, or other, if they surfed prior to disability, years in adaptive surfing and competition. Contest final scores were correlated with survey results.

RESULTS: Participants averaged 10 days per month in-water surfing (1-2 hours), majority 1 to 2 in-water assistants. Out-of-water training performed by >80%, lasting 1 to 2 hours >8 days per month. Surfing prior to disability was 52% yes and 48% no. Participants surfed average 5.7 years and competed average of 2.5 years. Final scoring correlates significantly

and positively with in-water training days per month ($r = 0.436$, $P = .033$), significantly and negatively with prior disability surf practice ($r = -0.539$, $P = .021$), and significantly and positively with years of surfing prior to disability ($r = 0.769$, $P = .009$). Out-of-water training was not conclusively correlated with higher final scores, some activities correlated positively, some negatively, and some with no correlation.

CONCLUSIONS: In-water surfing time was a key factor for higher scoring. While prior to disability surf experience did not correlate with higher scoring, years surfing prior to disability did. Final scoring was positively influenced by the amount of sport-specific in-water surfing.

CLINICAL RELEVANCE: This study demonstrates that in-water surfing is superior to out-of-water training. While these training types can be used in combination, efforts should be made to increase accessibility for in-water training to increase both the number of athletes and the level of ability of athletes. Improving accessibility and opportunities for in-water training may improve the amount of in-water training and level of competition for the path to the Paralympics.

SPL24

HAND DOMINANCE AND SIDENESS INFLUENCE NECK AND SHOULDER MOBILITY IN COLLEGE BASEBALL PITCHERS

Laurie L. Devaney, Jason Keith Grimes

PURPOSE/HYPOTHESIS: To explore the relationship between lateral preference and neck and shoulder mobility in college baseball pitchers. The hypothesis is that hand dominance and sidedness influence neck and shoulder mobility profiles in baseball pitchers.

NUMBER OF SUBJECTS: Forty-nine.

MATERIALS AND METHODS: During preseason, 49 healthy collegiate pitchers were measured for height, weight, active neck range of motion, the cervical flexion rotation test, and shoulder passive range of motion. They reported hand dominance and completed the Lateral Preference Inventory (LPI) to determine sidedness (hand, foot, eye, ear) which was classified as "Right" or "Non Right" (both left and mixed dominance). Multivariate analysis of variance was performed to assess differences in mobility measures with respect to hand dominance and sidedness.

RESULTS: Of the 49 pitchers, 38 were right hand dominant and 11 were left hand dominant. Twenty-six were classified as Right sided, and 23 were Non-Right sided according to LPI score. Right-handed pitchers had a different overall mobility profile than left-handed pitchers ($P < .001$). Right-handed pitchers had less dominant cervical side bending (-5.9° ; 95% CI: -10.6° , -1.2° ; $P = .02$), dominant shoulder internal rotation (-8.4° ; 95% CI: -13.6° , -3.2° ; $P = .002$), nondominant external rotation (-6.7° ; 95% CI: -12.6° , -0.5° ; $P = .03$), nondominant flexion (-17.4° ; 95% CI: -24.6° , -10.1° ; $P < .001$), and nondominant total rotation motion (-8.5° ; 95% CI: -16.7° , -0.3° ; $P = .049$) than left handed pitchers. Additionally, right-handed pitchers demonstrated greater side to side differences in cervical sidebending (-8.9° ; 95% CI: -13.3° , -4.5° ; $P < .001$) and shoulder internal rotation (-6.5° ; 95% CI: -12.3° , -0.8° ; $P = .03$) and external rotation (-5.9° ; 95% CI: -10.6° , -1.2° ; $P < .001$), and lower side to side differences in flexion (9.9° ; 95% CI: 4.9° , 14.9° ; $P < .001$) and horizontal adduction (6.7° ; 95% CI: 1.7° , 11.6° ; $P = .01$). The overall mobility profile did not differ between Right and Non-Right sided pitchers ($P = .231$). However, Right sided pitchers had less neck extension (-6.9° ; 95% CI: -12° , -1.8° ; $P = .01$) and greater side to side differences in shoulder ER (6.1° ; 95% CI: 1.6° , 10.6° ; $P = .01$), flexion (8.4° ; 95% CI: 1.2° , 15.5° ; $P = .02$), and total rotation range of motion (7.1° ; 95% CI: 2.0° , 12.3° ; $P = .01$). Effect sizes were small to moderate.

CONCLUSIONS: Neck and shoulder mobility differ according to handedness and lateral preference in college baseball pitchers.

CLINICAL RELEVANCE: Neck and shoulder mobility measures are part of the injury risk assessment for baseball pitchers. Knowledge of the influence of lateral preference on mobility patterns will assist the clinician in interpretation of these risk factors in a clinical context.

SPL25

SOCCER PLAYERS WHO RUPTURE THEIR ANTERIOR CRUCIATE LIGAMENT EXHIBIT BIOMECHANICAL RISK FACTORS DURING A 90° CUT

Celeste Dix, Amelia Joanna Hanford Arundale, Holly Jacinda Silvers-Granelli, Ryan David Zarzycki, Adam Marmon, Lynn Snyder-Mackler

PURPOSE/HYPOTHESIS: The majority of ACL injuries among female soccer players occur via a noncontact mechanism. Cutting is a common movement during which noncontact ACL injuries occur in soccer players. Retrospective video analysis of ACL injuries among team handball players has indicated that players are typically in knee valgus at the time of injury. Prospective analysis of a vertical drop jump has also indicated that greater lower extremity valgus collapse is a biomechanical risk factor for ACL injury during landing tasks. We do not know whether the biomechanics of a sport-specific cutting task differ between players who go on to ACL injury and those who do not. Therefore, the purpose of this study was to determine whether the kinematics and kinetics of a 90° cutting task differ between collegiate women's soccer players who go on to ACL injury and those who remain uninjured.

NUMBER OF SUBJECTS: Sixty-two NCAA Division I and II women's soccer players.

MATERIALS AND METHODS: Players completed preseason motion analysis of a 90° cutting task. Kinematic and kinetic data were recorded simultaneously using an 8-camera motion system and embedded force plate. Each team's athletic trainer recorded injuries throughout the season, and 4 noncontact ACL injuries were reported. Descriptive statistics were computed for injured limbs and the mean of healthy participants' uninjured limbs. A MANOVA was used to determine if there were differences between injured and uninjured players for components of valgus collapse including: peak hip adduction, hip internal rotation and knee abduction angles. Participants were excluded from analysis if they reported prior history of ACL reconstruction. Alpha was set a priori at $P < .05$.

RESULTS: Mean hip adduction angle was $-5.24^\circ \pm 5.0^\circ$ (negative signifies abduction) for uninjured players and $-0.02^\circ \pm 3.96^\circ$ for injured players. Mean hip internal rotation angle was $9.83^\circ \pm 5.6^\circ$ (positive signifies internal rotation) for uninjured players and $7.60^\circ \pm 2.58^\circ$ for injured players. Mean knee abduction angle was $-4.31^\circ \pm 3.2^\circ$ (negative signifies abduction) for uninjured players and $-3.66^\circ \pm 1.68^\circ$ for uninjured players. While the difference between uninjured and injured players was only significant for hip adduction angle ($P = .045$, $\eta^2 = 0.065$), differences for hip adduction and internal rotation angles exceeded smallest detectable change values.

CONCLUSIONS: Players who went on to ACL injury demonstrated greater components of valgus collapse during a 90° cut, which may indicate that this task warrants further study in a larger cohort as a sport-specific screening tool for ACL injury risk. These results may also be used to guide development of exercise-based injury prevention interventions.

CLINICAL RELEVANCE: Women collegiate soccer players who went on to ACL injury had more valgus collapse during a cutting task than those who did not go on to an ACL injury. There is strong evidence that ACL injury rates can be reduced with exercise based interventions, and that the components of valgus collapse can be affected by these programs.

SPL26

WHICH IS BETTER FOR TENDON HEALING: DEEP FRICTION MASSAGE OR AUGMENTED SOFT TISSUE MOBILIZATION?

Mirna Magdy Elias, Nagwa Abu Elwafa, Hend Wageh, Tasneem Mohammad, Mahmoud Nabhan, Nabila Hassan, Aliaa Rehan Youssef

PURPOSE/HYPOTHESIS: Deep friction massage (DFM) and Augmented Soft Tissue Mobilization (ASTM) are used to enhance tendon healing after strain. Yet, their clinical effectiveness is still lacking scientific evidence.

Considering injury heterogeneity and variable presentation in humans, animal models may allow better understanding of treatment efficacy at a structural level. Thus, this study compared the efficacy of DFM and ASTM on tissue healing after induced strain in rats. Further, it investigated whether treatment response is dependent on massage initiation time.

NUMBER OF SUBJECTS: Sixty healthy adult male Wistar rats.

MATERIALS AND METHODS: This study was conducted and approved by the Institutional Ethics committee. Rats were randomly and equally assigned into 6 groups as following: (1) DFM starting at the subacute (day 7), (2) DFM starting at the chronic stage (day 14), (3) ASTM starting at the subacute (day 7), (4) ASTM at the chronic stage (day 14), (5) an injured control (to assess natural recovery or the “wait-and-see” approach), and (6) a normal control group (to provide reference for normal tissue appearance). All animals, except the normal control, had the right tibialis anterior tendon strained using a valid noninvasive passive stretching method. Massage was applied using the Graston tool (G plus 2-3-6, USA) for 3 minutes, every 4 days, for 4 sessions. Massage pressure was maintained at 1.5 N/mm², guided by pressure sensors. Massage direction was transverse for DFM and longitudinal for the ASTM. At the 27th day, rats were euthanized. Then, tibias tendon was harvested and processed for histopathological examination using the modified Movin scoring system that assesses fiber structure, arrangement, cellularity and vascularity.

RESULTS: Compared to injured control, animals that received the ASTM at the subacute stage significantly improved ($P = .044$). Compared to normal animals, DFM applied at the subacute stage resulted in a significant tendon deterioration ($P = .004$). For treatment initiation time, DFM applied at the subacute stage increased tissue damage ($P = .028$), whereas ASTM was not affected by the time of commencing treatment ($P = .368$). For massage techniques, DFM was the worst when applied at the subacute stage ($P = .002$), whereas both techniques had similar effects when commenced at the chronic stage ($P = .391$).

CONCLUSIONS: At the subacute stage, ASTM may improve tendon healing whereas DFM may increase tissue damage. At the chronic stage, DFM and ASTM are not better than the “wait-and-see” approach.

CLINICAL RELEVANCE: In rats, ASTM may improve tendon healing than natural recovery when applied at the subacute stage. For the chronic stage, ASTM and DFM add no benefit over natural recovery. Thus, employing the “wait-and-see” policy at this stage may be more appropriate. A more rigor longitudinal clinical trials are needed to confirm the current results. Further, other aspects, such as patients’ satisfaction and improvement in clinical presentation should also be considered to reach a solid conclusion.

SPL27

LOWER EXTREMITY KINETICS DURING RUNNING IN FEMALES WITH AND WITHOUT PATELLOFEMORAL PAIN

Lauren N. Erickson, Kylie A. Davis, Michael Samaan, Brian Noehren

PURPOSE/HYPOTHESIS: Patellofemoral pain (PFP) is the most common overuse knee injury among runners and is twice as prevalent in females compared to males. Clinically, step length and overstriding are commonly assessed when evaluating injured runners as longer step lengths have been associated with greater patellofemoral joint stress. Gait retraining techniques, such as step rate modification, are frequently used to make adjustments in these variables with the goal of altering the associated kinetics. However, whether baseline differences in these variables exist between those with and without PFP has not been defined. Therefore, the purpose of this study was to compare cadence, step length, overstriding, and kinetic variables in females with PFP and healthy controls while running.

NUMBER OF SUBJECTS: Thirty-five female recreational runners were recruited for this study (PFP: $n = 18$; mean $\pm$ SD age, 25 ± 6.3 years; BMI, $21.5 \pm$

1.9 kg/m²; distance, 15 ± 5.0 mi/wk; controls: $n = 17$; age, 26 ± 3.4 years; BMI, 21.4 ± 2.0 kg/m²; distance, 22 ± 11.5 mi/wk).

MATERIALS AND METHODS: An instrumented gait analysis was performed while subjects ran at 3.3 m/s wearing standardized laboratory shoes. Overstriding was assessed as the horizontal distance between the distal heel marker and the body’s center of gravity (COG) at initial contact. Variables of interest included cadence, step length, heel-to-COG distance at initial contact, initial impact peak, average loading rate, and peak braking force. Independent t tests were used to compare differences between groups ($\alpha < .05$).

RESULTS: Female runners with PFP did not demonstrate significant differences in cadence (PFP, 175.3 ± 8.2 steps/min; control, 177.2 ± 6.6 steps/min; $P = .471$), step length (PFP, 1.13 ± 0.05 m; control, 1.11 ± 0.04 m; $P = .252$), heel-to-COG distance at initial contact (PFP, $.128 \pm 0.03$ m; control, 0.135 ± 0.03 m; $P = .493$), initial impact peak (PFP, 1.61 ± 0.32 BW; control, 1.55 ± 0.28 BW; $P = .552$), average loading rate (PFP, 70.7 ± 15.7 BW/s; control, 66.8 ± 14.7 BW/s; $P = .901$), and peak braking force (PFP, -0.33 ± 0.05 BW; control, -0.33 ± 0.03 BW; $P = .952$) compared to healthy controls.

CONCLUSIONS: Runners with PFP did not exhibit differences in cadence, step length, overstriding, or kinetic variables compared to their healthy counterparts. This suggests that patellofemoral pain is not attributable to overstriding or altered kinetics during running and challenges the common assumptions of lower cadence, overstriding, and increased ground reaction forces in runners with PFP.

CLINICAL RELEVANCE: Although running-related PFP has been associated with altered biomechanics, spatiotemporal and kinetic variables appear to be poor indicators of running-related symptoms. While step rate modification may serve to reduce patellofemoral joint stress, step length and overstriding should not be used as an indicator that an impairment exists. Clinicians need to take a multifactorial approach when treating female runners with PFP and gait retraining should be tailored to each runner in order to optimize outcomes.

SPL28

ACCURACY OF THE REGION OF LIMB STABILITY METRIC IN PREDICTING RISK FOR LOWER-LIMB INJURY IN DIVISION I FOOTBALL

Luis Alejandro Feigenbaum, Ignacio Gaumaurd, Kyoung J. Kim, Michele Alexandria Raya, Jeffrey Thomas Ruiz, Julia Laura Rapicavoli, Thomas Best, Lee D. Kaplan, Robert S. Gailey

PURPOSE/HYPOTHESIS: To determine if a measure of lower-limb segment stability derived from body-worn inertial measurement units (IMU) can predict risk for lower limb musculoskeletal injury in Division I collegiate football players (D1CFP).

NUMBER OF SUBJECTS: One hundred four.

MATERIALS AND METHODS: The Region of Limb Stability (ROLS) values were collected in a cohort of D1CFPs during preseason. ROLS is a measure of static knee joint stability, defined by thigh and shank excursion (square centimeters) in the anterior-to-posterior (AP) and medial-to-lateral (ML) direction during single-limb stance (SLS). The ROLS Symmetry Index (SI) (percent) is the ratio between lower limb ROLS values where 100% suggests absolute symmetry.

RESULTS: One hundred four D1CFP participated in this study and were divided into 2 groups: (1) No previous lower limb injury or no in-season injury ($n = 70$, noninjured group) and (2) No previous lower limb injury, but in-season injury requiring surgery ($n = 34$, injured group). The mean $\pm$ SD ROLS SIs was $82.86\% \pm 14.75\%$ and $65.58\% \pm 16.46\%$ for the non-injured and injured group, respectively. Significant differences in ROLS SI were found between groups ($P < .001$). The ROLS SI demonstrated an AUC of 0.8 (95% CI: 0.71, 0.88; $P < .001$) with a SE of 0.04 indicating that the ROLS SI has good predictive accuracy in detecting those healthy D1CFPs at risk for lower-limb injury resulting in surgery.

CONCLUSIONS: This study demonstrated the efficacy of an IMU-based mobile system for the direct assessment of lower limb stability and risk for injury resulting in surgery in DICFPs. Increase in thigh and shank excursions and/or decrease in symmetry index (SI) may predict risk of injury to the less stable limb. Higher predictive ability was achieved comparing lower limbs rather than single leg assessments. The ROLS is a measure that demonstrated good sensitivity and specificity in detecting those collegiate DICFPs at risk for lower limb MSK injuries requiring surgery that were healthy and asymptomatic during preseason testing.

CLINICAL RELEVANCE: Increase in thigh and shank excursions and/or decrease in symmetry index (SI) between lower limbs may be a predictor of risk for future injury. The technologies used in this study were shown to be both feasible to implement and applicable to the population being be able to gather a holistic idea of the potential causes for postural instability.

SPL29

EFFECTS OF TASK AND MATURATION ON KNEE ABDUCTION IN FEMALE ATHLETES

Kevin R. Ford, Audrey E. Westbrook, Anh-Dung Nguyen, Mark Vincent Paterno, Jeffrey B. Taylor

PURPOSE/HYPOTHESIS: Neuromuscular training programs that aim to reduce anterior cruciate ligament (ACL) injury target high-risk biomechanics associated with injury. High knee abduction moments (KAM) may be the most important movement strategy to target. Furthermore, females show significant increases in KAM following rapid growth during adolescence compared to males. These data focus on landing during a drop vertical jump maneuver. Single-leg deceleration and pivoting tasks are often incorporated into assessments of movement quality. However, investigations are lacking which report the effects of maturation on KAM during unplanned cutting which may be a common mechanism of injury in soccer. The purpose of this study was to determine the effects of maturation and task on KAM in young female soccer players.

NUMBER OF SUBJECTS: One hundred thirty-nine female soccer players volunteered to participate in this study (prepubertal [PRE]: $n = 17$, 84.0% adult stature; mean $\pm$ SD age, 10.3 $\pm$ 0.6 years; height, 137.8 $\pm$ 6.8 cm; weight, 34.2 $\pm$ 4.5 kg; pubertal [PUB]: $n = 32$, 91.1% adult stature; age, 11.9 $\pm$ 0.8 years; height, 151.1 $\pm$ 5.7 cm; weight, 43.3 $\pm$ 6.0 kg; postpubertal [POST]: $n = 90$, 97.9% adult stature; age, 14.6 $\pm$ 1.6 years; height, 162.6 $\pm$ 5.6 cm; weight, 56.2 $\pm$ 8.8 kg).

MATERIALS AND METHODS: Participants were categorized into maturational groups based on percent of adult stature. A drop vertical jump (DVJ) and an unplanned cut (CUT) were performed over an embedded force platform with artificial turf. Standard 3-D motion analysis techniques were used to calculate peak KAM of the dominant limb during each task. A repeated-measures ANOVA was used to determine the differences in KAM between task and maturational group ($P < .05$).

RESULTS: A main effect of maturation was found with KAM for both tasks ($P < .001$). Post hoc analysis showed that during the CUT, POST (-32.4 Nm; 95% CI: -35.7 , -29.1) had significantly greater KAM than PRE ($P = .013$; -21.8 Nm; 95% CI: -29.4 , -14.1) and PUB ($P < .001$; -19.8 Nm; 95% CI: -25.4 , -14.3). Similarly, during the DVJ, POST (-27.3 Nm; 95% CI: -30.1 , -24.5) had significantly greater KAM than PRE ($P < .001$; -13.1 Nm; 95% CI: -19.5 , -6.6) and PUB ($P < .001$; -14.3 Nm; 95% CI: -19.0 , -9.6). Additionally, a main effect of task ($P < .001$) indicated across all groups, the CUT had greater KAM than DVJ.

CONCLUSIONS: KAM was greater in an unplanned single leg cutting maneuver in young soccer players compared to a DVJ. Additionally, the players that had recently completed their adolescent growth had greater KAM compared to pubertal and postpubertal athletes.

CLINICAL RELEVANCE: Physical therapists working with young female soccer players should consider the relationship of maturational status and high frontal plane knee loading. Additionally, with the high incidence of second ACL injury in this population, attention on primary risk factors

should also be addressed throughout the rehabilitation process in young patients following an ACL reconstruction.

SPL30

BAND PULL-APART EXERCISE: EFFECTS OF MOVEMENT DIRECTION AND HAND POSITION ON SHOULDER MUSCLE ACTIVITY

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PURPOSE/HYPOTHESIS: Elastic band pull-apart exercise is commonly used in rehabilitation. Extent of muscle activation during this exercise is unknown. The purpose of this study was to document the extent of electromyographic (EMG) activity during the band pull-apart exercise and to determine the effects of different movement directions and hand positions on muscle activation.

NUMBER OF SUBJECTS: Ten healthy subjects (all male; mean $\pm$ SD age, 36 $\pm$ 12 years).

MATERIALS AND METHODS: Surface EMG activity was measured from 7 muscles of the dominant shoulder: supraspinatus, infraspinatus, teres minor, upper trapezius, middle trapezius, lower trapezius and posterior deltoid. After measurement of maximal voluntary contraction (MVC) for each muscle, subjects performed the band pull-apart exercise in 3 hand positions (palm up, neutral, down) and 3 movement directions (diagonal dominant arm up, horizontal, diagonal dominant arm down). Elastic band resistance was set to elicit moderate exertion (5/10 on the Borg CR10 scale). Order of exercise was randomized and 3 repetitions of each exercise were performed. Mean peak EMG activity in each muscle across the repetitions was calculated and expressed as a percentage of MVC. Peak normalized EMG activity in each muscle was compared in 2-way (hand position by direction) repeated-measures ANOVA.

RESULTS: Peak muscle activity ranged from 15.3% to 72.6% of MVC across muscles and exercise conditions. Supraspinatus activity was highest in palm down position, followed by neutral (main effect of hand position, $P = .002$) and highest in diagonal up direction followed by horizontal (main effect of direction, $P < .001$). Infraspinatus activity was highest in palm up position, followed by neutral (main effect of hand position, $P < .001$) and highest in diagonal up direction followed by horizontal (main effect of direction, $P = .011$). Highest teres minor activity occurred in palm up position, followed by neutral (main effect of hand position, $P = .009$); direction did not have a significant effect. Upper trapezius activity was highest in palm down position, followed by neutral (main effect of hand position, $P = .004$) and highest in diagonal up direction followed by horizontal (main effect of direction, $P < .001$). Highest middle trapezius activity occurred in diagonal down direction (main effect of direction, $P < .001$); hand position did not have a significant effect. Lower trapezius activity was highest in palm up position, followed by neutral (main effect of hand position, $P < .001$) and highest in diagonal up direction followed by horizontal (main effect of direction, $P < .001$). Posterior deltoid activity was highest in palm down position, followed by neutral (main effect of hand position, $P = .001$) and highest in diagonal up direction, followed by horizontal (main effect of direction, $P = .02$).

CONCLUSIONS: Elastic band pull-apart exercise effectively activates shoulder muscles. Altering hand position and movement direction can significantly facilitate or inhibit muscle activity.

CLINICAL RELEVANCE: Clinicians may alter a patient's hand position and movement direction while performing the band pull-apart exercise to increase muscle activity in target muscles or suppress unwanted muscle activity.

SPL31

KINESIOPHOBIA AND DUAL-TASK POSTURAL STABILITY FOLLOWING CONCUSSION: IMPLICATIONS FOR LOWER EXTREMITY INJURY IN OLDER ADOLESCENTS

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PURPOSE/HYPOTHESIS: It is estimated that 1.0 to 1.8 million sports-related concussions occur every year in the United States. Following a concussion, athletes are at a significantly greater risk for suffering a musculoskeletal injury upon return to sport (RTS). The reasons for this are unclear, but previous literature has demonstrated that it could be due to changes in neurocognitive function that remain unresolved. There may also be issues related to the fear of reinjury. This study determined the effects of concussion on dynamic and static postural stability, with and without a dual-task challenge, along with kinesiophobia at the time of RTS and 6 months post RTS. We hypothesized that concussed subjects will demonstrate worse postural stability and higher kinesiophobia scores than the control group, but these differences would resolve at 6 months.

NUMBER OF SUBJECTS: Twenty subjects including 12 (mean $\pm$ SD age, 16.1 $\pm$ 1.4 years; height, 172.3 $\pm$ 11.3 cm; weight, 65.7 $\pm$ 15.3 kg) who had suffered a sports-related concussion and had been cleared for RTS. Testing also included 8 healthy individuals (age, 16.5 $\pm$ 2.1 years; height, 172.2 $\pm$ 10.9 cm; weight, 67.9 $\pm$ 15.4 kg) who were matched to the concussed group by age, sex, and sport.

MATERIALS AND METHODS: Subjects in the concussed group underwent testing after they were cleared for RTS (60.6 $\pm$ 54 days following concussion) by a licensed health care provider and again 6 months post RTS. Control subjects underwent the same testing 2 times separated by 6 months. Dynamic postural stability was measured during a single-leg landing with and without a dual-task challenge. A dynamic postural stability index was calculated and averaged across 3 trials for each condition. Static postural stability was assessed during single-leg stance under eyes open, eyes closed, and dual-task conditions. A cumulative score of ground reaction force variability was calculated and averaged across 3 trials for each condition. The dual-task condition incorporated a Stroop task. Kinesiophobia was assessed with the 11 question Tampa Scale of Kinesiophobia from (TSK-11). Initial statistical analysis began with a 2-way ANOVA (group by test session) followed by pairwise comparisons based on the results of the 2-way ANOVA. Statistical significance was set a priori at $P < .05$.

RESULTS: None of the analyses for the postural stability variables resulted in a statistical significance. The result of the 2-way ANOVA for the TSK-11 scores was statistically significant ($P = .0142$). Concussed subjects presented with significantly higher TSK-11 scores at baseline (19.2 $\pm$ 4.3 versus 13.8 $\pm$ 3.3) than the control group. The TSK-11 scores were not significantly different for either group at the 6-month follow-up (concussed, 18.8 $\pm$ 3.2; control, 17.1 $\pm$ 3.8).

CONCLUSIONS: Dynamic and static postural stability, even under dual-task challenge conditions, are not sensitive indicators of RTS lower extremity injury risk in postconcussion adolescent athletes. Whereas, kinesiophobia may have clinical utility when assessing baseline differences in young concussed athletes.

CLINICAL RELEVANCE: The lack of significant differences in postural stability under all conditions may be due to a recovery from the initial injury as the average time from concussion to testing following RTS was approximately 2 months. The higher kinesiophobia scores that persist through 6 months after RTS may provide some insight into the increased risk of musculoskeletal injury in this population. Caution must be taken though given the small sample size of the study and use of the TSK-11 in this population.

SPL32

HOP DISTANCE, BUT NOT ANKLE POWER, IMPROVES FOLLOWING NEUROMUSCULAR TRAINING IN ATHLETES POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Alex Garnaut, Rachel Tatarski, Stephanie Di Stasi

PURPOSE/HYPOTHESIS: Performance on the single-leg hop for distance (SLH) is used in return-to-sport testing following anterior cruciate lig-

ament reconstruction (ACLR). Ankle contribution during the propulsive phase of a SLH likely affects performance post ACLR. The purpose was to evaluate the effects of a neuromuscular training (NMT) program on ankle kinetics in athletes with ACLR compared to healthy controls (HC). We hypothesized that athletes post ACLR would have lower sagittal ankle power and shorter hop distance compared to their uninvolved limb and HCs, and that these deficits would resolve post NMT.

NUMBER OF SUBJECTS: Sixteen ACLR subjects (37% male; mean $\pm$ SD age, 21.9 $\pm$ 6.6 years; BMI, 26.1 $\pm$ 4.2 kg/m²; 9.9 $\pm$ 4.5 months post ACLR; pre-test IKDC, 74.1 $\pm$ 8.1; Tegner median, 5 $\pm$ 1.5) and 16 HCs (37% male; age, 24.6 $\pm$ 2.4 years; BMI, 24.9 $\pm$ 2.6 kg/m²; Tegner median, 6 $\pm$ 1.0), matched by sex and age (± 5 years).

MATERIALS AND METHODS: ACLR subjects were tested before and after a 12-session NMT program; HC were tested once. Involved limbs of the ACLR group were matched to randomly assigned limbs of the HC. The means of 2 SLH per limb were analyzed (take-off, 0.5 seconds prior to the ground reaction force (GRF) < 10 N during 3-D motion analysis. Hop distance was normalized to height. Generalized estimating equations were used to assess time-by-limb (ACLR group; pre-post NMT) and group-by-limb (ACLR post-NMT versus HC) interactions (covariate was BMI) for hop distance, peak ankle power (W/kg) and peak A/P GRF (N/kg); $\alpha = .05$. Means and 95% confidence intervals were reported.

RESULTS: In the ACLR group analysis, there was a significant interaction for hop distance ($P = .005$), indicating an improvement in the INV limb after NMT (before, 0.82; 0.77, 0.88; after, 0.87; 0.82, 0.92; $P = .008$). Hop distance asymmetry present at baseline ($P = .059$) was not present after NMT ($P = .671$). An interaction was identified for ankle power ($P = .002$), indicating limb asymmetries before (INV: 12.2 W/kg; 11.0, 13.3; UN: 14.1 W/kg; 12.8, 15.4; $P = .001$) and after NMT (INV: 12.8 W/kg; 11.8, 13.9; UN: 14.5 W/kg; 13.3, 15.7; $P = .001$). There was an interaction for A/P GRF indicating a significant increase on the INV limb after NMT ($P < .001$), but no limb asymmetries at either time ($P \geq .115$). In the group-by-limb analysis, there were no interactions or main effects for hop distance ($P \geq .206$) or peak A/P GRF ($P \geq .604$). There was an interaction for ankle power ($P = .003$), indicating less power in the INV limb of the ACLR group (12.8 W/kg; 11.8, 13.9) compared to the matched limb of HCs (15.1 W/kg; 12.5, 16.5; $P = .042$).

CONCLUSIONS: Despite improved hop distance, ACLR subjects demonstrated reduced ankle power in the INV limb that did not improve with NMT and was lower than HCs. These data indicate that symmetry measures may not provide an accurate assessment of residual performance deficits.

CLINICAL RELEVANCE: Deficient ankle power may be a common, but under-recognized, impairment post-ACLR and can negatively affect hop performance. Along with knee-specific impairments, deficits at the ankle may translate to poorer performance. Effective treatment throughout the lower extremity may optimize outcomes in this population.

SPL33

DEFICITS IN KNEE ENERGY ABSORPTION CONTRIBUTION FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION ARE NOT RELATED TO EARLY KNEE LOADING

James Craig Garrison, Joseph Patrick Hannon, Shiho Goto, Angel Grondin, Curtis Bush, Jim Bothwell

PURPOSE/HYPOTHESIS: The purpose of this study was to observe the "load" of participants during the early phases of recovery following anterior cruciate ligament reconstruction (ACL-R) and to examine if this was related to kinetic deficits commonly seen during a squat task at 8 weeks following surgery.

NUMBER OF SUBJECTS: A total of 17 participants (8 male, 9 female) were enrolled in the study (mean $\pm$ SD age, 15.7 $\pm$ 1.3 years; height, 167.4 $\pm$ 10.4 cm; mass, 72.1 $\pm$ 14.6 kg). All participants were level 1 athletes who sustained a primary anterior cruciate ligament injury and underwent ACL-R with either a bone-patellar tendon-bone graft or hamstring graft. Participants were tested at 8 weeks following surgery.

MATERIALS AND METHODS: All participants completed 5 double-limb squats. An 8 camera Qualisys Motion Capture System and 2 AMTI force plates were used to calculate the energy absorption contribution (EAC) for the knee joint. All values were normalized to the subjects' height and weight. An arbitrary unit (AU) for "load" was calculated by multiplying the participant's total exercise time spent in physical therapy by their self-reported rating of perceived exertion (RPE) for each session. Additionally, participants' home exercise program (HEP) arbitrary unit (HEP AU) was calculated in the same fashion (time spent on HEP over the week X RPE). These 2 numbers were averaged to obtain 1 AU value for each of the participants' first 8 weeks of rehabilitation following surgery. Furthermore, participants were provided a Fitbit step tracker and their average number of steps was recorded for this same period. Pearson product correlations were run to assess for the relationship between knee loading over the first 8 weeks following surgery and knee EAC; and between average step count over the first 8 weeks and knee EAC. The alpha level was set at $P < .05$.

RESULTS: There was no significant relationship between "load" and knee EAC ($r = 0.407$, $P = .204$). Likewise, no relationship between the average step count over the first 8 weeks and knee EAC ($r = 0.436$, $P = .157$) was found.

CONCLUSIONS: Early exercise load is not related to knee loading during a double-limb squat at 8 weeks following ACL-R.

CLINICAL RELEVANCE: "Load" monitoring and "load" management continues to be a topic of interest in rehabilitation and performance settings. In this context, it does not appear that early loading as measured by exercise time and RPE and total steps is related to the ability to effectively load the surgical knee during a DLS at 8 weeks following ACL-R.

SPL34

ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION GRAFT CHOICE INCREASED LIKELIHOOD OF MEETING RETURN-TO-SPORT CRITERIA AT 6 MONTHS

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Jonathan Riboh*

PURPOSE/HYPOTHESIS: ACL graft tears and contralateral injuries are problematic in pediatric sports medicine, with a combined incidence of 25% to 35%. Recent publications have highlighted a high failure rate with hamstring autografts in young patients, while others have suggested lower failure rates with quadriceps autografts. However, little is known about the possible reasons for this difference. We hypothesized that the use of quadriceps soft tissue autografts would lessen postoperative neuromuscular deficits compared to other autografts, and therefore, young athletes would achieve objective return to sport (RTS) criteria more rapidly.

NUMBER OF SUBJECTS: Sixty-eight.

MATERIALS AND METHODS: A retrospective review of consecutive patients who underwent ACL reconstruction by a single surgeon and completed a comprehensive series of physical performance tests (PPTs) at 6 months postsurgery was conducted. A chart review of demographic and surgical data was completed. Patients performed 9 common PPTs; limb symmetry index (LSI) was established and $LSI > 90\%$ was used as the cutoff for passing each individual test. Athletes met RTS criteria if they achieved $LSI > 90\%$ on at least 8 of 9 tests. Multivariate linear and logistic regressions were performed to assess the effect of age (dichotomous; pediatric (< 16 years) versus skeletally mature), gender, graft type, concomitant meniscal surgery, and time postop, on the number of tests an individual could pass and the likelihood of passing the battery of PPTs, respectively.

RESULTS: The cohort of 68 young, active patients (mean $\pm$ SD age, 18.9 ± 7.5 years; 56% pediatric; 46% female; graft type: 63% BTB, 16% hamstring, 15% quadriceps, 6% ITB) were tested at a mean $\pm$ SD of 6.7 ± 1.9 months. Overall, 35% of patients "passed" the battery of PPTs. Upon logistic regression, age and concomitant meniscal surgery were poor predictors of "passing." In contrast, use of quadriceps was a strong predic-

tor of passing (OR = 14.1; 95% CI: 2.4, 83; $P = .003$ compared to BTB). Upon linear regression, use of quadriceps was again a strong predictor of the number of individual PPTs passed ($B = 1.8$; 95% CI: 0.33, 3.3; $P = .02$ compared to BTB). No other demographic variables predicted "passing" or number of individual PPTs passed.

CONCLUSIONS: Young, active patients undergoing ACL reconstruction with quadriceps autograft are 14 times more likely to meet RTS criteria at 6 months postop than similar patients with BTB, hamstring or ITB autograft.

CLINICAL RELEVANCE: This study may provide valuable insight into the decreased failure rates suggested with the quadriceps autograft. Additionally, this study confirms the majority of these high-risk, young athletes do not meet RTS criteria at 6 months postoperatively.

SPL35

BRAIN ACTIVITY ASSOCIATED WITH DROP LANDING AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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Cody Criss, Adam Haggerty, Meredith Chaput, James Onate*

PURPOSE/HYPOTHESIS: Anterior cruciate ligament reconstruction (ACLR) induces neuroplasticity to control the knee joint that can impair patient function. However, prior reports have focused on neural recording during isolated and simple knee motor tasks that lack ecological validity. Action-observation, whereby an individual watches a movement from a first person perspective and imagines themselves completing the movement, engages a portion of neural activity that is needed to actually complete the movement (often referred to as mirror neurons). Our purpose was to employ an action-observation paradigm of jump-landing during neuroimaging in patients with ACLR and matched controls. We hypothesized that the ACLR group would have increased neural activity in brain regions responsible for cognitive control of movement.

NUMBER OF SUBJECTS: Fifteen patients with left knee ACLR (8 female, 7 male; mean $\pm$ SD age, 23.76 ± 3.20 years; height, 1.80 ± 0.08 m; weight, 83.0 ± 19.8 kg; Tegner activity level, 6.75 ± 2.0 ; 42 ± 36 months post surgery; 13 hamstring grafts, 2 patella-tendon grafts) and 15 sex, age, weight, height, sport, activity level and education level matched controls (8 female, 7 male; age, 24.6 ± 2.08 years; height, 1.74 ± 0.06 m; weight, 80.5 ± 12.55 kg; Tegner activity level, 6.75 ± 2.0) participated.

MATERIALS AND METHODS: Neuroimaging was completed on a 3-T Siemens Magnetom scanner with a 16-channel head coil. Functional brain imaging to capture neural activity (blood oxygen level dependent response) was completed during four 30-second cycles of 5 first person viewpoint drop vertical jumps. Brain activation patterns during action-observation of drop jumps were contrasted with an interspersed rest condition, with each participant's data averaged across trials. Results were reported as z scores, with higher scores indicating greater likelihood of activation and P value indicating the probability of finding activation when there was none. The 2 groups (patients, controls) were compared via a general linear model second-level mixed-effects a priori threshold at $z = 3.1$ and alpha level of less than .05 cluster corrected for multiple comparisons.

RESULTS: The ACLR group had increased neural activity in the posterior middle temporal gyrus (200 voxels; $z = 4.6$, $P = .008$) compared to controls.

CONCLUSIONS: The posterior middle temporal gyrus plays a key in role in the retrieval of context specific information to accommodate actions associated with demanding goals. Specifically, this region may support alterations in motor control to engage in a specific task under varied constraints or contexts, thus the ACLR individuals increased neural activity in this region may be associated with increased goal-oriented cognition demands to engage in drop landing.

CLINICAL RELEVANCE: The increased activity in patients with ACLR may indicate the injury or rehabilitation shifted neural activity for landing to engage more cognitive processes, such that landing neuromuscular control

is less “automatic.” Clinicians can incorporate contextual principles of motor learning via sport simulations, on the field training or virtual reality into movement therapy to potentially target the neural activity found to be increased in those with ACLR.

SPL36

12-WEEK QUADRICEPS STRENGTH PREDICTS QUADRICEPS STRENGTH AT TIME OF RETURN-TO-SPORT TESTING FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Joseph Patrick Hannon, James Craig Garrison, Sharon S. Wang-Price, Shiho Goto, Angel Grondin, Jim Bothwell, Curtis Bush

PURPOSE/HYPOTHESIS: Achieving optimal quadriceps strength following Anterior Cruciate Ligament reconstructive (ACL-R) surgery continues to challenge patients, clinicians and surgeons. Previous research has demonstrated that immediately following ACL-R quadriceps strength diminishes and may take up to 2 years to be restored. Despite our knowledge on long-term quadriceps strength our understanding of how early quadriceps strength potentially affects long-term strength is limited. Therefore, the purpose of this study was to assess the relationship between early quadriceps strength (12 weeks following ACL-R) and quadriceps strength at time of return to sport testing.

NUMBER OF SUBJECTS: A total of 123 participants (58 male, 65 female) were enrolled in the study (mean $\pm$ SD age, 16.0 ± 1.4 years; height, 1.72 ± 10.1 m; mass, 70.5 ± 16.3 kg). All participants were level 1 athletes who sustained a primary ACL injury and underwent ACL reconstruction with either a bone-patellar-bone graft or hamstring graft. Participants were tested at 2 time points; 12 weeks following surgery and again at time of return to sport testing.

MATERIALS AND METHODS: All participants completed isokinetic quadriceps strength testing on the Biodex Multi-Joint Testing and Rehabilitation System. Participants performed 5 consecutive concentric contractions at $60^\circ/\text{s}$ on the uninvolved limb following by the involved limb. All data were normalized to bodyweight. A linear regression was performed to assess the relationship between the involved quadriceps strength at 12 weeks following ACL-R and quadriceps strength at time of RTS testing. Alpha level was set at $P < .05$.

RESULTS: The linear regression showed a significant relationship between these 2 measures ($P < .001$), with a Pearson correlation coefficient of 0.710. The adjusted R^2 value of 0.50, indicated 50% of quadriceps strength at RTS can be explained by the quadriceps strength at 12 weeks. The formula for this relationship is quadriceps strength at RTS = $0.620 + 0.835 \times$ quadriceps strength at 12 weeks.

CONCLUSIONS: In this cohort of participants, quadriceps strength at 12 weeks following surgery explained 50% of the quadriceps strength at time of RTS.

CLINICAL RELEVANCE: These findings underscore the importance of early restoration of quadriceps strength. Clinicians should look to address quadriceps strength deficits early in the rehabilitation process.

SPL37

THE ELECTROMYOGRAPHIC PROFILE OF SELECTED SHOULDER MUSCULATURE DURING COMMON ECCENTRIC EXERCISES

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PURPOSE/HYPOTHESIS: EMG data has long been used to quantify muscle activation during physical activity. Several studies have determined that specific muscle patterns are active for common functional movements and even subtle changes to a given activity (such as hand/forearm placement or grip) can elicit changes in muscle activation. In rehabilitation of the shoulder, the rotator cuff and posterior shoulder girdle musculature are areas that receive a lot of attention. Strengthening of these structures can contribute to greater balance among the rotators of the shoulder

and improve overall function. The rotator cuff, in particular, provides a central, stabilizing mechanism to allow for unencumbered glenohumeral movement while mitigating adverse translational effects and subsequent impingement. Specific strengthening exercises for the rotator cuff including eccentric training are often utilized to accomplish this. What is currently unknown, however, are how variations in eccentric exercise performance quantitatively affect the rotator cuff or other shoulder musculature. The authors hypothesize that forearm positioning may affect EMG data about the shoulder within specific eccentric exercises.

NUMBER OF SUBJECTS: Ten subjects were recruited from the surrounding area; 8 male, 2 female.

MATERIALS AND METHODS: IRB approval and informed consent was obtained for this prospective observational study. Participants were enrolled with the following exclusion criteria: previous history of shoulder injury occurring in dominant extremity; current painful dysfunction resulting in exercise limitation; any health-related exercise limitation as ordered by physician. Ages outside of 18 to 65. Inability to access clinic and equipment. Subjects were then provided visual demonstration and instruction on the eccentric exercises. The following exercises were performed in a randomized order: (1) sidelying eccentric horizontal abduction (SL ER), (2) half-kneeling weighted ball decelerations (BALL DC), (3) seated eccentric external rotation in scaption (STD ER), (4) standing eccentric external rotation at 0° (STND ER), (5) supine eccentric external rotation at 90° (SUP ER). EMG surface electrode (Delsys, Inc, Natick, MA) placement to the posterior rotator cuff musculature was performed by an experienced research scientist with palpation assistance from an experienced physical therapist. All participants then performed the eccentric exercises with forearm position variants (pronation, neutral, supination) with exercises and forearm position order randomized. Exercises were completed with 1 initial repetition without resistance to normalize EMG data, followed by 10 repetitions under resistance with a trained physical therapist ensuring appropriate movement quality. All subjects were provided a rest period of at least 2 minutes in between exercises. Muscle activation of the infraspinatus, teres minor, and deltoids muscles were analyzed for each exercise using EMG analysis software (EMG Works, Delsys). Data were analyzed using a mixed-model ANOVA repeated across grip for each exercise followed by a Tukey post hoc test for pairwise comparisons. Type I error was set at $\alpha = .05$.

RESULTS: There were significant differences in EMG activity among the infraspinatus and teres minor during SL ER, STD ER, STND ER exercises with varying forearm positions. BALL DC and SUP ER did not produce significant differences between either forearm position for the rotator cuff musculature. Differences were observed between the middle and posterior deltoid during BALL DC.

CONCLUSIONS: In accordance with our hypothesis, there are differences in EMG muscle activity during eccentric rotator cuff exercises with varying forearm positions. Interestingly, the differences in EMG activity between forearm positions were not similar across the exercises. Thus, in light of our data, optimal forearm position to maximize targeting of the rotator cuff varies from exercise to exercise and should be considered when designing a rotator cuff strengthening or rehabilitation program.

CLINICAL RELEVANCE: Specific eccentric shoulder exercises activate muscles of the shoulder based on forearm position. This data provides physical therapists and other rehabilitation professionals information to more selectively and efficaciously prescribe exercises for the rotator cuff and shoulder.

SPL38

PERTURBATION TRAINING AND SECOND ANTERIOR CRUCIATE LIGAMENT INJURY PREVENTION: AN ACL-SPORTS STUDY

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PURPOSE/HYPOTHESIS: Athletes who return to cutting and pivoting sports have a significantly higher risk for a second ACL injury. Female athletes, particularly those under 18 at initial injury, have an even higher risk. While men and women have similar rates of graft rupture, women have higher rates of contralateral injury. Return to sports (RTS) criteria including strength, performance and timing can reduce the risk of second injury by 84%. Perturbation training is thought to improve knee stability through adaptations in neuromuscular control though potentially destabilizing activities. The common elements of the ACL-SPORTS program were so effective (1 injury in 40 male athletes) that the addition of perturbation training could not be assessed in men. We do not know if the addition of perturbation training affects the risk of second injury in female athletes after ACLR. The purpose was to determine if the addition of perturbation training to a second injury prevention program was more effective in reducing second injury rates in female athletes compared to the prevention program alone.

NUMBER OF SUBJECTS: Thirty-nine female athletes who intended to return to cutting and pivoting sports were enrolled 3 to 9 months after primary ACLR. Inclusion criteria included 80% quadriceps index, minimal to no knee effusion, full knee range of motion and initiation of a running program. Athletes were randomized into either progressive strengthening, agility, plyometric and prevention (SAPP) exercises or SAPP plus perturbation training (SAPP+PERT) groups, each had 10 sessions in 5 weeks. All were required to pass RTS criteria: $\geq 90\%$ limb symmetry for quadriceps strength and 4 single leg hops and $\geq 90\%$ on the Knee Outcomes Survey Activities of Daily Living and a single item global rating of perceived knee function; 87% had returned to sport by 1 year, 100% by 2 years.

MATERIALS AND METHODS: The Anterior Cruciate Ligament-Specialized Post-Operative Return to Sports (ACL-SPORTS) program is used in the return to sports phase of ACLR rehabilitation. Occurrence and side of second ACL injury was collected for 2 years after primary ACLR. We compared rate and side of second ACL injury between the 2 groups using chi-square tests.

RESULTS: There were 9 second injuries; an overall second injury rate of 23.1%. There was 1 graft rupture and 4 contralateral injuries in the SAPP group and 3 graft ruptures and 1 contralateral injury in the SAPP+PERT group; this was not statistically different ($P = .77$). While there was only 1 contralateral injury in the SAPP+PERT and 4 contralateral injuries in the SAPP group, this difference was not statistically significant ($P = .25$).

CONCLUSIONS: Overall, the addition of perturbation had no effect on the risk of second injuries in female athletes. However, the 12.8% contralateral injury rate in the sample as a whole is lower than those found by Paterno (24%) and Webster (17%).

CLINICAL RELEVANCE: Ten sessions of SAPP training may have mitigated contralateral injury. SAPP training is easy to implement by coaches and staff in the RTS phase of rehabilitation while waiting to pass 9-month RTS criteria.

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MODIFIABLE PHYSICAL PERFORMANCE MEASURES PREDICTIVE OF SUCCESS IN COMPETITIVE AGING SWIMMERS

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PURPOSE/HYPOTHESIS: The purpose of this study was to identify modifiable physical performance characteristics associated with success in competitive aging swimmers.

NUMBER OF SUBJECTS: One hundred fifty-two (54 male, 98 female).

MATERIALS AND METHODS: Senior athletes registered and competing in swimming events at the National Senior Games between 2011 and 2017 volunteered to participate in this study. All participants signed an IRB-approved informed consent. Physical performance measures included hand grip strength via hydraulic dynamometer, the 5-times sit-to-stand test and goniometric measurement of shoulder flexion active range of motion (AROM). Outcomes of each subject's physical performance measures

were compared to their official race results during the year of testing for all completed events. Pearson's correlations were used to identify relationships between the physical performance measures and event times. Stepwise linear regression was then applied to each event by distance and stroke to determine the best model for predicting success.

RESULTS: Participant average $\pm$ SD age was 70.02 ± 10.15 years. Higher hand grip strength was associated with significantly faster performance times in all swimming events ($P < .005$). Greater shoulder flexion AROM was associated with significantly faster times in all backstroke events as well as the 50-m, 200-m, and 500-m freestyle events ($P < .02$). The 5-times sit-to-stand test was positively correlated to superior performance in all events ($P < .05$) with the exception of the 200-m freestyle. Stepwise models to predict success in freestyle events utilized hand grip strength and the 5-times sit-to-stand test together but found no significant predictive value ($P > .13$). The stepwise models for backstroke events of every distance found shoulder flexion AROM and hand grip strength to be consistent predictors of success with more than 40% of the variance in each model accounted for by these measures ($P < .04$). Stepwise models for breaststroke events of every distance found hand grip strength as the best predictor of success with more than 40% of the variance in each model attributed to hand grip strength alone ($P < .01$).

CONCLUSIONS: Hand grip strength was the most consistent predictor of success for senior athlete swimmers across all events. Shoulder flexion AROM demonstrated additional importance for success with backstroke events. The physical performance measures investigated in this study were unable to predict success in freestyle events though models pointed primarily to variables of strength as potential predictors. These results further support hand grip strength, already known as a "vital sign" in aging adults as a valid indicator of physical ability in aging athletes. These findings may be useful for motivating aging swimmers to increase their efforts toward strength training as a means of finding more success with competition.

CLINICAL RELEVANCE: Competitive aging swimmers interested in improving their performance across all events may benefit from increased strength training, while those focusing on backstroke should also target greater shoulder flexion AROM.

SPL40

MUSCLE STIFFNESS CHANGES IN ATHLETES FOLLOWING ACUTE HAMSTRING INJURY WITH AND WITHOUT EDEMA ON MAGNETIC RESONANCE IMAGING

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PURPOSE/HYPOTHESIS: Numerous classifications have been developed for diagnosis and prognosis of hamstring strain injury (HSI). The presence or absence of edematous findings on magnetic resonance imaging (MRI) are broadly classified as MRI-positive and MRI-negative, respectively. MRI-negative injuries are characterized as focal injuries with increased muscle tone, although characterizing a change in tone has not been objectively determined. Shearwave elastography is an ultrasound (US) imaging technique that characterizes tissue stiffness based on shear-wave speed (SWS) and may provide objective insights into muscle tone with MRI-negative HSI. The purpose of this study was to compare the SWS of injured muscle following acute HSI between individuals with and without edematous findings on MRI.

NUMBER OF SUBJECTS: Seventeen.

MATERIALS AND METHODS: Collegiate athletes diagnosed with a unilateral, acute HSI were included. Standard fluid-sensitive MRI sequences were used to determine the presence of edema. US imaging was performed by a licensed sonographer using an Aixplorer Clinical Scanner with a 50-mm linear array transducer (SL10-2) positioned along the long axis. Subjects were positioned in prone with neutral hip and knee positions. SWS mea-

surements were obtained over the injury site when visible on US or at the point of maximum pain to palpation. The distance from the ischial tuberosity to the injury site was measured and used to find the matching location on the noninjured limb. Three SWS values were taken at each site and the mean was reported for each location. Group results are reported as medians and interquartile ranges (median [Q1-Q3]). Wilcoxon signed-rank test was utilized for within-group comparison between-limbs. Mann-Whitney *U* test was utilized for between group comparisons of SWS.

RESULTS: Nine athletes were classified as MRI-positive (median age, 20 [Q1-Q3, 19-20] years; 9 male), 8 as MRI-negative (age, 20.5 [18-21] years; 6 male). Imaging occurred about 4 days after injury (MRI, 4 [4-6] days; US, 4.5 [3-5] days). The MRI-positive group demonstrated significantly lower SWS ($P = .011$) on the injured limb (1.7 [1.5-1.8] m/s) compared to the noninjured limb (2.0 [2.0-2.2] m/s), whereas the MRI-negative group demonstrated higher SWS ($P = .057$) on the injured limb (2.3 [2.1-2.4] m/s) compared to the noninjured limb (2.0 [2.0-2.1] m/s). Significantly higher SWS was found on the injured limb of the MRI-negative group compared to the MRI-positive group ($P = .002$). No between-group difference in SWS of the noninjured limbs was present ($P = .963$).

CONCLUSIONS: Following acute HSI, athletes with MRI-negative findings demonstrate increased SWS, which is an estimate of muscle stiffness, while athletes with MRI-positive findings have lower SWS values, likely a result of edema.

CLINICAL RELEVANCE: These findings suggest the presence of increased muscle stiffness following an MRI-negative HSI, supporting the clinical observation of increased muscle tone. The differences in SWS between MRI-negative and MRI-positive injuries may be a consideration in developing unique early treatment strategies for each type of injury. Further work is needed to determine if SWS values of the injured limb match the uninjured limb at the time of return to sport.

SPL41

DISTAL FEMUR BONE MINERAL DENSITY DEFICITS PERSIST 2 YEARS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN COLLEGIATE ATHLETES

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PURPOSE/HYPOTHESIS: Reduced bone mineral density (BMD), particularly of the distal femur, has been observed in the involved limb following anterior cruciate ligament reconstruction (ACLR). However, comparison to preinjury values is lacking, as is longitudinal long-term follow-up involving high-level athletes. The purpose of this study was to assess bilateral lower extremity BMD and lean mass (LM) at preinjury, 6, 12, and 24 months post ACLR.

NUMBER OF SUBJECTS: Seventeen Division I collegiate athletes (8 female) who underwent primary, unilateral ACLR surgery (bone-patellar tendon-bone, $n = 15$) were evaluated.

MATERIALS AND METHODS: BMD and LM measures were acquired via full-body dual-energy X-ray absorptiometry scans within 2.83 ± 2.15 months preinjury and at 6, 12, and 24 months post ACLR. Using 2-cm-high regions of interest (ROIs), BMD of both limbs was obtained at 5% (F5), 15% (F15), and 50% (F50) of femur length measured from the intercondylar notch, and at 5% (T5), 15% (T15), and 50% (T50) of tibia length measured from the proximal tibia plateau. LM values were obtained using ROIs of the thigh, pelvis, and lower limb. Linear mixed effects models with random effects for subject and limb were used to assess BMD and LM changes from baseline within the involved and uninjured limb. Interactions between limb and time were tested for each outcome. Tukey-adjusted *P* values assessing differences in least-square means within limb between preinjury and post-ACLR time points are provided.

RESULTS: Athletes returned to sport, on average, 8.7 ± 2.2 months post-ACLR. Prior to ACLR, no between limb differences in BMD or LM were detected at any ROI. Compared to preinjury, BMD of the involved fe-

mur decreased at F5 at 6 months (5.9%, $P < .001$) and at F15 at 6 months (4.0%, $P = .06$), 12 months (6.3%, $P < .001$), and 24 months (7.1%, $P = .001$); no significant differences were detected at F50 at any time point. BMD of the involved tibia was unchanged from preinjury at any ROI or time point. Thigh LM of the involved limb was reduced at 6 months (5.7%, $P < .001$), but not at 12 and 24 months. Pelvis and lower leg LM of the involved limb did not change over time. No significant changes over time were identified in BMD or LM of the uninjured limb except a reduction in T5 BMD at 24 months (7.6%, $P = .04$).

CONCLUSIONS: Following ACLR, distal femur BMD and thigh LM in the involved leg is reduced at 6 months. Despite return of thigh LM, the BMD reduction persists to 24 months post ACLR.

CLINICAL RELEVANCE: This distal femur bone loss may be due to multiple factors including but not limited to the surgical procedure, reduced quadriceps strength, activity reduction, and altered movement strategies. Further, it is possible that this bone loss, and its persistence, might be due to irreversible trabecular loss. These findings may have implications for long-term bone and cartilage health and future injury risk, but longer follow-ups are needed.

SPL42

DYNAMIC EXERTION TEST: FUNCTIONAL ASSESSMENT TO INFORM RETURN TO PLAY FOLLOWING SPORT-RELATED CONCUSSION

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PURPOSE/HYPOTHESIS: A comprehensive approach to inform safe return to play (RTP) postconcussion includes symptom, cognitive, vestibular, ocular, and exertion assessments. Expert consensus advocates for studies of safe exertion evaluations to improve clinical practice. Current protocols emphasize aerobic and exclude dynamic exertion, which perturb vestibular and oculomotor systems often affected by concussion. We recently developed the Dynamic Exertional Test (EXiT), which addresses both aerobic and dynamic exertion for RTP. The primary goal of this platform is to describe the components of EXiT and present preliminary data for pass and fail attempts on EXiT.

NUMBER OF SUBJECTS: Nineteen post-SRC males and females, aged 14 to 35 years, met ACSM's guidelines for regular aerobic activity, with a diagnosed sport-related concussion (SRC) ≤ 14 days of injury, and cleared to RTP by a clinician.

MATERIALS AND METHODS: Participants provided demographics, medical history, and completed Generalized Anxiety Disorder 7-item (GAD-7), Patient Health Questionnaire (PHQ-9) and EXiT assessment at RTP evaluation. EXiT is a 30-minute exertion assessment designed to evaluate aerobic, dynamic and functional movement to inform RTP. Heart rate (HR), rating of perceived exertion (RPE) on Borg scale and headache, dizziness and nausea are reported before, during and after testing. Aerobic component includes a 12-minute treadmill protocol at 70% to 89% HRmax. Dynamic circuit includes functional movements with emphasis on visual fixation: ball toss, box drills, zig-zag drill, pro agility run, and arrow agility tasks, which combine rapid directional changes and cognitive tasks. 30 seconds of rest after each component for symptom report, RPE, and HR.

RESULTS: Nineteen recently concussed patients completed the EXiT assessment at the RTP evaluation. Two patients who failed initial test and subsequently passed are the focus of this platform. Subject 1 (fail) visit: PHQ-9 1, GAD-7 5, BP pre 130/78 mmHg, BP post 122/72 mmHg, RPE at failure 17, symptom report at failure 7/10 nausea; And at clearance (pass) visit: PHQ-9 0, GAD-7 0, BP pre 110/66 mmHg, BP post 98/60 mmHg, RPE at finish 14, and asymptomatic. Subject 2 (fail) visit: PHQ-9 9, GAD-7 4, BP pre 130/78 mmHg, BP post 122/72 mmHg, RPE at failure 15, symptom report at failure 8/10 dizziness; And at clearance (pass) visit: PHQ-9 2, GAD-7 3, BP pre 110/66 mmHg, BP post 98/60 mmHg, RPE at finish 12, and asymptomatic.

CONCLUSIONS: Dynamic exertion components of the EXiT elicited symptoms in asymptomatic athletes with persistent dysautonomia and mood dysregulation. This preliminary evidence suggests that the EXiT may address a current gap in exertion assessments to better inform RTP.

CLINICAL RELEVANCE: One of the most significant challenges in managing SRC is determining safe RTP. Current approaches are predicated on symptom free status and emphasize aerobic-based exertion. The EXiT focuses on symptoms, tolerance to aerobic, dynamic, and functional activity.

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OPTIMIZING LOAD DOSAGE USING REPETITIONS IN RESERVE: A CASE STUDY OF A RUNNER WITH ACHILLES TENDINOPATHY

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BACKGROUND AND PURPOSE: Clinical practice guidelines strongly recommend strength training for the treatment of Achilles tendinopathy. Traditionally, strength training loads are based upon a percentage of 1-repetition maximum, though many injured patients are unable to tolerate this testing. This study aims to assess the feasibility and efficacy of using repetitions in reserve (RIR) to dose strength training load for Achilles tendinopathy.

CASE DESCRIPTION: One male long-distance runner (47 years old) who 3 months prior noted increased pain and stiffness in the mid-portion of his right Achilles tendon that prevented him from running. Treatment included calf stretching, isometric heel raises, progressive heavy slow resistance strengthening, and hip stability exercises. During strengthening exercises, the patient was instructed to maintain an RIR ≤ 3 . The load was progressed unless the patient reported an increase of Achilles pain from baseline of at least 3 points on a numeric pain-rating scale (NPRS). A walk/running protocol was introduced: 3 to 5 mi/wk, 5% to 10% increase in cadence, and adherence to pain guidelines (pain scale ≤ 3 , no limping, no pain the next day). A home exercise program (HEP) was prescribed with the same RIR and pain guidelines to be completed 3 times a week. A home exercise log was used to monitor compliance and exercise progression. Adverse events (increase pain $>3/10$ over baseline, persistent pain lasting more than 24 hours, and limping) were monitored during physical therapy and HEP. Outcomes included the Lower Extremity Functional Scale (LEFS), Tampa Scale of Kinesiophobia (TSK-11), NPRS during activities, dorsiflexion range of motion during standing lunge test, single leg heel raises, and GPS-tracked weekly running mileage. These measures were taken at baseline, discharge, and 24 weeks.

OUTCOMES: The patient completed 8 formal physical therapy sessions over 6 weeks. HEP compliance was 89% during physical therapy, and 88% after discharge. No adverse events were reported. LEFS score increased from 83.75% at baseline to 86.25% at discharge, to 96.25% at 24 weeks. TSK-11 score was stable between baseline and discharge (22 points at both time points), but decreased to 16 points at 24 weeks. Dorsiflexion during standing lunge test increased from 31° at baseline to 37° at discharge, to 40° at 24 weeks. Single-leg heel raises increased from 15 with 4/10 pain at baseline to 25 at discharge with 2/10 pain, to 30 pain free at 24 weeks. NPRS during activities decreased from 6/10 at baseline to 3/10 at discharge, to 2/10 at 24 weeks. Weekly running mileage was 16.85 miles at baseline and increased to 26.1 miles at 24 weeks.

DISCUSSION: A structured progressive strengthening approach based on RIR and pain management guidelines may be useful to ensure appropriate workload intensity during physical therapy sessions and HEP, while minimizing adverse events. Compliant patients may use RIR to self-manage their training workload based on day-to-day variation in symptoms and load tolerance, further enhancing independence.

SPL44

MOVEMENT PATTERNS DIFFER BETWEEN ATHLETES AND CONTROLS AFTER SPORT-RELATED CONCUSSION DURING A JUMP-LANDING TASK

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PURPOSE/HYPOTHESIS: A relationship between a positive history of sport-related concussion (SRC) and lower extremity (LE) injury has been well established in the literature, however, the mechanism of this relationship is still unknown. The purpose of this study was to determine if biomechanical differences exist during a double limb jump landing (DLJ) between athletes who have returned to play after SRC and healthy matched controls (Healthy).

NUMBER OF SUBJECTS: Thirty-three athletes who were 51.8 ± 62.6 days out from being released to sport after SRC and 178.5 ± 267.0 days out from initial SRC injury (mean $\pm$ SD age, 15.5 ± 2.2 years; height, 168.6 ± 8.4 cm; mass, 64.2 ± 11.6 kg; 9.6 ± 5.2 h/wk) were compared to 33 age, sex, activity-matched healthy controls (age, 15.5 ± 2.2 years; height, 169.6 ± 10.8 cm; mass, 65.0 ± 14.6 kg; 11.5 ± 7.1 h/wk). Both groups had equal representation of single (SRC, 23; healthy, 22) and multisport athletes (SRC, 10; healthy, 11). No significant differences existed between groups for descriptive data.

MATERIALS AND METHODS: Biomechanical performance during DLJ was assessed using an 8-camera Qualisys Motion Capture System and 2 AMTI force plates. The average of 5 consecutive trials was used to calculate lower extremity joint kinematics. Joint angles were examined in the frontal plane at initial contact (IC) and for peak displacement (PD) of the landing phase of the maneuver. The difference between IC and PD was used to calculate the total frontal plane displacement (TD). The vertical ground reaction force (vGRF) for each limb was also collected. All measurements were collected bilaterally and limb dominance was defined prior to testing. Independent *t* tests were performed to examine the differences between SRC and Healthy groups for vGRF, joint angles at IC, and TD in the frontal plane during the DLJ. Separate chi-square tests were used to determine if differences exist between groups in terms of single versus multisport athletes. Alpha level was set at $P < .05$ for all statistical analyses.

RESULTS: The SRC group demonstrated a significantly lower knee angle (increased valgus) in both limbs at IC in the frontal plane compared to healthy group (SRC_DOM, -5.02 ± 4.55 ; Healthy_DOM, -2.76 ± 4.61 ; $P = .049$; NonDOM, -4.18 ± 3.61 ; Healthy_NonDOM, -1.67 ± 3.51 ; $P = .006$). No differences were found between the SRC and Healthy groups in either limbs for peak vGRF (SRC_DOM, 3.03 ± 0.82 ; Healthy_DOM, 2.82 ± 0.76 ; $P = .29$; NonDOM, 2.93 ± 0.75 ; Healthy_NonDOM, 2.59 ± 0.79 ; $P = .078$), nor TD (SRC_DOM, -5.73 ± 3.30 ; Healthy_DOM, -4.83 ± 3.67 ; $P = .30$; NonDOM, -4.81 ± 3.12 ; Healthy_NonDOM, -4.19 ± 3.10 ; $P = .43$).

CONCLUSIONS: Athletes who have returned to sport after SRC land in greater knee valgus compared to healthy matched controls.

CLINICAL RELEVANCE: As further evidence continues to emerge about the positive relationship between history of concussion and the presence of LE injury up to 1 year after initial injury, biomechanical analysis can be used to give insight into the possible mechanisms of these relationships. Athletes with prior history of SRC demonstrate increased knee valgus bilaterally during a double limb jump landing task.

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ALTERED KNEE JOINT LOADING IN THOSE WHO FAIL RETURN-TO-SPORT CRITERIA AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Altered landing biomechanics are observed in young athletes following anterior cruciate ligament reconstruction (ACLR). It is currently unknown if landing biomechanics differ between young athletes who pass published return-to-sport (RTS) criteria compared to those who do not. The primary purpose was to test the hypothesis that young athletes who pass RTS criteria after ACLR would demonstrate more symmetrical landing mechanics compared to those who do not.

NUMBER OF SUBJECTS: One hundred nineteen young athletes (72% female; mean $\pm$ SD age, 17.4 ± 2.7 years) enrolled at the time of medical RTS clearance after primary, unilateral ACLR (8.2 ± 2.1 months post ACLR).

MATERIALS AND METHODS: Participants were tested within 4 weeks of medical RTS clearance that included quadriceps strength assessment, a single-leg hop test battery, completion of the International Knee Documentation Committee (IKDC) outcome measure, and 3-dimensional motion analysis. Participants were categorized as passing RTS criteria (PASS) if they met $>90\%$ limb symmetry on quadriceps isokinetic strength and the hop test battery, and scored >90 on the IKDC; and as failing RTS criteria (FAIL) if any criteria were not met. Kinematic, kinetic, and ground reaction force variables of interest were calculated during the landing phase of double-leg drop vertical jump (DVJ) and single-leg drop-landing (SLL) tasks: knee flexion excursion (KFE) during landing, peak knee internal extension moment (KEM; Nm/kg), peak knee abduction moment (Nm/kg), hip external rotation impulse (Nm-s/kg), and peak vertical ground reaction force (GRF; N/kg). For each variable, limb values and limb symmetry indices (LSI; percent) were calculated and compared between the PASS and FAIL groups using independent-samples t tests ($\alpha \leq .05$).

RESULTS: Twenty-four (20.2%) participants were in the PASS group and 95 (79.8%) in the FAIL group, with no group differences in demographics (all, $P > .05$) or time post-ACLR ($P = .178$). During the DVJ task, the FAIL group demonstrated lower involved limb KFE (59.1° versus 64.9° , $P = .008$), and lower symmetry on KFE LSI (94.5% versus 101% , $P = .004$), KEM LSI (76.5% versus 93.3% , $P = .002$), and GRF LSI (83.0% versus 96.5% , $P = .002$) compared to the PASS group. During the SLL task, the FAIL group demonstrated lower involved limb KFE (42.9° versus 49.7° , $P = .002$), lower symmetry on KFE LSI (87.8% versus 96.9% , $P = .011$), and lower involved limb KEM (2.16 versus 2.42 Nm/kg, $P = .046$), and KEM LSI (93.4% versus 80.29% , $P = .007$) compared to the PASS group.

CONCLUSIONS: Young athletes following ACLR who passed RTS criteria demonstrated more symmetrical sagittal plane loading of the involved knee during drop-landing tasks. No differences were found in frontal or transverse plane variables of interest.

CLINICAL RELEVANCE: Ensuring athletes have sufficient strength and function to meet RTS criteria appears to be associated with improved knee joint loading at RTS. Future research should attempt to understand the interactions among meeting RTS criteria, movement patterns, and long-term outcomes after ACLR.

SPL46

ASSESSMENT OF RESTORATION OF MUSCULAR PERFORMANCE FOLLOWING SHOULDER STABILIZATION SURGERY

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PURPOSE/HYPOTHESIS: Arthroscopic shoulder stabilization has been shown to reduce subsequent instability and result in excellent clinical outcomes. However, generally only 65% achieve preinjury levels of sport participation after stabilization. Often nonmodifiable and surgical factors are reported as the cause for the inability to return to preinjury levels of sports participation. However, it is also likely modifiable factors related to progress with postoperative rehabilitation and residual physical deficits contribute to the low return to preinjury level of sports rate. Frequently, return to sports clearance is provided 6 months after surgical shoulder stabilization. The purpose of this study was to investigate the physical status of patients 6 months after shoulder stabilization surgery. We hypothesized there would be residual deficits in strength, function, and endurance testing compared to the uninjured upper extremity and population norms.

NUMBER OF SUBJECTS: Forty-eight competitive and recreational athletes (38 male, 10 female) who had undergone shoulder stabilization surgery.

MATERIALS AND METHODS: Participants completed a battery of tests and measures in conjunction with their 6-month postoperative follow-up visit

with their physician. The battery of measures included self-reported functional level using the Subjective Shoulder Value (SSV), scaled 0% to 100% with 100% representing an entirely normal shoulder, the Brophy Activity Rating Scale (Brophy), isometric and isokinetic strength assessments, repetition to failure endurance testing, and completion of the Closed Kinetic Chain Upper Extremity Test (CKCUE) and the unilateral shotput test. All values were summarized using frequencies and percentages for nominal data and means $\pm$ SD (or median, interquartile range) for continuous data. Comparisons were made to the contralateral, noninjured side to assess for symmetry using paired t tests or its nonparametric equivalent. Additionally, symmetry was dichotomized as either being achieved ($\geq 90\%$) or failed ($< 90\%$) for unilateral tasks.

RESULTS: The self-reported Brophy prior to injury was 15/20 (13-17). At the time of testing, the Brophy was reported to be 13/20 (8-15) and the SSV was $88.7\% \pm 12.8\%$. Maximum isometric internal rotation (IR) at 90° abduction was significantly increased in the involved arm ($P = .02$) compared to the uninvolved arm, with no other motions showing significant side-to-side differences. However, 31.6%, 35.1%, 23.7%, and 13.9% failed to reach 90% symmetry to the uninjured side with external rotation (ER) at 0° abduction, ER at 90° abduction, IR at 0° abduction, and IR at 90° abduction, respectively. Peak torque with isokinetic testing was significantly lower in the involved arm with ER at $60^\circ/s$ ($P < .01$) and at $180^\circ/s$ ($P = .01$), as well as IR at $60^\circ/s$ ($P < .01$). Failure to achieve 90% bilateral symmetry was seen in 50.0%, 53.7%, 40.0%, and 34.1% of patients for ER at $60^\circ/s$, ER at $180^\circ/s$, IR at $60^\circ/s$, and IR at $180^\circ/s$, respectively. There were no significant difference with endurance testing using repetition to failure procedures for the posterior rotator cuff with ER at 0° and ER at 90° ($P > .4$). Nevertheless, 23.8% (ER at 0°) and 29.3% (ER at 90°) of patients were unable to achieve 90% symmetry to the uninjured side. The mean number of touches with the CKCUE test was 23.4 ± 3.6 , with 25.6% unable to achieve the goal of ≥ 21 touches. There were no significant differences in the distance achieved with the Unilateral Shot Put test ($P = .7$), and when considering hand dominance, only 4.7% were unable to achieve the expected level of symmetry.

CONCLUSIONS: Despite relatively high levels of self-reported function, the results suggest isolated strength deficits remain, especially in the posterior rotator cuff. When specifically examining the posterior shoulder musculature, 23% to 54% of patients tested where unable to achieve 90% symmetry with strength or endurance testing. With the exception of the Unilateral Shot Put, all methods were able to detect high rates of failure to achieve expected levels of strength or function. Isokinetic testing was the most discriminate at detecting isolated weakness and failure to achieve 90% symmetry.

CLINICAL RELEVANCE: The inability to return to preinjury levels of sport participation at the usual time of medical clearance is a multifactorial issue. Likely contributing to lack of readiness to return is the isolated weakness and deficits in the shoulder identified with common strength, endurance, and functional tests. Identification of such deficits can allow the clinician to direct interventions specifically aimed to abolish remaining shortfalls and best prepare their patient for a return to their desired sports activity.

SPL47

THE IMPACT OF FOOT ARCH CHARACTERISTICS ON CADENCE AND RUNNING MECHANICS IN YOUTH RUNNERS

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PURPOSE/HYPOTHESIS: The arch height index (AHI) is a valid and reliable method for assessing foot structure and deformation in adults and pediatrics. Previous literature reports static foot structure is predictive of dynamic foot arch motion and running mechanics in adults, but is inconclusive in pediatrics. The purpose of this study is to investigate the relationship between foot arch characteristics and running mechanics in youth runners.

NUMBER OF SUBJECTS: One hundred twenty-two (44 male, 78 female; mean $\pm$ SD age, 13.5 $\pm$ 2.7 years).

MATERIALS AND METHODS: Static foot posture, assessed using the seated AHI, was classified as planus, rectus, or cavus. Subjects then underwent 3-D motion analysis while running on a treadmill at a self-selected speed. Arch deformation (AD) calculated as the difference between seated and standing AHI, was classified as rigid, normal, or flexible. Static foot posture and AD classifications were determined based on a percentage of the range of cohort values of the seated AHI and AD values added to the minimum cohort values, respectively (planus and rigid, 0% to 40%; rectus and normal, 40% to 60%; cavus and flexible, 60% to 100%). The cohort was stratified to identify 16 planus/rigid (PR) and 22 cavus/flexible (CF) feet. Unpaired *t* tests ($P < .05$) were performed to compare temporal-spatial (TSP) and kinematic parameters (peak and average joint positions during stance phase) between the PR and CF groups.

RESULTS: TSP analysis revealed significant differences between cadence (PR, 162.1 $\pm$ 12.6 steps/min; CF, 174.0 $\pm$ 8.6 steps/min; $P < .01$) and stance duration (PR, 46.6% $\pm$ 7.1%; CF, 42.4% $\pm$ 3.7%; $P = .02$). No significant differences were found between self-selected running velocity or stride length. Kinematic analysis revealed significant differences in peak hip flexion (PR, 34.3° $\pm$ 5.4°; CF, 38.4° $\pm$ 5.4°; $P = .02$), average hip flexion position (PR, 17.3° $\pm$ 5.8°; CF, 21.0° $\pm$ 4.9°; $P = .04$), and peak knee extension (PR, -7.3° $\pm$ 3.8°; CF, -9.8° $\pm$ 3.2°; $P = .03$). No significant differences were found in foot progression angle or ankle kinematics.

CONCLUSIONS: Youth runners with PR feet demonstrated lower cadence and greater stance duration, than youth runners with CF feet. The PR group exhibited lower peak hip flexion and average hip flexion position, but greater knee extension than the CF group.

CLINICAL RELEVANCE: To our knowledge, this is the first report to measure the association between foot arch mobility and running mechanics in healthy youth runners. PR feet demonstrated reduced cadence and increased peak knee extension during stance compared to CF feet. Reduced cadence is associated with greater incidence of shin injury in high school runners. Increased knee extension is associated with Achilles tendon pain in adult runners. Our results suggest running retraining should be considered to decrease injury risk for runners with PR feet. Further prospective research is warranted to assess the effects of foot structure and arch deformation on running biomechanics, injury, and performance in youth runners.

SPL48

COMPARISON OF ADVANCED TRAINING OR TIME ALONE ON FUNCTIONAL AND PSYCHOLOGICAL OUTCOMES AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Adam Stephen Meierbachtol, Michael Obermeier, William Yungtum, Eric Roman Paur, John William Bottoms, Bradley Nelson, Marc Tompkins, Terese Lynn Chmielewski

PURPOSE/HYPOTHESIS: Advanced training is recommended to prepare patients with anterior cruciate ligament reconstruction (ACLR) for a return to sport. The benefit of advanced training compared to time alone is unknown. The purpose was to compare functional and psychological outcomes between patients that did or did not complete advanced training after ACLR. The hypothesis was that functional and psychological measures would improve more in those that completed advanced training.

NUMBER OF SUBJECTS: Subjects were 32 patients with a primary ACLR who were at least 5 months post-surgery and discharged from rehabilitation; 16 voluntarily completed advanced training (TRAIN; 5 male; mean age, 18.6 years) and 16 did not (NoTRAIN; 5 male; mean age, 19.6 years).

MATERIALS AND METHODS: TRAIN participated in a 5-week (10-session) group-format program comprised of jumping, agility and strengthening exercises. NoTRAIN was allowed to return to sport without supervised training. Baseline and follow-up testing were pretraining and posttraining in TRAIN and at equivalent time points in NoTRAIN. Demographic

variables were age, sex, injury mechanism and autograft type. Functional measures were single-leg hop tests: single, triple, crossover triple, and timed hops. A limb symmetry index was calculated by normalizing surgical side scores to nonsurgical side scores and expressing as a percentage. Psychological measures were Anterior Cruciate Ligament Return to Sports after Injury (ACL-RSI) for psychological readiness for sport; Tampa Scale of Kinesiophobia (TSK-11) for kinesiophobia, and Knee Activity Self Efficacy (KASE) for confidence in the knee during sport activity. Demographic variables were compared between groups. Separate mixed-model ANOVAs (group by time) were computed for each functional and psychological measure. Effect size (Cohen's *d*) of the change between groups was calculated for models with $P \leq .1$.

RESULTS: Groups did not differ on demographic variables ($P > .05$) nor baseline (TRAIN, 5.7 $\pm$ 0.8; NoTRAIN, 6.2 $\pm$ 0.7 months) or follow-up testing (TRAIN, 6.2 $\pm$ 0.7; NoTRAIN, 7.9 $\pm$ 0.7 months) time points. Group-by-time interaction was significant for single hop (TRAIN, 91 $\pm$ 5 to 94 $\pm$ 6; NoTRAIN, 92 $\pm$ 11 to 89 $\pm$ 12; $P = .045$; effect size, 0.74), with improvement only in TRAIN. Main effect of time was significant for triple hop (TRAIN, 91 $\pm$ 6 to 96 $\pm$ 4; NoTRAIN, 88 $\pm$ 13 to 91 $\pm$ 10), ACL-RSI (TRAIN, 63.2 $\pm$ 16.2 to 77.2 $\pm$ 13.7; NoTRAIN, 64.6 $\pm$ 23.9 to 77.8 $\pm$ 19.2), TSK-11 (TRAIN, 20.6 $\pm$ 4.3 to 17.9 $\pm$ 4.6; NoTRAIN, 19.0 $\pm$ 4.8 to 18.6 $\pm$ 3.8; effect size, 0.57) and KASE (TRAIN, 83.8 $\pm$ 10.5 to 93.2 $\pm$ 7.2; NoTRAIN, 84.1 $\pm$ 11.4 to 88.7 $\pm$ 8.0; effect size, 0.59).

CONCLUSIONS: Single-leg hop symmetry improved more with advanced training than time alone. Triple hop symmetry and all psychological measures improved over time, with a medium effect size for kinesiophobia and confidence in the knee.

CLINICAL RELEVANCE: Altered rehabilitation or more time may be needed to optimize functional and psychological readiness for sport after ACL reconstruction. Advanced training focused on plyometric and strengthening exercise improves single-leg hop performance and may have additional benefit for decreasing kinesiophobia and increasing confidence in the knee.

SPL49

FINGER GROWTH PLATE INJURIES IN ELITE ADOLESCENT ROCK CLIMBERS

Rachel Meyers, Steven Hobbs, David R. Howell, Aaron Provance

PURPOSE/HYPOTHESIS: With the inclusion of rock climbing in the 2020 Olympics, the number of adolescent competitors is on the rise. Finger growth plate injuries have been reported as the most common injuries among youth climbers. Prior studies have not examined the perceptions of adolescent climbers about youth-specific climbing injuries or the association between finger growth plate injuries and speed climbing, a mandatory discipline in the 2020 Olympics. The purpose of this study was to examine the awareness, perceptions, and training practices of youth specific climbing injuries and risk factors amongst elite, adolescent rock climbers.

NUMBER OF SUBJECTS: Two hundred sixty-seven youth climbers, aged 8 to 18 years, who competed in the 2017 USA Climbing Sport and Speed Youth National Championships (mean $\pm$ SD age, 14 $\pm$ 2.7 years; 52% male).

MATERIALS AND METHODS: Participants answered survey questions during athlete registration regarding their awareness of the most common youth climbing injury and safe training practices. Chi-square tests were used as omnibus tests for multiple comparisons and equality tests for 2-sample proportions. A Fisher's exact test was used to determine if training regularly on the International Federation of Sport Climbing speed wall was associated with a history of finger growth plate injuries.

RESULTS: The adult-specific A2 pulley injury was reported to be the most common youth climbing injury, 36%, with an average $\pm$ SD ranking of 3.09 $\pm$ 2.20 on a scale of 1 (most common) to 8 (least common). The second most commonly identified injury was a finger growth plate injury, 15%, with an average ranking of 4.0 $\pm$ 2.22, $P < .001$. Six percent of climbers accurately reported the safe age to start double dyno camping, a previously

established risk factor for finger growth plate injuries. Seventy-four percent overall reported finger growth plate injuries to either be a type of pulley injury or did not know. Finger growth plate injuries were significantly more common among adolescent climbers who trained regularly on the speed wall (adjusted odds ratio = 3.95; 95% CI: 1.14, 13.7; $P = .031$). Additionally, the group who reported a history of finger growth plate injuries reported 28% of the year speed climbing, which is less than an entire speed climbing season in the United States.

CONCLUSIONS: Misperceptions about skeletally immature climbing injuries and safe training practices are prevalent amongst youth climbers. Additionally, training regularly on the speed wall appears to be associated with a history of finger growth plate injuries. As climbing enters the 2020 Olympics, addressing misperceptions may help athletes, parents, and coaches understand the risk for finger growth plate injuries and guide adolescent climbers and parents to seek medical attention when appropriate. This study shows the need for education about youth-specific climbing injuries to reduce the incidence of finger growth plate injuries and the potential for permanent finger deformity and loss of function.

CLINICAL RELEVANCE: Educating medical professionals about the prevalence and risks of finger growth plate injuries and the scarcity of A2 pulley injuries in youth climbers may increase diagnostic accuracy, improve care, and reduce long-term complications.

SPL50

JUMP-LANDING MECHANICS FAIL TO DISTINGUISH PATIENTS' RETURN-TO-SPORT STATUS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Ryan L. Mizner, Audrey Rose Campbell Elias

PURPOSE/HYPOTHESIS: Nearly all patients who undergo ACL reconstruction anticipate a return to their preinjury level of sports participation, but only two thirds will ultimately meet this expectation. Psychological distress, such as fear of reinjury, has been the most telling factor that distinguishes patients' return to sport status. Poor jump landing mechanics have been linked with an increased reinjury risk and are often present as patients return to sport. Yet, how landing mechanics may associate with an athlete's decision to return to sport remains unclear. We propose that patients who return to their preinjury level of sports participation will have better jump landing mechanics compared to those do not.

NUMBER OF SUBJECTS: Eighty patients who had unilateral ACL reconstruction 6 to 48 months (22 ± 14 months) prior completed testing, grouped by whether they lowered or kept the same sports participation (Tegner Activity Score) after surgery.

MATERIALS AND METHODS: Patient-reported function and sports participation were determined via the IKDC survey and the Tegner Scale, while the ACL-RSI survey assessed psychological readiness for sport. Limb symmetry indices were calculated as a percentage of the uninvolved for isometric quadriceps strength, single-leg hop for distance (SLHD), and peak knee extension moment in a drop vertical jump (DVJ) and a single-leg landing (SLL) assessed via 3-D motion analysis as a measure of landing mechanics. Differences between groups were assessed using independent t tests.

RESULTS: Fifty-five percent of the cohort lowered their Tegner score following surgery (Pre, 8.6 ± 1.0 ; Post, 6.5 ± 1.4) and 45% kept at least the same score (Pre, 7.9 ± 1.8 ; Post, 7.9 ± 1.8). There were no differences ($P > .05$) between groups in age (23 ± 5 years versus 21 ± 5 years), BMI (25 ± 3 versus 25 ± 4 kg/m²), IKDC (82 ± 12 versus 83 ± 11), quadriceps strength (89 ± 16 versus 89 ± 14), SLHD (94 ± 9 versus 94 ± 9), or knee extensor moment for both DVJ (87 ± 18 versus 86 ± 17) and SLL (85 ± 16 versus 87 ± 17). Only ACL-RSI scores were different between groups, with the group with lowered sports participation having a lower score (59 ± 22 versus 70 ± 17 , $P = .016$).

CONCLUSIONS: Deficits in jump landing mechanics were substantial, yet do not differ based on patients return to a preinjury sport status. Patients' level of psychological distress is more strongly associated with a return to preinjury level of sports than other clinical measures.

CLINICAL RELEVANCE: The increased exposure to high-risk movements when returning to preinjury sports is not accompanied by corresponding improvements in jump landing mechanics; indeed, return to preinjury sport is unrelated to jump landing mechanics. Many patients have a psychological state to support their return to high demand sports, but they do so with landing mechanics that could increase their injury risk. In addition, landing deficits may not be adequately captured in exam and/or the stakeholders who help make return to sport decisions may not be aware of the degree of residual deficits.

SPL51

PROSPECTIVE VALIDATION AND RESPONSIVENESS OF THE UNIVERSITY OF WISCONSIN RUNNING INJURY AND RECOVERY INDEX

Evan Othmer Nelson, Stephanie Kliethermes, Bryan C. Heiderscheit

PURPOSE/HYPOTHESIS: The University of Wisconsin Running Injury and Recovery Index (UWRI) is the first patient-reported outcome measure (PRO) to assess running ability following running-related injury (RRI), demonstrating excellent reliability (ICC agreement = 0.93). By incorporating the multiple internal, external, or psychological factors influencing RRI recovery, the UWRI enables the magnitude of recovery or treatment response to be quantified during clinical assessments and research studies. The purpose of this prospective study was to analyze the validity and responsiveness of the UWRI as an evaluative PRO.

NUMBER OF SUBJECTS: Three hundred ninety-six participants (62.1% female; mean $\pm$ SD age, 34.5 ± 12.4 years; running experience, 12.7 ± 10.4 years; 98.5% recreational or competitive runners).

MATERIALS AND METHODS: Runners seeking care from a physical therapist for an RRI electronically completed PROs at the initial evaluation and 12 weeks later. UWRI change was validated against the global rating of change (GROC), VR-12 change, and change in body region PROs. Responsiveness was evaluated with anchor-based and distribution-based techniques. t tests evaluated differences in continuous variables and Pearson correlation coefficients were used to assess the strength of association.

RESULTS: UWRI change (7.7 ± 9.0 ; paired t test, $P < .001$) was correlated with GROC ($r = 0.67$; 95% CI: 0.57, 0.75; $P < .001$), as well as the changes in VR-12 physical component score (PCS) ($r = 0.54$; 95% CI: 0.42, 0.64; $P < .001$) and mental component score (MCS) ($r = 0.31$; 95% CI: 0.16, 0.44; $P < .001$). UWRI change was correlated with changes in the sport subscale of Foot and Ankle Ability Measure ($r = 0.75$; 95% CI: 0.63, 0.84; $P < .001$), 12-item international hip outcome tool ($r = 0.75$; 95% CI: 0.55, 0.87; $P < .001$), and anterior knee pain scale ($r = 0.48$; 95% CI: 0.21, 0.68; $P = .001$), but not associated with the Oswestry Disability Index 2.0 ($r = 0.05$; 95% CI: 0.57, 0.63; $P = .89$). The UWRI effect size was 1.15, standardized response mean difference was 0.87, responsiveness index was 1.33, minimal detectable change 95% CI was 4.75, and ceiling or floor effects were not present. UWRI change was significantly different in runners reporting significant improvement (12.2 ± 5.9), slight improvement (7.1 ± 6.6), no change (0.0 ± 9.1), and worsening (14.6 ± 7.4) on the GROC. The UWRI minimal detectable change 95% CI was 5 points and the minimal clinical important difference was 8 points.

CONCLUSIONS: The UWRI demonstrated longitudinal validity (GROC), convergent validity (PCS and body regions PROs), and divergent validity (MCS), as well as excellent internal and external responsiveness. The UWRI displayed excellent psychometric integrity and the ability to differentiate graduated levels of running ability during RRI recovery.

CLINICAL RELEVANCE: The UWRI is the only PRO validated in a population of individuals seeking care for a RRI. The UWRI is responsive to changes in running ability, enabling the comparison of patient-perceived ability with objective measures of training load or biomechanical assessments. Novice and professional runners should be targeted during future psychometric assessments.

SPL52

POSTCONCUSSION SYMPTOMS: CAN WE REHABILITATE SMARTER WITH HEART RATE VARIABILITY?

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PURPOSE/HYPOTHESIS: Sport-related concussions are complex pathophysiological disturbances to the brain caused by biomechanical forces. Persistent symptoms can complicate recovery and result in postconcussive syndrome. Rehabilitation is challenging due to variable symptoms and athletes' individualized responses to interventions (eg, graded exercise). Autonomic nervous system (ANS) dysfunction has been linked with concussion pathophysiology. Heart rate variability (HRV) is a noninvasive index of the ANS outflow at the heart and is used to monitor the body's physiological response to stressors. The aim of this study is to systematically review literature that investigates the relationship between ANS function indexed by HRV in subjects with a history of concussion.

NUMBER OF SUBJECTS: Primary research studies that measured HRV as a primary outcome measure in adults (≥ 18 years of age) with a history of concussion or mild traumatic brain injury (TBI).

MATERIALS AND METHODS: A comprehensive search strategy was developed and a systematic search was performed in the following databases from 1996 to June 26, 2019: CINAHL, SPORTDiscus, PubMed (MEDLINE), SCOPUS, PEDro, and Cochrane. The inclusion criteria were: (1) studies that monitored HRV in subjects with postconcussive symptoms; (2) studies on human subjects; (3) studies in the English language. Studies on unconscious subjects or those with moderate to severe TBI were excluded. Two independent reviewers (ASG, FP) screened the titles and abstracts of the records for inclusion eligibility. Full texts were pulled for all records assigned as "included" and data were extracted.

RESULTS: Final search yielded 1293 references and following duplicate removal, screening was performed on 955 references. Thirty-six full texts were retrieved, 2 were excluded from synthesis leaving 34 included studies. Preliminary analysis demonstrated patterns of ANS dysfunction indexed by reduction of parasympathetic HRV indices at rest and during exercise in subjects with a history of concussion or mild TBI. Measured HRV anomalies were present after acute concussion and in subjects with PCS.

CONCLUSIONS: Preliminary results appear to indicate that subjects with concussion demonstrate impaired ANS function indexed by reductions in HRV compared with healthy controls. Alterations in HRV are present at the onset of concussion but seem to also persist alongside prolonged symptoms due to concussion. Decrements in HRV parameters may signify a reduction in parasympathetic control and the body's inflexible, slowed recovery from concussion.

CLINICAL RELEVANCE: Subjective reports of postconcussion symptoms can be insufficient for monitoring an athlete's tolerance to progression of rehabilitation and return to sport protocols. The ANS holds an integral and adaptive role in directing the body's response to stressors like concussion injury. Results from this study suggest that monitoring changes in HRV may provide important information to help guide concussion rehabilitation.

SPL53

LANDING KINEMATICS, HOP TESTING, AND PATIENT-REPORTED OUTCOMES PREDICT SUCCESS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Current return-to-sport (RTS) tools fail to consistently identify successful outcomes after ACL reconstruction (ACLR). The purpose of this study was to identify a novel RTS tool that would identify patients at risk for future ACL injury in the 24 months after RTS or the inability to maintain preinjury level of activity for 1 year after RTS. The

tested hypothesis was that a novel combination of RTS measures would successfully identify patients at risk for future ACL injury and/or inability to return to preinjury level of activity.

NUMBER OF SUBJECTS: Seventy-five athletes (54 female; mean $\pm$ SD age, 16.8 ± 2.1 years; range, 13-23 years) after ACLR recently medically cleared to RTS.

MATERIALS AND METHODS: Patients completed a RTS assessment including strength, functional performance testing, patient reported outcome measures, and 3-D kinematic assessment of the single-leg hop for distance (SLHD) landing technique. Failure was defined as <90 on their PRO score and $<90\%$ limb symmetry (LSI) on strength and functional performance testing. Hip flexion excursion during the landing phase of the SLHD was quantified and patients were classified as failing if they presented with $>22^\circ$ of sagittal plane hip excursion during landing. Participants were tracked for 24 months after RTS to identify unsuccessful outcomes, defined as a second ACL injury or an inability to maintain preinjury level of activity (Tegner Activity Scale). Chi-square analyses were used to identify association between failing to meet individual RTS measures or clusters of RTS measures and unsuccessful outcomes.

RESULTS: Twenty percent ($n = 15$) suffered a second ACL injury and 52% ($n = 39$) were also unable to maintain their preinjury level of activity for 12 months after RTS. Patients who suffered a second ACL injury were younger (15.7 ± 1.6 years) than those who did not suffer a second ACL injury (17.1 ± 2.1 year; $P = .02$). No other demographic differences were seen ($P > .05$). Three variables were identified that predicted second ACL injury risk with high sensitivity (93.3%), but moderate specificity (45.0%). Specifically, patients who failed a screening tool inclusive of (1) IKDC <90 , (2) SLHD LSI $<90\%$, and (3) SLHD sagittal plane hip excursion $> 22^\circ$ when landing were 12 times (OR = 11.5; 95% CI: 1.4, 92.8; $P = .01$) more likely to suffer a second ACL injury. Further, patients failing this screening tool were 3 times (OR = 2.9; 95% CI: 1.1, 7.7; $P = .03$) more likely to either suffer a second ACL injury in the 24 months after RTS or be unable to maintain preinjury level of activity for 1 year after RTS.

CONCLUSIONS: The addition of landing kinematics during the SLHD to SLHD LSI and patient reported function on the IKDC, may serve as a highly sensitive screening tool to determine the likelihood of a successful outcome after ACLR and RTS.

CLINICAL RELEVANCE: The addition of a movement assessment to current RTS measures resulted in a sensitive screening tool to identify likelihood of a successful outcome after ACLR. This is critical to help improve current outcome after ACLR in athletes who return to sports. Future work must continue to identify tools with high specificity to develop confirmatory tests in this population.

SPL54

A COMPARISON OF CONCUSSIONS AND MUSCULOSKELETAL INJURIES IN MIDDLE SCHOOL AND HIGH SCHOOL STUDENT-ATHLETES

Sarah Peterson, Adam Daniel Lutz, Charles Alden Thigpen, Ellen Shanley

PURPOSE/HYPOTHESIS: Concussions and serious musculoskeletal (MSK) injuries in middle (MS) and high (HS) school athletes are a major concern due to negative academic and social ramifications. Few studies have examined the incidence and risk differences of concussions and MSK injuries between HS and MS student-athletes. Therefore, the purpose of this study was to report cumulative incidence and identify absolute risk differences in concussions and MSK injuries.

NUMBER OF SUBJECTS: One thousand fifty MS and 6968 HS student-athletes followed for 2017-2018 sport seasons.

MATERIALS AND METHODS: Total sport participation and injuries were documented by Athletic Trainers (AT) for MS and HS student-athletes from a large Athletic Repository. Cumulative incidence of concussions and MSK injuries are reported per 100 student-athletes with 95% confidence intervals (CI). Separate chi-square tests examined differences between MS and

HS student-athletes by contact status (contact or non) and severity based on time loss (severe, >21 days; mild/moderate, 7-21 days).

RESULTS: There were 311 (MS) and 1577 (HS) total injuries yielding cumulative incidence values of 29.6 and 22.6 per 100 athletes, respectively. MS student-athletes displayed an absolute risk difference of 6.9% (95% CI: 4.1%, 9.9%) greater than HS student athletes. HS athletes were 1.1 (95% CI: 1.0, 1.2; $P = .047$) times more likely to suffer a contact injury compared to MS athletes. MS athletes suffered concussions at a greater rate 5.4 and 3.0 per 100 athletes compared to HS athlete yielding an absolute risk difference of 2.4% (95% CI: 1.2%, 4.0%). Relative risk for mild or moderate (7-21-day time-loss injury) and severe/season ending (>21-day time-loss injury) was not different between MS and HS student athletes ($P = .2$).

CONCLUSIONS: Our results show MS athletes were at higher risk for concussion and MSK injury compared HS student-athletes. Future studies are warranted to confirm and explore these results.

CLINICAL RELEVANCE: Adolescent athletic injuries are common and MS athletes experience injuries similar to older HS athletes. Athletic medical coverage and support for athletic injuries should consider providing similar attention to MS as HS sports.

SPL55

LANDING BIOMECHANICS ARE NOT ALTERED BY SINGLE-DOSE ISOMETRIC EXERCISE IN MALE ATHLETES WITH PATELLAR TENDINOPATHY

Laura Stanley Pietrosimone, J. Troy Blackburn, Erik Wikstrom, David Berkoff, Sean Docking, Jill Cook, Darin Padua

PURPOSE/HYPOTHESIS: Some evidence supports isometric exercise for acute pain relief in individuals with symptomatic patellar tendinopathy (PT). Interventions that modify symptoms may alter biomechanical movement profiles to promote optimal tendon loading. Our purpose was to determine the acute effects of isometric exercise on landing biomechanics in individuals with symptomatic (SYM) and asymptomatic (ASYM) PT. We hypothesized that an isometric exercise protocol would reduce pain in the SYM group and increase tendon loading during the landing task.

NUMBER OF SUBJECTS: Twenty-eight male athletes (Tegner score of ≥ 5) classified into 2 groups based on tendon pain and ultrasound evaluation of the proximal patellar tendon: SYM PT ($n = 13$; mean $\pm$ SD age, 19.62 ± 1.61 years; height, 1.82 ± 0.05 m; weight, 83.46 ± 5.12 kg) and ASYM PT (ASYM) ($n = 15$; age, 21.13 ± 1.88 years; height, 1.84 ± 0.07 m; weight, 81.45 ± 13.26 kg).

MATERIALS AND METHODS: This was a single-blinded, randomized cross-over trial with 2 intervention conditions (isometric exercise protocol [ISO] and sham-control TENS [TENS]) separated by 7 to 10 days. 3-D kinematics and kinetics were collected using a 10-camera motion capture system and 2 force plates preintervention and postintervention. Participants completed 5 double-limb jump-landing trials from a 30-cm box positioned 50% of participant height from the force plates; the middle 3 trials were averaged for analysis. Knee flexion angle at initial contact (KFLEX), peak vertical ground reaction force (VGRF), patellar tendon force (FPT) and impulse (FPTI), internal knee extension moment (KEM) and impulse (KEMI), knee power (KP) and negative knee work (KW) were calculated for the involved limb. Pain on single-leg decline squat (SLDS) was assessed preintervention and postintervention. Change scores [(post - pre) $\times$ 100] were calculated for all dependent variables. A mixed-model repeated measures ANOVA compared change scores with an a priori alpha level of .05. Post hoc testing was performed as needed to identify interaction locations. Cohen's d effect sizes evaluated magnitude group differences.

RESULTS: There were no group-by-intervention interactions for change in SLDS pain ($F_{1,26} = 0.555$, $P = .463$). A significant group*intervention interaction for VGRF ($F_{1,26} = 5.33$, $P = .029$) was noted. However, neither group (ASYM: $t = -1.7$, $P = .107$; SYM: $t = -1.679$, $P = .119$) or inter-

vention (isometric: $t = -2.58$, $P = .016$; sham-TENS: $t = 0.72$, $P = .460$) comparisons demonstrated statistical significance with Bonferroni correction. There were no further significant group-by-intervention interactions ($P > .05$). These results were associated with weak to small effects ($d = 0.05$ - 0.37) of the isometric intervention on SYM.

CONCLUSIONS: Our results demonstrate that a single-dose isometric exercise protocol did not have an acute effect on landing biomechanics in male athletes with SYM or ASYM PT. While this study design was novel, the magnitude of baseline pain in our SYM cohort may not have been adequate to elicit analgesia as previously demonstrated, limiting the potential for influencing biomechanics.

CLINICAL RELEVANCE: Though isometric exercise is a tolerable and analgesic treatment option for athletes with SYM PT, they may not immediately change function. Future research should examine the effects of a longer isometric exercise program on movement profiles in athletes with higher levels of tendon pain.

SPL56

PREDICTION OF LOWER EXTREMITY INJURIES FROM VERTICAL JUMP KINETIC DATA IN COLLEGIATE ATHLETES

Marisa Luisa Pontillo, Brian Sennett, Shawn Hines

PURPOSE/HYPOTHESIS: The vertical jump provides critical kinetic information regarding athletic performance, and can be quantified by the force-time (F-T curve) with defined phases of movement. Alterations in the efficiency of mechanisms used for force production could potentially lead to abnormal force dissipation and resultant injury. The purpose of this study was to identify which force plate variables from a vertical jump task could identify collegiate athletes who sustained a lower extremity injury.

NUMBER OF SUBJECTS: Four hundred sixty-eight Division I varsity athletes.

MATERIALS AND METHODS: Vertical jump testing using a commercially available force plate system with dedicated software was performed by all healthy varsity collegiate athletes at several intervals throughout the athletic year over 3 academic years. The testing procedure consisted of each subject performing a series of 6 consecutive vertical jumps. Injuries were documented by the team athletic trainers and verified with the health care organization's electronic medical documentation system. Injuries were defined as occurring no more than 60 days after a jump and defined as lower extremity by OSICS 10 code; 234 lower extremity injuries were identified. Subjects were matched by age, sex and sport. Vertical jump variables used were average eccentric rate of force development (EFD), average relative concentric force (RCF), and concentric relative impulse (CRI), indicating the athletes' ability to load movements and generate force, the ability to explode/transmit force, and finish movements forcefully for each jump, respectively, which were normalized to T scores. t tests were used to assess differences between the injured and uninjured groups. Logistic regression was used to determine if the battery of variables could predict whether or not an athlete would sustain a lower extremity injury. Additionally, athletes who sustained an ACL injury were identified, matched, and analyzed correspondingly.

RESULTS: EFD, RCF, and CRI, when entered into the regression equation, showed the ability to predict lower extremity injury, $\chi^2 = 14.6$, $df = 4$, $P < .01$; with RCF independently showing significant prediction at $P = .02$. t tests showed significant differences between the ACL and healthy groups for RCF ($t = 2.27$, $df = 22$, $P = .03$), with the injured group scoring lower. EFD, RCF, and CRI also showed the ability to predict ACL injury, $\chi^2 = 13.9$, $df = 3$, $P < .01$, with EFD and RCF independently showing significant prediction at $P < .05$.

CONCLUSIONS: The force plate variables collected from vertical jumps were able to identify athletes who sustained a lower extremity injury. Additionally, these variables were able to identify athletes who sustained an ACL injury.

CLINICAL RELEVANCE: Athletes who demonstrate altered jump kinetics may be identified prior to sustaining a lower extremity injury.

SPL57

PREDICTION OF TRUNK INJURIES FROM CORE STABILITY TESTING IN COLLEGIATE ATHLETES

Marisa Luisa Pontillo, Ivo Milic-Strkalj, Brian Sennett

PURPOSE/HYPOTHESIS: Although the importance of core stability is often theorized to improve performance and reduce injury risk for both the spine and the extremities, there is currently very little evidence supporting if any clinical tests of core stability can predict trunk injuries. The limited evidence which exists focuses on particular sports, and only uses tests which focus on the muscle capacity aspect of core stability. The purpose of this study was to assess if variables attained from core stability testing could be used to identify collegiate athletes who will later sustain a trunk injury.

NUMBER OF SUBJECTS: Four hundred ninety-four Division I varsity athletes.

MATERIALS AND METHODS: Core stability testing consisted of a single arm plank position, performed blindfolded, for two 20-second trials for each upper extremity, on force plate system connected to a dedicated computer with commercially available software. Center-of-pressure data were quantified by velocity and frequency of motion and converted to T score, with a higher T score indicating better stability (decreased sway). Data were average across the 3 trials for each extremity. 18 trunk injuries were identified. Injuries were considered for the study if they occurred no more than 180 days after testing, were nontraumatic in nature, and affected the lumbar spine, abdominal, or thoracic spine structures. Mann-Whitney *U* was used to assess if differences existed between groups. Binary logistic regression was used to see if the force plate variables could be used to predict injury. *P* was set to .10.

RESULTS: Means $\pm$ SD for the uninjured group were 43.7 ± 10.6 and 43.5 ± 10.7 for left/right respectively; for the injured group, 36.9 ± 8.7 and 40.7 ± 7.3 . Mann-Whitney *U* showed significant differences between the trunk injury and healthy groups for both the left and right side ($P < .01$ and $P = .07$, respectively). Both extremity variables, when entered into the regression equation, show the ability to predict injury ($\chi^2 = 10.8$, $P < .01$).

CONCLUSIONS: Athletes who later sustained an abdominal, thoracic spine, or lumbar spine injury demonstrated poor core stability versus the uninjured cohort. The injured group also appeared to have greater asymmetry in core stability versus the injured group.

CLINICAL RELEVANCE: The blindfolded, single arm plank position is adequately challenging to assess core stability in athletes, and can predict trunk injuries in the collegiate athlete population.

SPL58

GLUTEAL MUSCLE MORPHOLOGY AND ITS ASSOCIATION WITH HIP JOINT LOADING DURING GAIT FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

John Michael Popovich, Amanda M. Tobin, Ivanna Mendoza, Liang-Ching Tsai

PURPOSE/HYPOTHESIS: Anterior cruciate ligament reconstruction (ACLR) research has primarily focused on knee-specific outcomes, though there is growing interest in proximal factors (eg, gluteal muscles) and its putative association with patient recovery and subsequent joint health post-ACLR. Considering the mechanical linkage between the hip and knee, examining the clinical notion that proximal muscles contribute to quadriceps muscle deficits and altered joint loading is warranted. This study aimed to determine gluteal muscle morphology in patients post-ACLR and its association with loading demand at the hip and knee during gait.

NUMBER OF SUBJECTS: Twelve with unilateral ACLR (7 women).

MATERIALS AND METHODS: All subjects underwent axial MRI scans (iliac crest to mid shank) at 6 months post ACLR. Cross-sectional areas for the gluteus maximus (GMAX), gluteus medius (GMED), gluteus minimus (GMIN) and QUAD muscles were determined for both the ACLR and uninjured legs with the examiners blinded to the leg of injury. Muscle volumes were calculated as the sum of cross-sectional areas multiplied by

the slice thickness. Subjects also underwent 3-D gait analysis to calculate peak hip and knee extensor moments during gait. Between-leg (ACLR versus Uninjured) comparisons were assessed using dependent t-tests. Between-leg differences in gluteal muscle volumes and hip/knee extensor moments were expressed as percent difference of the uninjured leg, and their relationships were assessed using Pearson's correlation.

RESULTS: The ACLR legs had significantly smaller QUAD muscles than the uninjured legs (1791.0 ± 485.8 versus 2164.2 ± 476.5 cm³, $P < .001$). Conversely, the GMAX of the ACLR legs were significantly larger than the uninjured legs (1118.0 ± 319.2 versus 1073.8 ± 317.3 cm³, $P = .009$). No significant differences for GMED or GMIN muscle volumes were observed between legs ($P = .41$ and $.64$, respectively). During gait, ACLR legs had significantly reduced peak knee extensor moments ($P = .02$), but no differences between legs were observed for peak hip extensor moments ($P = .67$). Between-leg differences in gluteal muscle volumes were not associated with between-leg differences in peak knee extensor moment during gait (all, $P > .50$). However, there was a significant relationship showing that those with larger relative GMAX muscle volumes of the ACLR legs walked with smaller relative hip extensor moments (less demand) ($r = 0.67$, $P = .02$).

CONCLUSIONS: Despite significant QUAD atrophy of the ACLR legs, the GMAX muscle of the ACLR legs was larger at 6 months post ACLR. Further, the demand/loading on the hip during gait was less in those with larger relative GMAX muscle volume of the ACLR leg.

CLINICAL RELEVANCE: While gluteal muscle volumes quantified in this study may have manifested from rehabilitation targeting proximal muscles, the observed larger GMAX muscle volume of the ACLR legs may also be an early indication of a compensatory strategy by ACLR patients. However, the clinical notion that gluteal muscle morphology affects knee mechanics is not supported by our cross-sectional observation, though further investigation is needed.

SPL59

IN VIVO MEASUREMENT OF THE SUBACROMIAL SPACE DURING PERFORMANCE OF THE SHOULDER DISTRACTION TEST

Michele Alexandria Raya, Lucie Marie Stagg, Dominic Anthony Piazza, Robert J. Pelaez, Darian Blake Ohling, Zahilly Giselle Salinas, Philip Edward Grattan

PURPOSE/HYPOTHESIS: The shoulder distraction test, first described by Cyriax, is used to differentiate between bursitis and tendonitis as possible causes of shoulder pain. The test involves inferior displacement of the humeral head to increase the subacromial (SA) space thereby decreasing pressure on the SA bursa during contraction of the supraspinatus (SS) muscle. If pain is present when a patient attempts an isometric abduction with the arm in neutral, then has reduced pain conducting the same contraction while the examiner performs an inferior distraction, this is considered indicative of bursitis as the increased SA space prevents the contracting muscle from compressing into a potentially inflamed bursa. Little is known as to whether the distraction test provides additional space in the SA area during an isometric SS contraction thus reducing pressure on the SA bursa. The purpose of this study was to measure SA space before and during performance of the distraction test to determine if increased SA space is maintained during an inferior distraction with simultaneous isometric contraction of the SS muscle.

NUMBER OF SUBJECTS: A convenience sample of 31 subjects (22-55 years old; 15 female) from a university setting.

MATERIALS AND METHODS: Subjects were positioned in supine with the shoulder at 0° abduction. An examiner created an ultrasound image of the shoulder at rest with the acromion and humeral head within the frame. A second examiner applied an inferior force to the arm equivalent to a Kaltenborn grade 3 inferior mobilization. Ultrasound images of the subacromial space were taken during this distraction, with and without an isometric SS contraction. Humeral head position was measured in ref-

erence to the inferior aspect of the acromion to determine the SA space during each condition.

RESULTS: Fifty-three shoulders were imaged and SA space measured with an average $\pm$ SD initial at-rest distance of 8.62 ± 2.2 mm, average distraction SA space of 9.62 ± 2.1 mm, and average sustained SA space during distraction and isometric contraction of 9.39 ± 1.9 mm. Paired t tests calculated the mean difference in SA space between rest and distraction as 1.0 mm with $P < .001$; between rest and distraction with isometric contraction as 0.77 mm with $P < .001$; and between distraction with/without SS contraction as 0.23 mm with $P = .09$. Seventy-seven percent of shoulders maintained an increased SAS during the isometric contraction with 42% of the total shoulders maintaining a 1 mm or greater increase from the at-rest start point.

CONCLUSIONS: Data support the biomechanical description of the distraction test. The SA space is opened during distraction and remains open when combined with isometric abduction. Future studies on the distraction test should be conducted on patients with symptomatic shoulder pathology.

CLINICAL RELEVANCE: This study provides diagnostic ultrasound evidence for a clinician to reproduce sufficient distraction to create a significant increase in SA space during performance of the distraction test.

SPL60

DOES RECENCY OF MUSCULOSKELETAL INJURY STRENGTHEN ASSOCIATION BETWEEN PAST INJURY HISTORY AND FUTURE INJURY RISK?

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PURPOSE/HYPOTHESIS: To compare presence of risk factors for future musculoskeletal injury between active duty soldiers with recent history of injury but cleared for duty, injury history within past 5 years, and no history of injury.

NUMBER OF SUBJECTS: Subjects ($n = 1922$) aged between 18 and 45 years were pooled from 2 different cohorts and consisted of 3 different groups of Soldiers: (1) those just cleared to return to full duty after a musculoskeletal injury to the lumbar spine (LS) or lower extremity (LE) ($n = 469$), (2) those with no current injury, but a history of low back pain (LBP) or LE injury within the last 5 years ($n = 583$), and (3) those with no history of LBP or LE injury within the last 5 years ($n = 870$).

MATERIALS AND METHODS: Measures included demographics, movement and physical performance (including Y-Balance Test, Functional Movement Screen, triple crossover hop, closed chain ankle dorsiflexion, and 2-mile run time), past injury history, lifestyle health factors (including overweight status, physical inactivity, smoking, and prior injury). Dichotomous group frequency comparisons were analyzed using the chi-square exact test, and odds ratios (OR) were reported with 95% confidence intervals using the lowest injury group as the reference standard. The Brown-Forsythe test was used to perform analysis of variance among groups for scale variables. Fit for duty status was determined by absence of documentation to limit physical duty (validated by the eProfile database), which is required by soldiers.

RESULTS: We found a significant relationship between recency of injury and the percent of individuals found with sufficient risk factors (5+) to place them in the high-risk for future injury category. In group 1, 70.3% ($n = 306$) presented with 5+ risk variables placing them in the high-risk category for future injury (OR = 29.9; 95% CI: 21.4, 41.8). In group 2, it was 43.7% ($n = 244$; OR = 9.8; 95% CI: 7.2, 13.4) and in group 3 only 7.3% ($n = 60$; reference standard) that reached a similar threshold for high-risk. Physical performance measures followed this same trend with the best performance on most measures seen in those with no prior injury, and the worst scores on most measures seen by those most recently cleared for unrestricted full duty after a preceding injury.

CONCLUSIONS: Among soldiers with no current duty restrictions, there

were significant differences in physical performance and the number of risk factors associated with future injury between all 3 groups, with a much higher proportion of individuals in the highest risk group and overall worst performance in those just recently cleared for unrestricted duty. Those with no prior injury in the last 5 years had the lowest proportion of individuals in the high-risk group.

CLINICAL RELEVANCE: Individuals most recently cleared to return to unrestricted duty after an injury presented with a large number of residual risk factors for future injury, and are likely being prematurely cleared for unrestricted duty.

SPL61

INFLUENCE OF BODY MASS INDEX ON SUBSEQUENT KNEE-RELATED FUNCTION IN YOUNG ATHLETES AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Following anterior cruciate ligament (ACL) reconstruction (ACLR), young athletes demonstrate decreased knee-related function and a high risk of second ACL injury. Investigations on the influence of body mass index (BMI) on these outcomes is limited. The purpose of this study was to test the hypothesis that young athletes with higher BMI at time of return to sport (RTS) after ACLR will demonstrate decreased knee-related function and higher incidence of second ACL injury within the first year following RTS.

NUMBER OF SUBJECTS: One hundred eighty-two participants (117 female) from a larger cohort study were included in this longitudinal, prospective analysis. Participants were enrolled within 4 weeks of medical clearance for RTS, categorized as healthy weight (HW) (BMI < 25 kg/m², $n = 129$; 94 female) or overweight (OW) (BMI ≥ 25 kg/m²; $n = 53$; 23 female), and tracked for 1 year.

MATERIALS AND METHODS: At time of RTS and 1 year post-RTS, all subjects completed laboratory testing, which included anthropometric assessment (height in centimeters and weight in kilograms), completion of the Knee injury and Osteoarthritis Outcome Score (KOOS) and International Knee Documentation Committee (IKDC) subjective knee form, isometric quadriceps strength assessment, and a battery of 4 single-limb hop tests (single hop [SH], triple hop [TrH], crossover hop [CH], and 6-m timed hop [TiH]). A limb symmetry index (LSI) was calculated for all strength and hop performance tests [(involved/uninvolved) $\times 100\%$]. Independent-samples t tests were used to determine between-group differences in demographics, patient-reported outcomes, and strength and hop test LSIs ($\alpha < .05$). Chi-square test was utilized to detect a between-group difference in the incidence of second ACL injury within the first year after RTS ($\alpha < .05$).

RESULTS: At time of RTS, a difference in age was found between HW and OW groups (HW, 16.1 ± 2.5 years; OW, 17.9 ± 3.3 years; $P = .001$). The HW group had higher KOOS ADL (HW, 98.2 ± 3.6 ; OW, 96.3 ± 7.6 ; $P = .018$) and Sports (HW, 88.6 ± 13.1 ; OW, 82.5 ± 13.8 ; $P = .005$) subscales, IKDC scores (HW, 90.7 ± 8.7 ; OW, 86.5 ± 12.1 ; $P = .01$), and higher symmetry on the TrH LSI (HW, $96.4\% \pm 0.1\%$; OW, $93.9\% \pm 0.1\%$; $P = .023$) and CH LSI ($96.3\% \pm 0.1\%$; OW, $93.6\% \pm 0.1\%$; $P = .045$) compared to the OW group. At 1 year following RTS, the HW group had higher KOOS Symptoms subscale (HW, 92.27 ± 10.2 ; OW, 86.8 ± 12.5 ; $P = .016$) compared to the OW group. There was no difference in incidence of second ACL injury within the first year between groups ($P = .33$).

CONCLUSIONS: According to our hypothesis, higher BMI at time of RTS after ACLR was associated with decreased knee-related function among young athletes. Fewer between-group differences were present 1 year following RTS. Incidence of second ACL injury did not differ between BMI groups.

CLINICAL RELEVANCE: While higher BMI at time of RTS may be associated with decreased knee-related function, this influence of BMI may dissipate

over the first year following RTS. However, future research is warranted in order to investigate the impact of BMI, along with other factors such as biomechanics, psychological factors, and physical activity levels, which may impact long-term outcomes and knee health.

SPL62

COMPARISON OF 3-D SHOULDER KINEMATICS BETWEEN DOMINANT AND NONDOMINANT SHOULDERS IN COLLEGIATE WOMEN'S VOLLEYBALL PLAYERS

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PURPOSE/HYPOTHESIS: Volleyball players frequently experience shoulder tendinitis, impingement, subluxation, and musculotendinous strain. Alterations in shoulder complex kinematics may contribute to these injuries. The purpose of this study was to investigate the humerothoracic, glenohumeral, and scapulothoracic joint kinematics of the dominant and nondominant arms in asymptomatic female volleyball players.

NUMBER OF SUBJECTS: Fourteen NCAA Division II women's volleyball players (mean $\pm$ SD age, 19.9 $\pm$ 1.2 years) participated in the study. All players were right hand dominant.

MATERIALS AND METHODS: Kinematics of both glenohumeral and scapulothoracic joints were collected during 3 repetitions of humerothoracic scapular plane abduction using the Polhemus G4 3-D electromagnetic motion capture system (Innsport, Chicago, IL). Data analyses to determine differences between dominant and nondominant shoulder peak scapular plane abduction and glenohumeral and scapulothoracic motion at 120° of scapular plane abduction were completed using paired *t* tests via SPSS Version 23.0 (IBM, Armonk, NY).

RESULTS: Participants demonstrated similar peak humerothoracic scapular plane abduction ($t = 0.076$, $P = .940$) between their dominant and nondominant shoulders. At 120° of humerothoracic scapular plane abduction, participants demonstrated 6.03° less glenohumeral elevation ($t = 4.25$, $P = .001$) and 6.85° more scapulothoracic upward rotation of ($t = 4.24$, $P = .001$) in their dominant shoulders.

CONCLUSIONS: There were significant differences in glenohumeral and scapulothoracic kinematics in during humerothoracic scapular plane abduction between the dominant and nondominant shoulders.

CLINICAL RELEVANCE: This is the first study which addresses the 3-D kinematics of the glenohumeral and scapulothoracic kinematics during humerothoracic elevation in the scapular plane in female volleyball players. One potential result of the identified kinematic differences is shortening the lever arms of the rotator cuff muscles. Further investigation into whether the identified kinematic changes protect volleyball players from or predispose them to injury is warranted.

SPL63

INJURY PREVENTION IN PARA SWIMMING

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PURPOSE/HYPOTHESIS: The sport of para swimming has experienced increased participation in recent years. Research on para swimmers regarding injuries and injury prevention is lacking compared to swimmers without impairment. This study aimed to gather data on typical injuries in para swimmers, injury prevention programs, and attitudes toward injury and injury prevention in this population.

NUMBER OF SUBJECTS: Twenty-one completed the survey (6 male, 15 female). Average $\pm$ SD age was 19.38 $\pm$ 4.62 years. Impairment type: 18 physical, 3 visual. Six of the 21 subjects completed the qualitative interviews (1 male, 5 female).

MATERIALS AND METHODS: A survey was distributed through RedCap to 56 elite and national members on the US Paralympic Swimming team, yielding 24 responses, of which 21 met the inclusion criteria (being a

para swimmer with physical or visual impairments on the US Paralympic team). Survey topics included demographic information, training habits, injury history, and participation in injury prevention programs, among others. Six qualitative interviews were conducted through Skype with 6 swimmers selected through convenience sample. Interviews were semi-structured with an interview guide derived from results of the survey. Interviews were transcribed and inductively coded using NVivo, and sentiments by interviewees were categorized under 4 themes: training, injury risk, injuries, and injury treatment/return to sport.

RESULTS: Eleven out of 21 respondents (52.4%) reported experiencing an injury that altered their weekly training. Six of 21 (28.6%) reported participating in an injury prevention program, although 19 of 21 (90.5%) reported participating in stretching and strength training as a part of practice. Interview respondents noted compensated body mechanics that impact injury risk, expressed value of individualized injury prevention programs, and stated the importance of knowledgeable coaching and rehabilitation staff.

CONCLUSIONS: Injury prevention programs are important components in para swimming training and need to be individualized to address swimming biomechanics and athlete-specific impairments. Increasing coaching knowledge and access to individualized programs may reduce injury prevalence among this at-risk population.

CLINICAL RELEVANCE: The results of this study may assist physical therapists, physiatrists, and other medical professionals in understanding the components of individualized injury prevention plans, and therefore improve the para swimmer's return to sport. The results can be used to educate coaches of para swimmers at all levels of competition on the importance of individualized training programs that address the compensations and corresponding risk of injury for swimmers.

SPL64

SHOULDER REHABILITATION IN A SLEDGE HOCKEY ATHLETE WITH BILATERAL LEG AMPUTATIONS: A CASE REPORT

Rebecca Emmaline Salstrand, Elizabeth Ann Myers

BAC KGROUND AND PURPOSE: Acute and chronic upper limb injuries are common in competitive adaptive athletes. Rehabilitation of an adaptive athlete's functionally-dependent upper limb presents a unique challenge due to the athlete's inability to take an appropriate rest period. The purpose of this case report is to describe the management of subacromial pain syndrome and thoracic spine hypomobility in a sledge hockey athlete with bilateral leg amputations.

CASE DESCRIPTION: The patient was a 28-year-old amateur sledge hockey athlete who presented with a 4-year history of progressive bilateral shoulder and upper thoracic spine pain. This pain was exacerbated with sport practices and instrumental activities of daily living. The athlete's continued sport participation in combination with his functional demands such as wheelchair propulsion, transfers, and overhead reaching resulted in an inability to properly rest the affected tissues. The clinicians utilized a gradual, progressive approach balancing mobility and pain relief with strengthening in order to not only reduce the patient's pain, but also to strengthen the patient with aims of preventing future shoulder dysfunction.

OUTCOMES: The patient's achievement of pain-free mobility was prolonged due to his continued activity. A rehabilitative setback occurred after the patient attended an intensive sledge hockey camp during the plan of care. After this setback, the patient prioritized rest and was able to quickly return to prior levels of activity. By the end of care, the patient exhibited decreased pain and irritability during sport and daily function, increased pain-free range of motion in the shoulder and thoracic spine, and improved scapular control.

DISCUSSION: Important considerations for this type of athlete include continuation of mobilization and flexibility exercises throughout the entire continuum of care and proper patient education on the importance of

rest and the role of balanced musculature. Rehabilitation should include training in multiplane movements. Additionally, clinicians should respect the patient's preference for continued sport participation and need for functional activity.

SPL65

INTEGRATING NEUROCOGNITION INTO CLINICAL SINGLE-LEG HOP TESTS

Janet Elise Simon, Nathan Millikan, Meredith Chaput, Dustin R. Grooms

PURPOSE/HYPOTHESIS: Functional testing to determine return-to-play readiness has typically only measured physical capability. However, many lower extremity injuries occur within a dynamic sporting environment taxing physical and neurocognitive abilities. Thus, integrating neurocognitive elements during functional testing can increase ecological validity. The purpose of this study was to determine the relationship and difference between the 4 foundational single-leg hop tests and 4 newly developed neurocognitive single-leg hop tests. We hypothesized that there would be a physical performance (hop distance) decrease for the neurocognitive condition.

NUMBER OF SUBJECTS: Twenty-two college-aged participants (9 male, 13 female; mean $\pm$ SD age, 20.9 $\pm$ 2.5 years; height, 171.2 $\pm$ 11.7 cm; weight, 70.3 $\pm$ 11.0 kg) participated.

MATERIALS AND METHODS: All participants were healthy and active for 3 days a week for at least 1 hour. Participants performed 4 single-leg hop tests (single-leg hop, single-leg crossover hop, single-leg triple hop, and single-leg 6-m hop) in the traditional method and under neurocognitive challenge in a randomized order. The neurocognitive conditions were im-

plemented using the FitLight system (Fitlight Sports Corp, Aurora, Canada) to add cognitive elements and have been found to have good to excellent reliability (ICC = 0.87-0.92). Maximum distance was measured for the single-leg hop, single-leg crossover hop, and single-leg triple hop both conditions. Fastest time was measured for the single-leg 6-m hop for both conditions. Two repeated-measures MANOVAs were conducted for each leg to determine the difference between conditions (traditional and neurocognitive) for the 4 hop dependent variables. If the overall MANOVA was significant follow-up univariate ANOVAs were conducted for each dependent variable. Alpha level was set at less than .05.

RESULTS: The repeated measures MANOVA was significant for condition for right and left legs ($P < .05$). Specifically, the crossover hop (average mean difference 30.12 cm and change of 10.4%), triple hop (average mean difference of 32.53 cm and change of 7.1%), and 6-meter hop (average mean difference of 1.36 seconds and change of 81.7%) were statistically different between traditional and neurocognitive conditions ($P < .05$). However, the single-leg hop was not significantly different between traditional and neurocognitive conditions ($P > .05$, average mean difference of 2.86 cm and change of 1.9%).

CONCLUSIONS: Performance degradation was seen on the crossover, triple, and 6-m hops for the neurocognitive hop condition compared to the traditional condition but not the single-leg hop.

CLINICAL RELEVANCE: The addition of neurocognitive reactive, visual-spatial processing, and anticipatory components to simulate the cognitive demand of sport scenarios may improve functional testing for return to sport. The neurocognitive hop tests provide the ability for a clinician to assess an individual's physical and cognitive abilities simultaneously.

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American Academy of Sports Physical Therapy Platform Presentation Abstracts SPL66-SPL118

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SPL66

THE INFLUENCE OF ATTENTIONAL FOCUS ON LANDING STIFFNESS IN FEMALE ATHLETES

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PURPOSE/HYPOTHESIS: Female athletes who exhibit high vertical ground reaction forces (vGRFs) and minimal knee flexion during landing appear to be at risk for noncontact anterior cruciate ligament (ACL) injuries. As a result, ACL injury prevention often involves training athletes to avoid this 'stiff' landing pattern. During training, clinicians typically provide verbal instructions to alter an athlete's landing technique. Verbal instructions can promote either an internal or an external focus of attention. With an internal focus (IF) individuals attend to a specific aspect of their movement (eg, the position/motion of their knees), whereas with an external focus (EF) they attend to the effect of their movement (eg, the sound produced during landing). An EF appears to result in superior performance for a variety of movement tasks. However, there is a need to examine how attentional focus influences landing mechanics associated with ACL injury risk. The purpose of this study was to compare the influence of instructions promoting an EF versus those promoting an IF on landing mechanics.

NUMBER OF SUBJECTS: Sixteen uninjured female athletes.

MATERIALS AND METHODS: Following a brief warm-up, participants completed double-leg drop landings from a 31-cm height using their typical technique (baseline). They then performed additional drop landings after receiving instructions promoting an IF or an EF. The instructions provided for the IF condition were, "focus on bending your knees when you land," whereas the instructions provided for the EF condition were, "focus on landing softly." The order of the IF and EF conditions was counterbalanced. A multicamera system and force plate were used to record motion and forces during the landings. The peak vGRF, knee flexion angle at peak vGRF, and leg stiffness were identified for each landing. Leg stiffness was calculated by dividing the peak vGRF by the vertical excursion of the pelvis. Repeated measures ANOVAs were used to compare landing mechanics among the conditions (baseline, IF, EF). Post hoc tests were conducted in the case of a significant omnibus test.

RESULTS: There were significant differences among the conditions for the peak vGRFs ($P < .001$), knee flexion angles at peak vGRF ($P = .01$), and leg stiffness ($P < .001$). Peak vGRFs were lower for the IF ($P < .001$) and EF ($P < .001$) conditions versus baseline; however, there was no difference be-

tween the IF and EF conditions ($P = .09$). Knee flexion angles were greater for the IF ($P < .001$) and EF ($P < .001$) conditions versus baseline, as well as for the EF condition versus the IF condition ($P = .01$). Leg stiffness was lower for the IF ($P < .001$) and EF ($P < .001$) conditions versus baseline, as well as for the EF condition versus the IF condition ($P = .04$).

CONCLUSIONS: Female athletes demonstrated a greater increase in knee flexion and reduction in leg stiffness when they were provided with instructions promoting an EF versus when they were provided with instructions promoting an IF.

CLINICAL RELEVANCE: It appears that clinicians should provide instructions that promote an EF when training athletes to avoid stiff landings.

SPL67

SHOULDER STRENGTH AND RANGE OF MOTION IN HEALTHY COLLEGIATE SOFTBALL PLAYERS

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PURPOSE/HYPOTHESIS: Shoulder range of motion (ROM) and strength are key injury evaluation components for overhead athletes. Most normative values are derived from male baseball players with limited information specific to female softball players. The purpose of this study was to determine between limb differences in shoulder ROM and strength in healthy collegiate softball players.

NUMBER OF SUBJECTS: Twenty-three healthy collegiate softball players (mean $\pm$ SD age, 19.9 $\pm$ 1.2 years; height, 170.5 $\pm$ 4.3 cm; mass, 78.4 $\pm$ 11.3 kg) participated.

MATERIALS AND METHODS: Outcome measures included shoulder ROM (internal (IR) and external rotation (ER)), isometric strength (IR, ER, flexion, abduction (135°), and horizontal abduction) and a measure of dynamic strength (Upper Extremity Y-Balance Test [UEYBT]). Arm tested first for each test was randomized between tests and individuals. The dominant arm (DOM) was classified as the preferred throwing arm. Paired-samples t tests were used to determine between limb differences for each outcome measure.

RESULTS: There was a significant difference between limbs for ER ROM ($P = .02$; DOM, 96.7° $\pm$ 12.7°; NonDOM, 84.6° $\pm$ 9.1°) and IR ROM ($P < .001$; DOM, 65.1° $\pm$ 10.6°; NonDOM, 77.3° $\pm$ 11.1°). There were no significant differences between limbs for ER strength ($P = .43$; DOM, 1.68 $\pm$ 0.39 N/kg; NonDOM, 1.72 $\pm$ 0.36 N/kg), or IR strength ($P = .82$; DOM, 1.84 $\pm$ 0.40 N/kg; NonDOM, 1.85 $\pm$ 0.44 N/kg), shoulder flexion ($P = .25$; DOM, 0.40 $\pm$ 0.11 N/kg; NonDOM, 0.42 $\pm$ 0.12 N/kg), abduc-

tion ($P = .40$; DOM, 0.51 ± 0.11 N/kg; NonDOM, 0.52 ± 0.11 N/kg), or horizontal abduction ($P = .37$; DOM, 0.56 ± 0.10 N/kg; NonDOM, 0.58 ± 0.14 N/kg). Additionally there were no significant differences between limbs for the UEYBT in the superolateral ($P = .37$; DOM, $48.8\% \pm 8.9\%$ arm length; NonDOM, $49.8\% \pm 9.2\%$ arm length), inferolateral ($P = .06$; DOM, $67.7\% \pm 10.9\%$ arm length; NonDOM, $71.7\% \pm 12.8\%$ arm length) or medial ($P = .34$; DOM, $85.5\% \pm 9.0\%$ arm length; NonDOM, $86.6\% \pm 10.1\%$ arm length) directions.

CONCLUSIONS: Female collegiate softball players demonstrated greater ER ROM and less IR ROM in the DOM arm, relative to the NonDOM arm, which is consistent with softball and baseball participants in previous studies. However, collegiate softball players in the current study demonstrated relatively symmetrical performance on isometric and dynamic strength measures which contrasts with previous studies using male baseball players. This suggests performance differences between limbs may be sport or sex specific.

CLINICAL RELEVANCE: Establishing normative data for collegiate softball players allows clinicians to assess deficits in shoulder ROM and strength between limbs. These findings can provide insight to injury prediction and guide the assessment and rehabilitation interventions for this population. These tests and measures performed can easily be implemented into the clinic with minimal cost and setup.

SPL68

ASSOCIATION BETWEEN FEMORAL ANTEVERSION AND HIP FUNCTION ON THE DYNAMIC VALGUS INDEX

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PURPOSE/HYPOTHESIS: Clinicians assess lower extremity control by observing hip adduction and knee valgus during a single-leg squat (SLS). Factors like femoral anteversion (FA) and altered hip neuromuscular control may adversely affect SLS performance. A limitation of prior works has been attention devoted toward the knee, but not the hip, frontal plane project angle (FPPA). Increased pelvis-on-hip motion can increase knee valgus loading but not necessarily be captured with the knee FPPA (k-FPPA). The dynamic valgus index (DVI) is a measure combining the k-FPPA and hip FPPA (h-FPPA) to better represent hip and knee kinematics. To date, no data exist regarding the association between FA and hip function on the DVI during a SLS. We hypothesized a positive correlation between FA and hip EMG activity and DVI during a SLS and a negative correlation with hip strength.

NUMBER OF SUBJECTS: Nineteen.

MATERIALS AND METHODS: Nineteen healthy individuals participated. Femoral anteversion was measured to the nearest degree using diagnostic ultrasound. The average of 2 measures was analyzed. Surface EMG electrodes were donned on the gluteus maximus (GMX) and gluteus medius (GM). Subjects performed 3 maximum voluntary isometric contractions (MVIC) for each muscle. The highest halves of activity represented 100% activation. Isometric hip extensor and abductor strength were simultaneously assessed. The average peak force, normalized to subject mass, was analyzed. Two-dimensional motion capture was used to assess k- and h-FPPA. EMG data were collected as subjects performed 5 repetitions of a SLS. EMG data were sampled at 2000 Hz; band-pass filtered (20-450 Hz); RMS over a 125-millisecond window; and expressed at 100% MVIC (percent MVIC). Video data were sampled at 100 Hz and smoothed with a second-order low-pass filter at 6 Hz. The k-FPPA was between the anterior superior iliac spine (ASIS), midpoint of the distal femur, and midpoint of the malleoli. The h-FPPA was between the contralateral ASIS, ipsilateral ASIS, and midpoint of the distal femur. The peak k- and h-FPPA were combined to represent the peak DVI. The average DVI was analyzed. Bivariate correlations were used to determine associations between peak DVI and femoral anteversion; GMX and GM activity; and hip abductor and extensor strength. The P value was .05.

RESULTS: A moderate correlation ($r = 0.62$, $P = .005$) existed between peak DVI and GM EMG activity. No other significant correlations occurred.

CONCLUSIONS: GM activity, not hip abductor nor extensor strength, was associated with peak DVI during a SLS. Increased GM activity suggested that subjects required greater neural drive to complete the task. Lack of association between peak DVI and FA showed that bony structure had little influence on SLS performance.

CLINICAL RELEVANCE: Study findings provided evidence for using motor control strategies, rather than hip strengthening exercise, to improve SLS performance. Having no FA association was clinically important since FA would not be modifiable with rehabilitation. Clinicians should consider using movement re-education that incorporates cues for GM activation for individuals who demonstrate an increased DVI during a SLS.

SPL69

WOMEN WHO GO ON TO SECOND ANTERIOR CRUCIATE LIGAMENT INJURY RESTORE QUADRICEPS STRENGTH SYMMETRY EARLIER AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Angela Hutchinson Smith, Jacob J. Capin, Lynn Snyder-Mackler

PURPOSE/HYPOTHESIS: Up to 25% of young female athletes who undergo ACL reconstruction (ACLR) experience a second injury in the 12 months following return to sport (RTS). However, delaying RTS until at least 9 months post ACLR can significantly reduce the risk of second knee injury. Our purpose was to analyze group differences in functional and patient-reported outcome measures between female athletes with ACLR who did and did not sustain a second ACL injury after completing a RTS program. **NUMBER OF SUBJECTS:** Thirty-five female level 1 to 2 athletes after ACLR (age, <25 years).

MATERIALS AND METHODS: Enrollment occurred after primary ACLR and rehab upon achieving postop milestones: ≥ 12 weeks postop, $\geq 80\%$ isometric quadriceps strength index (QI), minimal effusion and full ROM. Subjects completed a RTS program, including 10 sessions of strengthening, agility, and plyometrics. All subjects completed a posttraining test battery including: isometric quadriceps strength index, single-legged hop indices, Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADLS), Global Rating Scale (GRS), and International Knee Documentation Committee 2000 (IKDC 2000). Test results were used to inform RTS; passing criteria included: $\geq 90\%$ for QI, limb symmetry index on 4 single-legged hop tests, KOS-ADLS, and GRS. Subjects were followed for 2 years after ACLR to assess for occurrence of second ACL injury. Statistical analysis was completed using descriptive statistics and independent t-tests to assess for differences between groups.

RESULTS: Nine participants (mean $\pm$ SD age, 16.0 ± 1.8 years) went on to have a second ACL injury and 26 (age, 17.3 ± 2.5 years) did not. Significant differences were seen between groups at post training for QI (second injury mean $\pm$ SD, $99.4\% \pm 10.9\%$; no reinjury, $87.3\% \pm 10.7\%$; $P = .006$). There was a trend toward differences in time (weeks) from surgery to complete training. (35.2 ± 7.8 and 29.6 ± 8.1 , $P = .077$). There were no significant differences between groups in any of the 4 hop tests or patient reported outcome measures. Fifty-five percent (5/9) in the second injury group passed RTS versus 23% (6/26) in the no reinjury group.

CONCLUSIONS: Female athletes who went on to sustain a second injury completed the RTS program 5.5 weeks earlier than those that did not. At posttraining testing, athletes in the second injury group demonstrated better quadriceps strength symmetry and a greater proportion met RTS criteria than those in the no reinjury group.

CLINICAL RELEVANCE: Restoring quadriceps strength symmetry after ACLR is an important clinical milestone; however, those that meet this milestone earlier may return to sport earlier as well, lending further support to the growing literature that delaying RTS reduces second injury risk. RTS decision making must be multifactorial, with consideration for both performance and time-based benchmarks to account for biological healing.

SPL70

UTILITY OF THE SINGLE ASSESSMENT NUMERIC EVALUATION IN REHABILITATION PHASES OF BASEBALL

Wesley Edward Talley, Charles Alden Thigpen, Daniel Kline, Michael Kissenberth

PURPOSE/HYPOTHESIS: Region and activity specific patient-reported outcomes (PROs) have been used to examine function following treatment in patients and athletes. Previous studies have examined region specific PROs to help guide care through the rehab process and activity related PROs to clarify function at time of return to sport. The reliability and validity of the SANE has been established in those with knee and upper extremity impairments. The validation of the Functional Arm Scale for Throwers (FAST) has been established as a possible region (shoulder and elbow) and activity related PRO for softball and baseball players helping to guide care players through rehab and back to sport.

NUMBER OF SUBJECTS: Thirty-one baseball players were referred to physical therapy for the management of either elbow or shoulder pathology related to sport.

MATERIALS AND METHODS: Demographics including age, height/weight, school year, position, and hand dominance were collected to determine if associations exist between position, rehabilitation phase, body segment, and injury recovery. Starters and relief pitchers were grouped as pitchers while any player primarily acting as an infielder, outfielder, or catcher was grouped as a position player. FAST and SANE were given throughout the rehab process to determine if an association existed between the SANE and the FAST. The SANE is a 1 question survey that asks patients to rate the percentage of normal for their shoulder/elbow. The FAST is a 22-question survey with an additional 9 questions for pitchers. The questions are phrased in a way that asks about the ability to complete daily activities, to throw and to function in sport. Bivariate correlations and univariate ANOVAs were used to determine the association and between group differences of the PRO, player position, phase of rehabilitation and injury site.

RESULTS: There were 17 elbow and 14 shoulder patients presenting for rehabilitation (average age, 16.3 years). There was a similar number of conservatively treated elbow and shoulder patients ($P = .63$). The FAST and SANE scores were similar for players regardless of position. Outcome measures were highly correlated for both pitchers ($r = 0.92$) and position players ($r = 0.77$). The FAST and SANE are correlated at $r = 0.82$ ($P = .001$) and $r = 0.8$ ($P = .001$) in initial and return to throwing phases respectively. The scores differed for players based on the phase of rehab and position (46.1 ± 25.2 versus 22.00 ± 17) as well as during the initial and return to throwing phases in pitchers and (53 ± 10.5 versus 28 ± 13.1) in position players. Scores demonstrate significantly less disability in the interval throwing phase ($P = .001$).

CONCLUSIONS: Based on these results, there is a high correlation between the SANE and the FAST regardless of position played. The SANE can be used to measure progress for athletes with either shoulder or elbow impairments and guide care through the phases of rehab.

CLINICAL RELEVANCE: This study demonstrates that the SANE can be used to measure progress through rehab for baseball players

SPL71

HIP STRENGTH AND HIP AND PELVIC MECHANICS IN HEALTHY YOUTH RUNNERS

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PURPOSE/HYPOTHESIS: While previous research has assessed the relationship between hip strength and running mechanics in adolescent and young adult male runners, little is known about this relationship in healthy young female runners. Therefore, the purpose of this study was to assess the relationship between hip strength and lower extremity mechanics in healthy male and female youth runners.

NUMBER OF SUBJECTS: One hundred eighteen (47 male, 71 female; mean $\pm$ SD age, 13.5 ± 2.8 years; height, 157.2 ± 14.2 cm; mass, 46.9 ± 13.2 kg).

MATERIALS AND METHODS: Participants were instrumented with reflective markers and underwent 3-D motion analysis while running on a motorized treadmill at a self-selected speed. Pelvic and hip peak angles and range of motion (ROM) were measured during the stance phase of the running cycle. Peak isometric hip abduction strength (HABD) and peak isokinetic ($120^\circ/\text{s}$) hip extension strength (HEXT) were measured bilaterally and normalized to body weight. HABD was tested in side-lying with a handheld dynamometer. HEXT was tested in prone with a dynamometer machine. Pearson correlation coefficients were calculated between hip strength and stance phase hip ROM and peak stance phase pelvis and hip angles ($P < .05$) in male and female runners.

RESULTS: Across all runners, there were significant positive correlations between HEXT and HABD strength ($r = 0.347$, $P < .01$). Significant positive correlations were also found between HABD and stance phase hip adduction (HADD) ROM ($r = 0.323$, $P < .01$). Strength measures of HABD and HEXT were not related to pelvic kinematics in any plane ($P > .05$). For females, HABD was negatively correlated with peak pelvic drop ($r = -0.327$, $P < .01$). HABD was positively correlated with stance phase HADD ROM ($r = 0.337$, $P < .01$). For males, HEXT was positively correlated to sagittal plane hip ROM ($r = 0.429$, $P < .01$) and HABD was positively correlated to HADD ROM ($r = 0.313$, $P < .01$).

CONCLUSIONS: In healthy youth male and female runners, HABD was positively correlated to stance phase HADD ROM. At the pelvis, female runners demonstrated a negative correlation between HABD and peak pelvic drop. At the hip, male runners demonstrated a positive relationship between HEXT and sagittal plane hip ROM.

CLINICAL RELEVANCE: Contrary to previous research, hip strength was positively associated with increased stance phase hip adduction ROM and was not related to transverse plane hip ROM. While there were similarities across sexes, several key differences exist. For youth females, hip abductor strength was negatively correlated to peak pelvic drop. Similar findings have been reported previously in female collegiate runners. Injured runners have been reported to have greater pelvic drop than healthy runners. Coupled with the current study, these findings suggest stronger HABD muscles may be clinically meaningful for healthy female runners. For males, peak hip extensor strength was positively correlated to stance phase hip ROM. Previously, hip extensor strength was reported as inversely correlated with knee extensor work. Increased knee extensor work is related to greater patellofemoral joint forces and injury potential. When considered in the context of prior work, results from the current study suggest stronger hip extensor muscles may be protective against knee injury in male youth runners. Prospective studies are warranted to further investigate these associations and their relationship to injury risk and running performance.

SPL72

SELF-REPORTED MEASURES CORRELATE WITH HIP ABDUCTION STRENGTH IN CHILDREN AFTER PEDIATRIC ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Despite a significant increase in the number of pediatric anterior cruciate ligament reconstructions (ACLR) performed in recent years, there is a dearth of evidence regarding outcomes specific to children who undergo surgical techniques to respect open physes during the reconstruction procedure. The purpose of this study was to examine the correlation between thigh and hip strength with patient-reported measures of function in skeletally immature patients after a physes-sparing ACLR procedure. It was hypothesized that higher thigh and hip strength would be associated with higher function on patient-reported measures.

NUMBER OF SUBJECTS: Twenty-six children were examined after primary, unilateral, physal-sparing ACLR as a part of an ongoing longitudinal study (100% male; ITB autograft; mean $\pm$ SD age, 11.8 $\pm$ 1.8 years; time since surgery, 6.7 $\pm$ 3.8 months; range, 3-16 months).

MATERIALS AND METHODS: All participants completed 1 testing session that included strength assessment and completion of patient-reported measures of function. Bilateral isometric thigh strength (quadriceps [QF] and hamstrings [HS]) was assessed with isokinetic dynamometry (Biodex Pro System 4) at 60° of knee flexion. Bilateral isometric hip abduction (Abd) strength was measured with handheld dynamometer (JTECH Medical) with the patient in a stabilized sidelying position. A limb symmetry index (LSI) was calculated for each strength measure as (involved/uninvolved) $\times$ 100%. Self-reported function was evaluated with the Pediatric Quality of Life Inventory Physical Functioning scale (PedsQLPhys), the Pediatric International Knee Documentation scale (PediKDC), and the Sport and Quality of Life subscale scores of the Knee Injury and Osteoarthritis Outcome Score for children (KOOS-ChildSport, KOOS-ChildQOL, respectively). Pearson correlation coefficients were calculated between thigh and self-reported functional measures with significance set a priori at $\alpha < .05$.

RESULTS: HS LSI was positively correlated with PedsQLPhys ($r = 0.45$, $P = .02$), PediKDC ($r = 0.52$, $P < .01$), KOOS-ChildSport ($r = 0.51$, $P < .01$), and the KOOS-ChildQOL ($r = 0.43$, $P = .03$). Abd LSI was positively correlated with PedsQLPhys ($r = 0.43$, $P = .03$), PediKDC ($r = 0.54$, $P < .01$), KOOS-ChildSport ($r = 0.62$, $P < .01$), and KOOS-ChildQOL ($r = 0.73$, $P < .01$). QF LSI demonstrated no significant correlations with any self-reported functional measure.

CONCLUSIONS: Despite the well-established importance of QF LSI following ACLR in the skeletally mature population, QF LSI was not associated with self-reported function in children following pACLR in this study. HS LSI and Abd LSI were both moderately strongly positively associated with all self-reported functional measures examined.

CLINICAL RELEVANCE: All children in this study underwent an over-the-top ACLR procedure with ITB autograft, and these findings may indicate the importance of HS and Abd strength to postoperative function. Future work is needed to further examine outcomes after pACLR in order to properly inform the future development of technique-specific rehabilitative guidelines.

SPL73

THE RELATIONSHIP BETWEEN PERFECTIONISM AND RUNNING-RELATED INJURY IN HIGH SCHOOL RUNNERS

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PURPOSE/HYPOTHESIS: High school distance runners have a high incidence of running-related injury (RRI). While anatomical, biomechanical, and training load factors have been associated with RRI, psychological factors like perfectionism have been suggested to contribute to the risk of RRI. Perfectionism behaviors can be adaptive or maladaptive. The primary purpose of this study was to examine the relationship between perfectionism behaviors and the increased likelihood of RRI in high school cross-country runners.

NUMBER OF SUBJECTS: Overall, 93 runners (35 female, 58 male) who competed in the 2018 interscholastic cross-country season participated in the study.

MATERIALS AND METHODS: A prospective observational cohort design was employed. Prior to the start of the season, the runners completed the Sport Multidimensional Perfectionism Scale-2 (Sport MPS-2) and study survey. The SPORT MPS-2 is composed of 6 subscales: personal standards (PS), concerns over mistakes (COM), doubts about actions (DAA), perceived parental pressure (PPP), perceived coach pressure (PCP), and organization (O). All runners were uninjured at time of assessment. The coaches completed the Daily Injury Report to record RRI incidence and time loss due to RRI throughout the season. Independent t tests were

used to compare mean differences between boy and girl runners for the 6 SPORT MPS-2 subscales. Odds ratios (OR) and 95% confidence intervals (CI) were used to determine the risk relationship of RRI and the 6 perfectionism SPORT MPS-2 subscales.

RESULTS: Twenty-six runners (28%) experienced a time loss RRI during the 2018 season, with a higher incidence among female runners (37.1%) than males (22.4%). On average, females reported significantly higher scores (23.6 $\pm$ 6.8) for the COM subscale than males (20.8 $\pm$ 5.7, $P = .03$). No significant differences were found between females and males for the other 5 SPORT MPS-2 subscales ($P > .05$). Overall, runners who reported ≥ 3.1 (on a 1-5 scale) for the DAA subscale were 3 times more likely (OR = 3.02; 95% CI: 1.1, 8.6; $P = .04$) to incur a RRI during the season than runners who reported < 3.1 on the DAA subscale. While the risk associations for the DAA subscale were similar for females (OR = 3.96; 95% CI: 0.8, 20.7; $P = .12$) and males (OR = 2.41; 95% CI: 0.6, 10.0; $P = .24$), the gender-specific risk associations were not statistically significant. No significant risk associations were found between the other 5 SPORT MPS-2 perfectionism subscales and RRI ($P > .05$).

CONCLUSIONS: High school runners with greater DAA scores appear to be more likely to sustain a RRI during a cross-country season.

CLINICAL RELEVANCE: Some maladaptive perfectionist behaviors, especially those with higher dissatisfaction and uncertainty about their training and competition preparation, may help to identify runners who may be at increased likelihood of a running-related injury. Accordingly, programs that can help reduce these behaviors may help prevent running-related injuries among high school cross-country runners.

SPL74

MUSCLE FORCE CHARACTERISTICS OF MALE AND FEMALE COLLEGIATE CROSS-COUNTRY RUNNERS DURING OVERGROUND RUNNING

Charles Nathan Vannatta, Thomas Gus Almonroeder, Thomas Kernozek, Stacey A. Meardon

PURPOSE/HYPOTHESIS: Males and females demonstrate unique running mechanics that may contribute to sex-related differences in common running related injuries. Understanding sex differences in muscle forces during running can advance current understanding of sex disparities to inform intervention approaches. Previous studies investigating running mechanics have typically captured averaged measures across multiple running trials and have largely examined discrete parameters (eg, peak forces). Examining intertrial variability and muscle force characteristics across time series data may help identify important differences not detected with more traditional analyses. Therefore, our purpose was to compare muscle force characteristics and intertrial variability between males and female during running.

NUMBER OF SUBJECTS: Thirty-four.

MATERIALS AND METHODS: Twenty female and 14 male collegiate cross-country runners were examined. Retroreflective markers were captured on each runner as they completed 5 overground running trials where their right foot contacted a force platform within a 20-m runway. Running speed was controlled to $\pm 5\%$ of each runner's typical training pace. Kinetic and kinematic data were input into the Human Body Model (Motek Medical, Amsterdam, the Netherlands) to estimate muscle forces. Principle components analysis was used to capture the primary sources of variance from the muscle force time series. Principal components (PC) reflected variance in the overall magnitude, timing of peaks, and differences in local peaks across the time series. Mean PC scores captured average performance and the standard deviation of the PC scores captured intertrial variability. Two-way analysis of covariance was used to compare the mean PC scores and intertrial variability for the normalized muscle forces of the gluteus maximus and medius, quadriceps, hamstrings, gastrocnemius, and soleus. Sex and footstrike pattern (rearfoot, nonrearfoot) were included as between-factors and running speed was a covariate in our statistical model.

RESULTS: The proportion of rearfoot versus nonrearfoot strike runners was similar in males and females. Principal components analysis indicated that the magnitude of the forces for the hamstrings, gastrocnemius, and soleus muscles were higher across the majority of stance for the male runners (versus female runners), regardless of footstrike pattern. Males also demonstrated greater intertrial variability in the timing of the peak gluteus maximus force and the magnitude of local peaks across the gastrocnemius force time series. These differences were independent of footstrike pattern.

CONCLUSIONS: Males and females appear to employ unique lower extremity muscle force characteristics during overground running. Males demonstrated greater muscle forces and variability in timing of peak muscle forces.

CLINICAL RELEVANCE: These data may provide insight into potential sex differences in injury rates and mechanisms and may assist clinicians in training and rehabilitation programs for runners.

SPL75

EFFECTS OF ANKLE SPRAINS AND DUAL TASKS ON COINCIDENCE ANTICIPATION PERFORMANCE IN FEMALE BASKETBALL PLAYERS

Vien Vu, Attila Kovacs, Charles Nathan Vannatta, Emily Wughalter, Thomas Kernozek

PURPOSE/HYPOTHESIS: Coincidence Anticipation Time (CAT) is the ability to predict when an object will arrive at a designated point in space and time. Bassin timers have been used to accurately measure timing aspects of a motor program as it relates to CAT. Errors in timing may be related to unsuccessful performance and/or risk of injury as they may indicate mistiming movement response. Neuroplastic changes in the brain have been reported after ligamentous injury such as decreased motor cortex activation. These changes suggest neural resources may be allocated there as a compensation, leaving deficits in areas that dictate movement timing. CAT may be a means of objectively measuring deficits in movement timing. Additionally, sports involving divided attention may also challenge allocation in areas that influence timing. Thus, deficits in movement timing under dual task conditions may assist in identifying those at injury risk. The primary purpose of this study is to determine differences in CAT across single versus dual task performance. We hypothesize that timing errors will be significantly larger in the dual task. The secondary purpose is to determine differences in CAT performance across dual task performance between injured and uninjured players. We hypothesize that the injured group will have significantly larger AE, CE, and VE.

NUMBER OF SUBJECTS: Twenty-one.

MATERIALS AND METHODS: Female athletes completed an anticipation task using a Bassin Timer under 2 conditions. The single task condition consisted 30 trials of a button-push when participants perceived a light reaching a target. The dual task condition consisted of the same task while simultaneously dribbling a basketball. Presence of a history of ankle sprain was noted through self-report and used to create injured and uninjured groups. Raw algebraic error data were extracted from the Bassin timer. Absolute Error (AE), Constant Error (CE), and Variable Error (VE) were taken for all participants across single and dual task paradigms. To examine differences between single versus dual task AE, CE, and VE, a 1-way repeated measures ANOVA was employed for each speed. To compare dual task AE, CE, and VE between injured versus uninjured participants, a 2 (injured versus noninjured)-by-3 (stimulus speeds) MANOVA was employed.

RESULTS: No significant difference was revealed for AE, CE, or VE across single versus dual task conditions except VE at 9 mph. No significant difference was revealed for dual task AE, CE, or VE between the injured versus uninjured group.

CONCLUSIONS: Familiar tasks added during performance and rehab training may not affect or challenge an athlete's CAT significantly different than performing a single task. The injured group trended toward less of

an early response in CE by 10 to 19 milliseconds which may be relevant to ligamentous injuries as prior studies have reported that ACL injuries occur within 17 to 50 milliseconds.

CLINICAL RELEVANCE: Simple or familiar tasks may not affect the timing of individuals' motor programming. More research is needed to elucidate the role of CAT in injury and determine if higher level tasks affect CAT.

SPL76

PREVENTION AND MANAGEMENT OF RUNNING-RELATED INJURIES IN ULTRARUNNERS

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PURPOSE/HYPOTHESIS: Ultrarunning, running beyond marathon distances, has grown significantly in popularity over the past decade. Given the high prevalence of running-related injuries and the multifactorial nature of these injuries, the process whereby ultrarunners seek to achieve consistent and injury-free training and to complete running events greater than 42.2 km (26.2 miles) is not well understood. The purpose of this study was to describe the prevention and management strategies used by ultrarunners for running-related injuries.

NUMBER OF SUBJECTS: This study involved 37 semi-structured in-depth interviews with 28 ultrarunners and field observation at 2 different ultramarathon events.

MATERIALS AND METHODS: In this study, the analysis of data collected via semi-structured, in-depth interviews and field observations were applied to a grounded theory construct aimed at describing the behavior of ultrarunners with regard to prevention and management strategies for running-related injuries.

RESULTS: Three overarching themes emerged from the data which reflected strategies used by participants to prevent and manage injuries during their ultrarunning participation: "listen to your body," "back on track," and "mental toughness."

CONCLUSIONS: Rigid adherence to high-volume training programs and overscheduling ultramarathon events were considered to be contributory to overuse running-related injuries, whereas training activity guided by perceived exertion and focusing on a particular goal race for the calendar year were described as effective injury prevention strategies. Management strategies included problem solving to determine appropriate levels of running activity as well as engaging in fitness alternatives perceived to boost the physical and mental health of ultrarunners during time off running. Study participants utilized a "me against me" strategy for challenges associated with obligatory training tendencies and pressures associated with online performance tracking tools. Positive thinking strategies were deemed useful for ultrarunning participation; however, these strategies led to mixed results for the management of running-related injuries.

CLINICAL RELEVANCE: Professional running coaches and medical professionals working with ultrarunners, should design training programs and implement rehabilitation protocols so as to facilitate the prevention and management of running-related injuries. In doing so, coaches and clinicians can help guide ultrarunners to avoid unnecessary barriers that might otherwise keep these endurance athletes from remaining healthy or achieving a swift and complete recovery from running-related injuries.

SPL77

THE RELATIONSHIP BETWEEN LOWER EXTREMITY RANGE OF MOTION, STRENGTH, AND INJURY IN COLLEGIATE GYMNASTS: A PILOT STUDY

Candace Young, Kaysha Marie Heck, Michelle L. Bruner, Michael W. Moser, Kevin W. Farmer, Giorgio Zeppieri

PURPOSE/HYPOTHESIS: Gymnastics is a demanding sport that places significant impact and forces on the lower extremity, which can result in injury. Competitive gymnasts have one of the highest rates of injury per hour of exposure in collegiate sports. The specific relationship between preseason lower extremity (LE) range of motion (ROM), strength and musculoskel-

etal injury has not been demonstrated in Division I collegiate gymnastics. The purpose of this pilot study was to compare preseason LE strength and ROM measurements in collegiate gymnasts who did or did not sustain musculoskeletal injury.

NUMBER OF SUBJECTS: Fifteen Division I collegiate female gymnasts (mean $\pm$ SD age, 20.5 $\pm$ 0.95 years; weight, 136.9 $\pm$ 24.27 lb; height, 61.5 $\pm$ 3.3 inches) were tracked over 2 competitive seasons.

MATERIALS AND METHODS: All participants underwent preseason LE strength, flexibility, and ROM screening prior to the start of each competitive season. Gluteus medius, gluteus maximus, and iliopsoas strength were measured with a handheld dynamometer. Hamstring and quadriceps strength were measured with isokinetic testing. Hamstring, iliopsoas, iliotibial band, and quadriceps flexibility, were taken with a goniometer using a 2-tester method. Soleus flexibility, hip flexion, and hip internal and external rotation ROM were measured using bubble inclinometer. Musculoskeletal injury resulting in a missed practice, competitive event, or supervised activity was tracked prospectively and recorded by the athletic training staff. Musculoskeletal injuries were categorized into 5 categories: hip/thigh/upper leg, knee, lower leg, ankle, or foot. Independent-samples *t* tests compared preseason LE strength, flexibility, and ROM between injured versus noninjured groups.

RESULTS: There were a total of 22 LE injuries: 2 hip/thigh/upper leg, 5 knee, 2 lower leg, 10 ankle, and 3 foot injuries. Significant group difference in preseason hamstring flexibility (mean $\pm$ SD, 99 $\pm$ 19.8 and 99 $\pm$ 1.4), iliopsoas flexibility (mean $\pm$ SD, -2.5 $\pm$ 2.12 and 4.39 $\pm$ 11.4), and hamstring/quadriceps strength ratios (mean $\pm$ SD, 0.58 $\pm$ 0 and 0.69 $\pm$ 0.28) were identified between gymnasts who sustained a hip/thigh/upper leg injury and those who did not. There was a significant difference in hip flexion ROM (mean $\pm$ SD, 121 $\pm$ 5.66 and 114 $\pm$ 5.57) and gluteus medius strength (mean $\pm$ SD, 33.4 $\pm$ 1.69 and 39.9 $\pm$ 7.2) in patients who sustained a lower-leg injury compared to those who did not. There were no significant differences in preseason ROM, flexibility, and strength measurements for patients who sustained a knee, foot, or ankle injury compared to those who did not ($P > .05$).

CONCLUSIONS: Collegiate gymnasts with hip/thigh/upper-leg injury demonstrated increased preseason hamstring and iliopsoas flexibility, and decreased preseason hamstring/quadriceps strength ratio. Collegiate gymnasts who sustained a lower-leg injury had increased hip flexion ROM and decreased gluteus medius strength compared to those who did not.

CLINICAL RELEVANCE: The findings suggest increased preseason hip ROM and flexibility, and decreased proximal strength may help identify collegiate gymnasts who may be more at risk for developing an upper or lower leg injury, but not a knee, foot, or ankle injury.

SPL78

PRESEASON STRENGTH AND RANGE OF MOTION DIFFER IN COLLEGE SOFTBALL PLAYERS SUSTAINING INJURIES DURING THE COMPETITIVE SEASON

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PURPOSE/HYPOTHESIS: Preseason upper (UE) and lower (LE) extremity range of motion (ROM) and strength have been described in baseball players that sustain in-season musculoskeletal injuries, but are not well explored in college softball players. The purpose of this study was to assess whether preseason shoulder and hip ROM and strength differ between Division I softball players who did or did not sustain a spine, dominant UE, or LE injury during the subsequent season.

NUMBER OF SUBJECTS: A prospective cohort of 43 Division I college softball players over 6 competitive seasons (106 player seasons).

MATERIALS AND METHODS: During preseason screening, the following measures were collected bilaterally: (1) shoulder internal rotation (IR) and external rotation (ER) ROM; (2) shoulder IR and ER strength; (3) hip IR and ER ROM; and (4) hip abduction and extension strength. Hip and

shoulder total arc of rotation motion (TARC) was calculated by summing IR and ER ROM. The dominant shoulder ER to IR strength ratio was calculated. During the subsequent competitive season, the athletic trainer tracked the occurrence of noncontact musculoskeletal injuries occurring at spine, LE, and dominant UE resulting in at least 1 missed practice, training session or game. Independent-samples *t* tests compared preseason ROM and strength between softball athletes who sustained: a spine injury verse those who did not, a dominant UE injury verse those who did not, and a LE injury verse those who did not.

RESULTS: Over 6 seasons, 35 players suffered 61 injuries (12 spine, 11 dominant UE, and 38 LE injuries). Softball players that suffered spine injuries had significantly lower nondominant hip IR (mean difference, -3.3°; 95% confidence interval [CI]: -6.5°, -0.2°; $P = .04$) and TARC (mean difference, -5.0°; 95% CI: -9.3°, -0.8°; $P = .02$) ROM compared to noninjured players. Players that suffered LE injuries had significantly greater dominant hip abduction (mean difference, 5.1 lb; 95% CI: 2.1, 8.2 lb; $P < .01$), hip extension (mean difference, 3.4 lb; 95% CI: 0.4, 6.4 lb; $P = .03$) and shoulder ER/IR index (mean difference, 0.1 lb; 95% CI: -0.2, -0.01 lb; $P = .02$), as well as nondominant hip abduction (mean difference, 5.3 lb; 95% CI: 2.1, 8.5 lb; $P < .01$) strength compared to uninjured players. No differences were found between players that suffered injury at the dominant UE compared to uninjured players.

CONCLUSIONS: Injured softball players have altered preseason hip ROM (spine injury) and shoulder and hip strength (LE injury) compared to uninjured softball players. In contrast, shoulder and hip ROM and strength screening did not characterize softball players who sustained in-season UE injuries.

CLINICAL RELEVANCE: Preseason screening may be valuable to identify softball players at risk for in-season spine and LE injuries. Deficits in hip rotation may generate maladaptive movements that increase the stress on the lumbar spine. Increased hip strength may be an adaptive mechanism to create and transfer more energy to the dominant arm, and potentially compensate for the lower ER strength relative to IR strength. However, there may be a trade-off between this potential increase in athletic performance verse LE injury risk.

SPL79

PROSPECTIVE EVALUATION OF FUNCTIONAL PERFORMANCE FOR LOWER EXTREMITY INJURY RECOVERY

Meredith Chaput, Dustin R. Grooms, Jae Yom, Janet Elise Simon

PURPOSE/HYPOTHESIS: Functional testing and comparison to the contralateral limb to determine return to play readiness after injury is a common clinical practice. However, the dependence on limb symmetry between the injured and uninjured limbs for return to play decision may be limited as the uninjured limb has up to a 15 times greater risk of injury relative to those who have no injury history. Thus, the purpose of this study was to compare limb symmetry and performance at baseline and at return to play on the single-leg hop for distance (SLHOP). We hypothesized individuals would return to play symmetric, but with performance deficits following a lower extremity injury.

NUMBER OF SUBJECTS: Two hundred thirty-six adolescent athletes (mean $\pm$ SD age, 15.69 $\pm$ 1.36 years; height, 171.12 $\pm$ 7.57 cm; weight, 70.34 $\pm$ 15.31 kg) completed the SLHOP before the beginning of the season (preinjury). Forty-four adolescent athletes sustained a lower extremity injury (26 ankle and 18 knee) and missed at least 3 days of sports participation (age, 15.05 $\pm$ 1.02 years; height, 168.57 $\pm$ 5.12 cm; weight, 69.31 $\pm$ 12.42 kg). All participants were members of their respective high school's football, girls' volleyball, or boys' or girls' basketball (18 football, 10 volleyball, 8 girls' basketball, and 8 boys' basketball).

MATERIALS AND METHODS: All individuals had completed the SLHOP before the beginning of the season (preinjury) and at discharge (postinjury). Each participant performed 3 trials of the SLHOP per leg during

each testing session (alternating legs). To be counted as a successful trial the participant had to maintain single leg postural stability for 2 seconds after the landing. The maximum distance across trials was used for all analyses. The independent variable was time (preinjury and postinjury). The dependent variables were injured and uninjured-leg SLHOP distance (centimeters), and SLHOP symmetry (percent = maximum distance of injured limb/maximum distance of uninjured limb $\times$ 100). Three dependent t tests were conducted for each dependent variable. Alpha level with a Bonferroni correction to account for multiple t tests was set at .017.

RESULTS: A degradation of 30% (mean $\pm$ SD difference, 30.23 ± 8.53 cm; $P < .001$) in SLHOP distance was seen preinjury to return to play on the injured side but also on the uninjured side 22% (mean $\pm$ SD difference, 22.36 ± 7.62 cm; $P < .001$). Limb symmetry was not significantly different preinjury to return to play (93.1% versus 94.6%, $P = .18$).

CONCLUSIONS: Following a lower extremity SLHOP performance degrades not only for the injured limb but also the uninjured limb. However, limb symmetry did not change following a lower extremity injury.

CLINICAL RELEVANCE: The classic recommendation is that return-to-play should occur when there is near symmetrical limb performance. Limb indices may overestimate function after injury while performance deficits still exist. These data support the need for baseline testing instead of depending on the uninjured limb to determine return to play decision making.

SPL80

IS THERE A DIFFERENCE BETWEEN STRENGTH, FLEXIBILITY, AND KINETICS BETWEEN POSTPARTUM RUNNERS AND NULLIPAROUS CONTROLS?

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PURPOSE/HYPOTHESIS: Despite the increased prevalence of running in women before and after childbirth, there is very little research on the physical changes and impairments experienced by these runners. Pregnancy and childbirth lead to well-established unique anatomical and physiological changes that more than likely influence strength, flexibility and kinetics (landing forces). Other than case studies, no studies have investigated strength, flexibility, and kinetics in a postpartum running population. The purpose of this pilot study was to determine if differences in kinetics, strength, and flexibility exist between postpartum runners and age-matched controls.

NUMBER OF SUBJECTS: Nine postpartum (PP) (mean $\pm$ SD age, 33.11 ± 5.58 years) and 9 age-matched women (age, 31.67 ± 4.55 years) without children (CON) participated in this study.

MATERIALS AND METHODS: Kinetic data were collected during overground running at 3.7 m/s using a force platform. Impact peak and loading rates in the vertical and posterior directions were calculated from the ground reaction forces during overground running. Hip and knee strength and straight leg raise (SLR) hamstring flexibility measures were collected using handheld dynamometer, inclinometer, and goniometer. Independent-samples t tests were used to compare the 2 groups.

RESULTS: Postpartum women had significantly greater braking loading rate compared to CON (PP, 15.74 ± 4.01 BW/s; CON, 12.33 ± 1.94 BW/s; $P = .04$). Postpartum women were seen to have tighter hamstrings (PP: right SLR, $72.59^\circ \pm 10.97^\circ$; CON: right SLR, $84.95^\circ \pm 9.64^\circ$; $P = .02$), weaker left hip abductors (PP, 0.13 ± 0.03 kg; CON, 0.17 ± 0.03 kg; $P = .01$) and weak bilateral hip adductors (PP, 0.09 ± 0.03 kg; CON, 0.15 ± 0.04 kg; $P = .003$).

CONCLUSIONS: This pilot study shows that postpartum runners may have hip strength deficits and less hamstring flexibility when compared to controls. When investigating kinetics, both groups had similar loading rates in a vertical direction but the postpartum runners had higher loading rates in the posterior direction (during braking), especially during shock absorption phase in the sagittal plane, indicating a difference in motor

control. These preliminary findings could indicate that postpartum runners, as early as 8 weeks postpartum, may show some similar running biomechanics compared to age-matched women who did not have a child, however, may have some altered motor control when running.

CLINICAL RELEVANCE: Return to running guidelines for the postpartum population has been derived mostly from studies looking at active postpartum women and hypothesizing recommendations for the postpartum runner. This pilot shows that postpartum runners may have unique responses to the pregnant and postpartum state, showing some flexibility and strength differences when measured statically and motor control differences in a dynamic state.

SPL81

RELATIONSHIP BETWEEN MUSCULOSKELETAL INJURY RISK ASSESSMENTS AMONG CAREER ACTIVE-DUTY FIREFIGHTERS

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PURPOSE/HYPOTHESIS: The Functional Movement Screen (FMS) and the Y-Balance Test (YBT) have been utilized as screening tools by clinicians due to previous research demonstrating an ability to predict future musculoskeletal injury (MSKI) among a variety of athlete populations. While the FMS is considered to be an assessment of functional movement quality, and the YBT is considered to be an assessment of dynamic balance ability, little information is known regarding the interrelationships between these tools, particularly within the tactical athlete population of firefighters. Therefore, the purpose of the current study was to examine the relationships between the FMS and YBT after accounting for the known influences of age and body mass index (BMI).

NUMBER OF SUBJECTS: Forty-nine male career active-duty firefighters (mean $\pm$ SD age, 40.7 ± 7.9 years; height, 179.2 ± 5.5 cm; body mass, 90.8 ± 9.1 kg; BMI, 28.3 ± 2.8 kg/m²).

MATERIALS AND METHODS: FMS subtest scores were summed to form a continuous Composite FMS (FMSCOMP) score (0–21). YBT reach directions were normalized to participant leg length and then averaged to form a continuous Composite YBT (YBTCOMP) score (percent). MSKI risk binary categorical variables (FMSRISK and YBTRISK) were created based on previously utilized cutoffs for the FMSCOMP (≤ 14 or > 14) and right versus left asymmetries during the anterior reach of the YBT (≥ 4 cm or < 4 cm). Multiple linear regression and semi-partial correlations were utilized to examine the ability of FMSCOMP scores to predict YBTCOMP scores, and the ability of YBTCOMP scores to predict FMSCOMP scores, after controlling for age and BMI. Logistic regression analyses were utilized to examine the ability of YBTCOMP scores to predict FMSRISK, and the ability of FMSCOMP scores to predict YBTRISK, after controlling for age and BMI.

RESULTS: FMSCOMP scores were able to significantly predict YBTCOMP scores ($R^2 = 0.164$, $P < .001$) and YBTCOMP scores were able to significantly predict FMSCOMP scores ($R^2 = 0.191$, $P < .001$), with a direct relationships observed between variables in both analyses ($r = 0.405$ and 0.437 , respectively). In addition, YBTCOMP scores were able to significantly predict FMSRISK category ($\chi^2 = 6.258$, $P = .012$), with an indirect relationship observed between variables (OR = 0.824; 95% CI: 0.708, 0.959). However, although a negative relationship was also observed (OR = 0.873; 95% CI: 0.657, 1.160), FMSCOMP scores were not able to significantly predict YBTRISK category ($\chi^2 = 0.883$, $P = .347$).

CONCLUSIONS: Results of this study suggest that after accounting for the influence of age and BMI, a direct relationship between functional movement quality and dynamic balance ability remains. However, while dynamic balance ability was able to predict FMS risk categories, functional movement quality was not able to predict YBT risk categories.

CLINICAL RELEVANCE: While functional movement quality is related to dynamic balance ability among firefighters, the determinants of MSKI risk based on YBT performance are due to factors other than functional movement quality within this population.

SPL82

RETURN TO SPORT PRIOR TO 7 MONTHS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IS ASSOCIATED WITH DECREASED FUTURE PARTICIPATION

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PURPOSE/HYPOTHESIS: Approximately 50 000 ACL injuries occur in US high school athletes each year. Previous research indicates varied rates of return to sport across all ACL injuries, and time to return to sport has been identified as important with respect to risk of future injury. However, few studies have examined these variables in high school athletes.

NUMBER OF SUBJECTS: Eighty-six (34 female) scholastic athletes (mean $\pm$ SD age, 15.9 ± 1.6 years) participated in the study.

MATERIALS AND METHODS: ACL injured athletes were identified by the school athletic trainer (AT) who confirmed they sustained their injury during a scholastic team-sponsored practice or game. Each athlete underwent ACL reconstruction, reported intention to return to sport of injury, and completed a criterion-based physical therapy program. ATs documented physician clearance and return to sport during the following academic season. ATs also documented participation, injury occurrence, and time loss for all athletes. Athletes were identified as able to return to sport if they were fully participating for the complete season in their sport of injury without time loss due to injury. A chi-square test was used to determine the difference in injury frequency between those athletes returning to sport before versus after 7 months from the date of surgery. Relative risk ratios were calculated comparing the risk of reinjury for athletes who returned to sport earlier than 7 months compared to those who did not. Statistical significance was set a priori at $\alpha = .05$.

RESULTS: Of 86 high school athletes, 65 (75%) were able to return to their sport of injury the following scholastic season while 21 were not. Athletes returned to sport on average 7.5 months following surgery (range, 5-14 months). When evaluating time to return to sport, athletes who returned to sport at less than 7 months (9 athletes) following surgery were 17 times (95% CI: 3.1, 111.0) more likely to fail to return for a full season compared to athletes who returned after 7 months (38 athletes). Of the athletes able to return to sport, 20/65 (30%) experienced subsequent injuries, with 10 of those injuries resulting in time loss, none of which were ACL injuries. This means that 57 (88%) were able to play the entire season without time loss. Time loss injuries were not influenced by time to return to sport ($P > .05$).

CONCLUSIONS: High school athletes increase their risk of failure to complete their next scholastic sport season following ACLR when they return to sport before 7 months post surgery. Only half of the athletes who returned to their sport of injury prior to 7 months were able to complete that season without a time-loss injury.

CLINICAL RELEVANCE: This study is novel in its ability to evaluate ACL injury and return to sport in a high school population, with injury, participation, and subsequent injury documented at scholastic events. While 74% of our high school athletes returned to sport, not all completed the next season. Our results are consistent with other populations showing that delaying return to full participation until at least 7 months should be strongly considered following ACLR.

SPL83

FEMALE ADOLESCENT SOCCER PLAYERS UTILIZE DIFFERENT STRATEGIES BETWEEN LIMBS DURING A LATERAL VERTICAL JUMP

Matthew D. DeLang, James Craig Garrison, Joseph Patrick Hannon, Jim Bothwell

PURPOSE/HYPOTHESIS: Multiplanar dynamic stability is an important unilateral function in soccer performance but has been scarcely examined in female soccer players. Previous literature mainly examines uniplanar and unidirectional hop tests. To address this gap between hop testing and on-

field performance demands, the single limb lateral hop to vertical jump (LVJ) task was devised. This study aims to (1) examine dominant versus nondominant limb functional performance during the jump portion of the task and (2) establish performance baseline data in female adolescent soccer players.

NUMBER OF SUBJECTS: Seventeen.

MATERIALS AND METHODS: Seventeen healthy, adolescent, female soccer players participated in LVJ testing captured by 3-D motion-analysis cameras and force plates. LVJ task measures included single leg vertical jump height and joint-by-joint energy generation contribution (EGC). Energy generation is calculated as the positive portion of the power curve and for purposes of this study, energy generation contribution was considered in the context of percent contribution of the hip, knee, and ankle during the jump portion of the task. Isokinetic quadriceps strength testing was performed on the Biodex Multi-Joint Testing and Rehabilitation System. Participants performed 5 consecutive concentric contractions at $60^\circ/\text{s}$ on the uninvolved limb followed by the involved limb. Multiple paired t tests were used to calculate for between-limb differences in hip, knee, and ankle EGC, quadriceps strength, and jump height between limbs.

RESULTS: Dominant versus nondominant limb quadriceps strength ($P = .644$), jump height ($P = .589$), and ankle EGC ($P = .383$) did not significantly differ. EGC was greater in the dominant hip (Dom, $29.7\% \pm 8.6\%$; NonDom, $18.4\% \pm 6.3\%$; $P < .001$) and nondominant knee (Dom, $22.8\% \pm 6.8\%$; NonDom, $36.2\% \pm 8.5\%$; $P < .001$).

CONCLUSIONS: Despite similar strength and jump height performance, female adolescent soccer players demonstrate different lower extremity strategies to produce power during a lateral vertical jump.

CLINICAL RELEVANCE: Symmetrical between-limb vertical jump height does not account for between limb asymmetries highlighted by EGC. Clinicians must acknowledge symmetry may not always tell the underlying story.

SPL84

INFLUENCE OF A 3-WEEK, GROUP-BASED TRAINING PROGRAM ON VERTICAL LOADING RATE DURING RUNNING

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PURPOSE/HYPOTHESIS: Running injuries are a major burden on military healthcare resources. Evidence of training programs that may reduce injury susceptibility in military settings are lacking. This study sought to assess the ability of a 3-week run training program to reduce average vertical loading rate (AVLR) in habitual rearfoot strike (RFS) runners and determine whether these changes would persist over a 3-month period without structured follow-up.

NUMBER OF SUBJECTS: Thirty healthy participants (47% women) without neuromusculoskeletal injury completed the study. Participants included habitual RFS ($n = 17$) and nonrearfoot strike (NRFS) runners ($n = 13$).

MATERIALS AND METHODS: Independent variables in this prospective, repeated measures cohort were group (RFS and NRFS) and time (baseline, posttraining and 3 months). The primary outcome of interest was AVLR. Following informed consent, a musculoskeletal screening exam, and warm-up, participants ran for 5 minutes on an instrumented treadmill (Noraxon, Scottsdale, AZ) while sagittal plane, high-speed video was recorded. Slow-motion video replay was assessed by 2 raters to determine foot strike patterns. NRFS runners were reassessed 3 weeks after their initial visit to confirm NRFS pattern consistency. RFS runners were enrolled in a 3-week training program addressing motor control patterns during running (ie, cadence, stride length, trunk lean, etc). Training sessions lasted 75 to 90 minutes, during which participants completed a warm-up, a video-based assessment of running form and motor patterns, 30 to 45 minutes of tailored training drills and tempo runs. Total weekly running volume increased from approximately 1.5 to 5 miles. RFS runners repeated testing immediately following the training program and 3 months later. It

was assumed that AVLr in NRFS runners would maintain consistency. A paired *t* test tested this assumption. No differences were identified, therefore AVLr from recorded time points were averaged and these values were carried forward as a surrogate for the 3-month assessment in this group. A 3-by-2 mixed-model ANOVA was then calculated to compare differences in AVLr between groups over time.

RESULTS: RFS and NRFS runners were demographically similar. The ANOVA demonstrated a group-by-time interaction ($F = 6.4$, $df = 1.6$, $P < .01$) which showed that AVLr significantly decreased from baseline to 3 weeks (mean change, 10.7 BW/s; $P < .001$) and remained lower at 3 months (mean change, 5.9 BW/s; $P = .02$). Additionally, though AVLr was higher in RFS versus NRFS runners at baseline (mean difference, 9.7 Bw/s), groups were similar at remaining time points.

CONCLUSIONS: Using a short term, group-based training program, AVLr was successfully reduced in habitual RFS runners to NRFS runner levels and maintained over 3 months without structured follow-up.

CLINICAL RELEVANCE: Group-based training programs with minimal instrumentation can produce robust changes in running parameters known to be associated with higher injury risk. Such interventions may be effective components of injury reduction strategies in military settings.

SPL85

CHANGES IN ENERGY ABSORPTION DURING A DROP-JUMP LANDING FOLLOWING NEUROMUSCULAR TRAINING

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PURPOSE/HYPOTHESIS: Young women participating in sports incur ACL injuries at a higher rate than men. Many ACL injuries occur without contact from another player, and may be the result of decreased neuromuscular control. Noncontact ACL injuries often occur while landing a jump, and stiff landings are associated with a higher risk of injury. Training focused on neuromuscular control and landing technique can reduce injury risk factors, and the use of perturbation training may enhance training by replicating unanticipated playing situations. Therefore, the purpose of this study was to determine whether participation in a mechanical perturbation training program changed energy absorption in the lower extremity in young women.

NUMBER OF SUBJECTS: Eleven training, 11 control.

MATERIALS AND METHODS: Participants completed prestudy and poststudy motion analysis of a bilateral drop jump, with feet landing on separate force plates. Participants with peak knee abduction moment >25.25 Nm were enrolled in the training group. The training group completed a 12-visit, 6-week neuromuscular training program that utilized a novel mechanical perturbation device. Training focused on plyometrics, and participants received verbal feedback on landing technique from an experienced physical therapist. The control group did not complete an intervention. Joint power was calculated using a 6-DOF approach for the hip, knee, ankle, and distal foot. Negative work was calculated for all constituents by the integration of power from initial contact to peak knee flexion. The percent contribution of each constituent to total limb power was then calculated. Changes in energy absorption were analyzed for the nondominant lower extremity with 2-way ANOVAs with factors of group and time. Alpha was set a priori at $P < .05$.

RESULTS: There was a significant interaction for the ankle ($P = .03$). Energy absorption increased in the control group (prestudy mean, 19.4%; poststudy mean, 23.0%), and decreased in the intervention group (prestudy mean, 22.2%; poststudy mean, 21.8%). There was a main effect (ME) of time for the knee ($P = .03$). Energy absorption decreased in the control group (prestudy mean, 54.9%; poststudy mean, 50.9%) and the intervention group (prestudy mean, 51.6%; poststudy mean, 48.7%). Energy absorption decreased at the foot for the control (prestudy mean, 8.0%; poststudy mean, 7.8%) and intervention groups (prestudy mean, 8.7%; poststudy mean, 7.5%), but there was not a ME of time ($P = .15$) or inter-

action ($P = .29$). Energy absorption increased in the hip for the control (prestudy mean, 25.3%; poststudy mean, 27.8%) and intervention groups (prestudy mean, 26.0%; poststudy mean, 28.4%), but there was not a ME of time ($P = .16$) or interaction ($P = .99$).

CONCLUSIONS: Distal lower extremity energy absorption may be reduced with neuromuscular training. However, when compared to the control group, it is unclear what portion of these changes can be attributed to participation in the training program.

CLINICAL RELEVANCE: Decreases in energy absorption in the ankle may represent a softer landing and increased use of hip musculature. These changes may be a safer landing pattern for young women, and indicate further study in a larger cohort is warranted.

SPL86

SUBSEQUENT ANTERIOR CRUCIATE LIGAMENT INJURY IN SCHOOL-AGE PATIENTS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION WITH CONTRALATERAL PATELLAR TENDON GRAFT

Sarah Anne Eaton, Rodney Benner, K. Donald Shelbourne, Tinker Gray

PURPOSE/HYPOTHESIS: Injury to the ipsilateral graft or contralateral ACL after primary ACL reconstruction is devastating to young athletes. Return to sport rates after ACL reconstruction vary greatly, and patients are being advised to wait up to 2 years after surgery before returning to sport. We hypothesized that subsequent ACL tear rate to either knee will not be different based on time of return to sport and that females would have a higher rate of contralateral ACL injury, but no difference in ipsilateral tear rate.

NUMBER OF SUBJECTS: Six hundred eighteen.

MATERIALS AND METHODS: Between 1998 and 2013, 851 patients who were ≤ 18 years old at the time of primary ACL reconstruction with contralateral patellar tendon graft were enrolled into the study. KT-1000 arthrometer testing was recorded to evaluate postoperative stability. Patients reported their preoperative and postoperative level of sport participation, as well as the time of return to sport using an activity rating scale. We recorded subsequent ACL injury to either knee within 5 years of surgery. Injury rates were evaluated based on sex and time to return to sport before or after 6 months after surgery, and correlation of time of return to the time of injury was calculated.

RESULTS: Of patients meeting criteria for the study, 618 (407 female, 211 male) had complete data (73%). The mean KT-1000 arthrometer manual maximum difference between knees was 1.9 ± 1.3 mm, with 91.6% of patients having ≤ 3 -mm difference between knees. The rate at which patients returned to their presurgery level of sport was 88%, with no difference in rates between males and females. The subsequent ACL graft tear rate was 9.3% in females and 11.4% in males ($P = .42$). The contralateral ACL tear rate was 10.6% in females and 5.7% in males ($P = .043$). The number of patients who returned to activity < 6 months after surgery was 253 (62%) for females and 138 (65%) for males. For females, the rate of subsequent ACL graft tear (9.1% versus 9.7% for return before or after 60 months, respectively; $P = .974$) or contralateral ACL tear (10.7% versus 10.4% for return before or after 60 months, respectively; $P = .885$) was not statistically significantly different based on time or return. For males, the rate of subsequent ACL tear (13.0% versus 8.2% for return before or after 60 months, respectively; $P = .226$) or contralateral ACL tear (4.3% versus 8.2% for return before or after 60 months, respectively; $P = .253$) was not statistically significantly different based on time of return. There was no correlation between time of return and time of subsequent tear to either knee for both males and females.

CONCLUSIONS: ACL reconstruction using a contralateral patellar tendon graft reliably allows young patients to return to their presurgery level of sport.

CLINICAL RELEVANCE: The rate of subsequent graft tear was not statistically significantly different based on sex, but the contralateral tear rate was statistically significantly higher in females. The rate of graft tear or subse-

quent contralateral tear was not statistically significantly different based on time of returning to sport; furthermore, there was no correlation of time of return to time of subsequent injury.

SPL87

TRENDS IN LOWER EXTREMITY MOVEMENT QUALITY AMONG US MILITARY ACADEMY CADETS, 2005-2017: A JUMP-ACL STUDY

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PURPOSE/HYPOTHESIS: The Landing Error Scoring System (LESS) is a valid and reliable clinical screening tool of lower extremity movement quality. The LESS has been used for over a decade to screen cadets in basic training at the US Military Academy at West Point (USMA). During this time, US youth activity levels have decreased significantly and rates of sport specialization and some injuries in youth athletes have increased, suggesting a decline in lower extremity movement quality among incoming USMA cadets may have occurred. This study seeks to determine if there were significant changes in lower extremity movement quality in the form of total LESS scores and plane-specific subscales in several recent cohorts of incoming USMA cadets.

NUMBER OF SUBJECTS: Seven thousand five hundred ninety-one.

MATERIALS AND METHODS: Incoming USMA cadets from 12 recent cohorts (2005-2017, excluding 2010) performed the LESS jump-landing task and filled out a demographic questionnaire. Descriptive statistics for total LESS scores and 2 plane-specific subscale scores (sagittal and frontal/transverse) were calculated for each cohort and separately for each sex. Multiple linear regression analyses adjusted for sex and injury history were used to examine trends in total LESS and subscale scores over time. Locally weighted scatterplot smoothing (LOESS) was used to visually examine changes in each explanatory variable during the study period.

RESULTS: Statistically significant inverse trends were found between total LESS score and year ($P < .01$) and sagittal plane subscale and year ($P < .01$). A statistically significant direct trend was found for the frontal/transverse plane subscale and year ($P < .01$). However, each of these trends had a small associated effect size, and none were considered clinically meaningful (total change less than 1 LESS item).

CONCLUSIONS: Lower extremity movement quality in the form of total LESS score and plane-specific subscale scores was stable in incoming USMA cadets during the years 2005 through 2017.

CLINICAL RELEVANCE: This study is the largest to date to use the LESS and provides updated normative values for total LESS scores for each sex. It is also the first to define and provide normative values for plane-specific subscales of the LESS. The results of this study also demonstrate that there has been no meaningful change in lower extremity movement quality among incoming USMA cadets in recent years.

SPL88

CHANGES IN HIP ACTIVE RANGE OF MOTION FROM PRESEASON TO POSTSEASON IN MEN AND WOMEN ICE HOCKEY PLAYERS

Jeffrey John Ferguson, Sara Farquhar Voorhees, Benjamin Wolden

PURPOSE/HYPOTHESIS: Due to the forces at the hip with ice skating, hockey players are at risk for noncontact musculoskeletal injuries. Soft tissue injuries are the most frequent hockey related injury in men and women. Lower-body injuries account for 30.7% in men and 48.6% in women. Past epidemiological studies found the hip to be more affected than other body areas in hockey players, especially in men compared to women. Changes in hip AROM from pre to post season in ice hockey players is unknown; determining these changes is important to develop an understanding between hip AROM and injury. We hypothesized that hip AROM in all planes would decrease from pre to post season.

NUMBER OF SUBJECTS: Seventy-seven consenting participants of 4 ice hockey teams: 1 college men's team ($n = 15$), 2 high school men's teams ($n = 51$),

and 1 high school women's team ($n = 11$). Hip AROM was assessed within 2 weeks of the start of the practice season, and within 2 weeks after the last game of the season.

MATERIALS AND METHODS: Hip AROM was assessed according to standard procedures. Hip AROM from pre to post season were compared using repeated-measures ANOVA with post hoc analysis.

RESULTS: Overall, bilateral hip AROM decrease significantly in flexion, extension, abduction, IR, and ER ($P < .007$) from pre to post season; adduction AROM significantly increased bilaterally throughout the season ($P < .001$). College men had a decrease in hip AROM bilaterally with flexion, extension, abduction, IR, and ER ($P < .004$); adduction was unchanged ($P > .05$). High school men had decreased hip AROM bilaterally in flexion, extension, abduction, IR, and ER ($P < .001$) with adduction AROM increasing bilaterally ($P < .001$). High school women had decrease flexion, extension, abduction, IR, and ER AROM ($P < .027$) with adduction AROM unchanged bilaterally ($P > .42$). By gender, women have greater bilateral hip extension pre and postseason compared to males (21° pre and 18° post compared to 18° pre and 12° post; $P < .05$). There is no difference in flexion, abduction, or ER AROM ($P > .562$). Women have more adduction AROM compared to men preseason (24° compared to 16° , $P < .001$) and postseason (16° compared to 12° , $P < .001$). There is no gender difference in IR AROM preseason ($P > .171$), however females have a significantly greater IR AROM post season compared to males (36° compared to 28° , $P < .001$).

CONCLUSIONS: This is the first study to assess changes in men and women hip AROM pre and post ice hockey season. The hip adduction increase may indicate a compensation pattern to accommodate for the loss of AROM in other planes of motion, causing a change in skating mechanics as the season progresses. This indicates that forces applied within a hockey season cause changes in hip AROM in men and women. The greater adduction and IR AROM in women may contribute to altered skating mechanics compared to men.

CLINICAL RELEVANCE: Loss of hip AROM may have implications for strength or body position that may be a contributing factor in noncontact injuries.

SPL89

FLEXOR-PRONATOR MASS TRAINING EXERCISES SELECTIVELY ACTIVATE FOREARM MUSCULATURE

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PURPOSE/HYPOTHESIS: The flexor-pronator mass of the forearm contributes dynamic stability to the medial elbow. Training this muscle group is essential for overhead athletes, however, there is lack of evidence supporting use of training exercises. The purpose of this study was to document the magnitude of muscle activation during flexor-pronator mass training exercises using elastic band resistance. We hypothesized that 2 exercises would sufficiently but differently activate the pronator versus the flexor muscles.

NUMBER OF SUBJECTS: Ten healthy subjects (all male; mean $\pm$ SD age, 36 ± 12 years).

MATERIALS AND METHODS: Surface EMG activity was measured from 3 muscles of the dominant-side forearm: flexor carpi ulnaris (FCU), flexor digitorum superficialis (FDS), and pronator teres (PT). After measurement of maximal voluntary contraction (MVC) for each muscle, subjects performed wrist ulnar deviation and forearm pronation exercises using elastic band resistance. Resistance was set to elicit moderate exertion (5/10 on the Borg CR10 scale). Order of exercise was randomized and 3 repetitions of each exercise were performed. Mean peak EMG activity in each muscle across repetitions during each exercise was calculated and expressed as a percentage of MVC. Peak normalized EMG activity in each muscle was compared using 2-way (exercise by muscle) repeated-measures ANOVA with post hoc pairwise comparisons if a significant interaction was found.

RESULTS: There was an exercise by muscle interaction effect ($P < .001$). The ulnar deviation exercise selectively activated FCU (40.3%) versus FDS (19.5%, $P = .009$) and PT (21.5%, $P = .022$). Conversely, the pronation exercise selectively activated FDS (63.8%, $P = .002$) and PT (73.0%, $P = .001$) versus FDS (27.4%).

CONCLUSIONS: The ulnar deviation and pronation exercises using elastic band resistance selectively and effectively activated the flexor-pronator mass musculature.

CLINICAL RELEVANCE: The ulnar deviation and pronation exercises using elastic band resistance are practical and effective means of training the flexor-pronator mass. These exercises can be readily prescribed to athletes and patients to improve medial elbow stability during sports performance.

SPL90

RELIABILITY AND VALIDITY OF 2-DIMENSIONAL ANALYSIS OF SINGLE-LEG HOP TESTING AT RETURN TO SPORT AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Two-dimensional (2-D) video analysis is 1 method to assess movement patterns in patients following anterior cruciate ligament (ACL) reconstruction (ACLR) as a part of the return-to-sport (RTS) decision-making process. Reliability and validity of 2-D video analysis has yet to be reported after ACLR. The purpose of this study was to evaluate the interrater reliability and validity of sagittal plane 2-D video analysis during the landing phase of a single-leg hop for distance (SLHD) in patients after ACLR. The tested hypothesis was that 2-D analysis would be a reliable and valid tool to assess SLHD landing kinematics after ACLR at time of RTS clearance.

NUMBER OF SUBJECTS: Sixteen participants after ACLR at time of RTS (mean $\pm$ SD age, 16.3 $\pm$ 2.4 years; mean time from ACLR to RTS, 7.5 $\pm$ 2.4 months).

MATERIALS AND METHODS: Each participant performed a SLHD test in a 3-D motion capture volume. Simultaneous kinematic analysis was performed with a 3-D motion capture system (Motion Analysis Corp.) and 2-D video analysis (Dartfish software). Two clinicians independently measured 2-D sagittal plane trunk, hip, and knee angles at initial contact (IC) and maximum depth (MD) of the center of mass during landing. Measures were taken with 2 methods: (1) using anatomic landmark retroreflective markers and (2) estimating the location of anatomical landmarks, without using the retro-reflective markers. Mean 2-D joint angles and joint excursions were calculated, and validity was determined through comparison to the same variables of interest with 3-D analysis. Interrater reliability and intermethod reliability (with and without markers) was assessed using ICC. Pearson correlations were used to assess the criterion validity of the 2-D measurement of SLHD landing kinematics.

RESULTS: Two-dimensional assessment of SLHD sagittal plane landing kinematics of the trunk, hip, and knee were found to have excellent interrater reliability (all, $P < .001$), with ICCs > 0.90 for all variables both visually estimated and calculated using anatomic markers. When comparing previously identified high risk hip kinematics, 2-D assessment using anatomic marker placement and visual estimation of bony landmarks had moderate correlations to 3-D measures ($r = 0.64$, $P = .033$ and $r = 0.73$, $P = .003$, respectively).

CONCLUSIONS: These data support the hypothesis that 2-D video analysis of SLHD landing is a reliable and valid clinical tool to evaluate movement patterns in patients after ACLR.

CLINICAL RELEVANCE: These data help support the potential widespread use of 2-D video analysis in clinical settings as a means to provide objective measures of movement patterns as part of a RTS assessment after ACLR. Future studies should validate these findings and determine if 2-D mea-

sures of movement quality are associated with the risk of future second ACL injury or other outcomes after ACLR.

SPL91

MONITORING OVERUSE INJURIES IN A COHORT OF COLLEGIATE CROSS-COUNTRY RUNNERS ACROSS A COMPETITIVE SEASON

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PURPOSE/HYPOTHESIS: Musculoskeletal overuse injuries are difficult to predict and a concern in endurance sports due to their complex pathophysiology. Traditional time-loss injury surveillance methods lack the sensitivity needed to capture the ongoing burden of overuse injuries. The Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire was developed to quantify overuse injury burden in sport through monitoring symptoms and their effects on sport participation, training, pain and performance. This study aimed to (1) assess feasibility of the OSTRC in college runners; and (2) report the prevalence and pattern of overuse injuries during a competitive season.

NUMBER OF SUBJECTS: Twenty-nine healthy, college-aged runners (mean $\pm$ SD age, 21 $\pm$ 1 years; 11 female, 18 male).

MATERIALS AND METHODS: Weekly, web-based OSTRC questionnaires were collected for 3 months. Subjects selected up to 2 anatomical areas of greatest concern on the body map and completed the OSTRC. The 4 OSTRC questions were summed weekly to calculate a "severity score" (SS) ranging from 0 to 100, with 0 indicating no problems and 100 indicating maximal consequences due to overuse problem. Subjects had 2 days to complete the questionnaire to avoid recall bias. Feasibility of OSTRC was evaluated with average weekly response rate and number of athletes completing all questionnaires. Total number of overuse problems (SS > 0) and their corresponding areas of concern were identified. Weekly prevalence of overuse problems (SS > 0) and substantial overuse problems were calculated.

RESULTS: Average weekly response rate was 97%, with 25 of 29 (86%) subjects responding to all 12 questionnaires; 242 overuse problems were reported with an average weekly prevalence of 64%. The median SS for all overuse problems was 20 (IQR, 0-28), with an increase in the mean SS over the study. Most commonly reported areas of overuse injury problems were the calf, anterior lower limb, and hamstrings (15%, 13%, and 11% of all cases). Low back injuries represented 8% of all cases. Forty-two injuries were "substantial overuse problems," causing moderate to severe reductions in training/sport performance, or an inability to participate in sport. Fifty-nine percent of subjects reported at least 1 substantial overuse problem during the study.

CONCLUSIONS: This study identified the prevalence and quantified the impact of overuse injuries in collegiate runners. Excellent response rate for the OSTRC questionnaire supported the feasibility of this self-report measure to monitor overuse injury. Unlike prior studies, low back pain was more prevalent in this cohort in comparison to ankle or knee injuries.

CLINICAL RELEVANCE: Effective treatment of overuse injuries begins with accurate and timely detection. This study confirmed the usefulness of the OSTRC for collegiate athletes as it demonstrated high adherence with low burden. OSTRC identified injuries that are not commonly reported with traditional time-loss injury reports in runners.

SPL92

HEAVY SLOW RESISTANCE TRAINING FOR PARTIAL PATELLAR TENDON TEAR IN A DIVISION I SOCCER PLAYER

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BACKGROUND AND PURPOSE: A common source of anterior knee pain is the patellar tendon, especially in activities that place high demands of the knee extensors. Patellar tendinopathy is the most common diagnosis for patellar tendon pain. Without the aid of imaging, a partial tear may be clinically indistinguishable from patellar tendinopathy. The purpose of this case study was to describe the use of heavy slow resistance training

(HSR) for a partial patellar tendon tear using the pain monitoring model for exercise progression and return to sport.

CASE DESCRIPTION: The patient was a 21-year-old female Division I soccer player, with a history of patellar tendinopathy. The patient sustained a noncontact injury when landing from a jump, resulting in severe anterior right knee pain. An MRI revealed a right partial patellar tendon tear. During her initial visit, 1 month after injury, ultrasound evaluation revealed focal thickening, a large hypoechoic region, and loss of collagen fiber organization at the inferior pole of the patella. As these changes may be present in both patellar tendinopathy or partial rupture, HSR was initiated to resolve symptoms and allow the athlete to return to sport. HSR was used for 14 visits over the course of 2 months which included isolated quad strengthening exercises with a 3-second concentric/eccentric phase. Exercise intensity was progressed each visit, allowing her to exercise until a point of 5/10 pain. The performed a self-directed home exercise program for 2 months prior to beginning a graded return to sport progression with supervision from her athletic trainer.

OUTCOMES: At initial evaluation Victorian Institute of Sport Assessment-Patellar Tendon (VISA-P) score was 50, knee extension limb symmetry index (KE-LSI) was 75%, tendon thickness was 0.97 cm, counter movement jump (CMJ) height of 7.73 cm with 1/10 pain, drop countermovement jump (DCMJ) height of 8.56 cm with 1/10 pain, pain with palpation at the inferior pole 6/10. At a 4-month follow-up VISA-P was 40, KE-LSI was 91.4%, tendon thickness was 0.757 cm, CMJ height of 11.93 cm with 3/10 pain, DCMJ height of 11.3 cm with 3/10 pain, pain with palpation at the inferior pole was 2/10. After 5 months of conservative treatment, the patient was cleared to return to sport without limitations.

DISCUSSION: In this case study, the athlete was able to return to sport using a HSR program in coordination with the pain monitoring model. An understanding of the pain monitoring model is integral to using HSR, as the patient was allowed to continue loading as long as pain remained <5/10. Lower extremity function improved evidenced by an increase in height on the CMJ and drop CMJ. A decrease in VISA-P between the initial and 4-month time point suggest that the use of other clinical measures such as muscle performance, pain with palpation and pain with activity should be used to make a true assessment of the athlete's improvement.

SPL93

DOES MECHANISM OF INJURY INFLUENCE PATIENT-REPORTED OUTCOMES AND TREATMENT METRICS IN SHOULDER INSTABILITY PATIENTS?

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PURPOSE/HYPOTHESIS: Previous research indicates that physical therapy is an appropriate intervention for shoulder instability based on postintervention PROs. However, no study has examined differences in PROs and episode-level treatment metrics by mechanism of injury (MOI; sport or nonsport). The purpose of this study was to examine differences in PROs and episode-level treatment metrics by MOI.

NUMBER OF SUBJECTS: Fifty-one patients with shoulder instability (MOI sport, $n = 21$; other, $n = 30$).

MATERIALS AND METHODS: Demographic information and episode-level treatment metrics (CPT codes, visits, and PROs) were extracted from the ATI Patient Outcomes Registry. Additional chart review was completed to confirm diagnosis of shoulder instability, MOI, and baseline irritability. Patients were excluded if the episode of conservative care was less than 2 weeks or if pertinent baseline or episode-level information were unavailable. Separate univariate ANOVAs compared differences between groups for initial and final PENN scores, and episode-level treatment parameters (active, exercise-based units per visit [UPV], manual therapy [MT] UPV, and modality [mod] UPV). Statistical significance was established a priori ($\alpha = .05$).

RESULTS: Shoulder instability with sport MOI demonstrated higher initial PENN compared to other MOI (66.9 ± 20.4 versus 51.7 ± 21.6 , $P = .02$),

respectively. The same was true of final PENN (88.1 ± 15.6 versus 77.5 ± 20.3 , $P = .05$). There was no significant difference in change in PENN ($P = .488$). Episode-level treatment metrics including active physical therapy utilization demonstrated similar active UPV (3.3 ± 0.6 versus 3.1 ± 0.6 , $P = .1866$), MT UPV (0.5 ± 0.5 versus 0.8 ± 0.6 , $P = .098$), mod UPV (0.2 ± 0.5 versus 0.3 ± 0.4 , $P = .3678$), and visits (12.8 ± 5.3 versus 15.6 ± 8.3 , $P = .169$).

CONCLUSIONS: This study demonstrates that patients with sports-related shoulder instability display greater self-reported function at baseline and discharge despite similar intensity and duration of physical therapy treatment than those presenting with other mechanisms of injury. Additional studies will be needed to confirm these results in larger cohorts of shoulder instability patients.

CLINICAL RELEVANCE: Patients with a sport related MOI achieved higher outcome scores at the completion of rehabilitation when compared with patients with nonsport related injury mechanisms. This may indicate that an overall return to higher functional is possible. However, additional studies in this patient population with larger cohorts and longer follow-up will be needed to confirm these results.

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A FEEDBACK STRATEGY FOR PREVENTING NONCONTACT KNEE INJURY IN YOUTH SPORTS

James Michael Hackney

PURPOSE/HYPOTHESIS: High knee flexion torque, insufficient hip flexion, and high knee valgus torque during high-speed sports activities are correlated with a high incidence of noncontact athletic knee pain and injuries. Studies have shown that knee kinematics are modifiable through training. We tested a device dependent exercise program to provide subjects with kinematic feedback in order to decrease knee valgus torque and knee to hip flexion torque ratio.

NUMBER OF SUBJECTS: Subjects were nineteen healthy young adults (11 female) without a history of lower extremity surgery or recent injury: mean $\pm$ SD age, 22.8 ± 0.4 years; body mass, 73.9 ± 18.1 kg; height, 171.3 ± 9.3 cm.

MATERIALS AND METHODS: We used an optical motion capture system and 2 force plates to measure maximum knee valgus torque, and knee and hip flexion torque for a drop jump from a 30-cm platform, before and after a 4-week training period. During the training period, all subjects practiced 2-footed jumping and lateral bounding 4 times per week for 4 weeks. The treatment group ($n = 11$) used the device, which was a bar across their shoulders and nylon stirrups secured to each foot, with latex tubing secured vertically between the bar and the stirrups. The subjects used visual and tactile input from the tubing against their knees as feedback on dynamic knee position during the exercises. This group only also received feedback from an investigator on correct use of the device during each session. We compared pretest to posttest maximum knee valgus torque, and knee to hip maximum flexion torque ratio measured from 5 repetitions of drop jump through paired t test; and posttest-pretest difference scores in maximum knee valgus maximum knee valgus torque and knee to hip maximum flexion torque ratio between the treatment and control groups through independent t tests.

RESULTS: For the treatment group, maximum knee valgus torque decreased an average of 55.5 ± 50.7 Nm ($P = .001$). The maximum knee to hip flexion torque ratio decreased $69\% \pm 94\%$ ($P < .001$). The data also showed a trend for decreasing knee valgus torque, with mean decrease of 18.4 ± 49.4 Nm ($P = .11$), and significance for decreasing the knee to hip flexion torque ratio $67\% \pm 137\%$ ($P = .001$) compared to subjects exercising independently without a device.

CONCLUSIONS: After a 4-week supervised session of exercising with the device and feedback, subjects showed a significant decrease in maximum knee valgus torque and knee/hip flexion torque ratio during drop jump compared to pretest, and decrease in knee/hip flexion ratio compared to a control group.

CLINICAL RELEVANCE: The modifications observed in knee kinematics may help decrease risk of noncontact knee injury in youth sports that include jumping, landing, or bounding-type tasks.

SPL95

STIFFNESS OF THE FOREARM FLEXOR-PRONATOR MUSCLE MAY REDUCE STRESS ON THE ULNAR COLLATERAL LIGAMENT

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PURPOSE/HYPOTHESIS: Medial elbow injury is common among baseball players. It has been reported that more than 60 pitches increase medial elbow joint space gapping, but the effect on medial elbow stabilizers is not known. Our hypothesis was that repetitive pitching would reduce the stiffness of medial elbow stabilizers. The purpose of this study was to investigate medial elbow joint space gapping and the stiffness of the ulnar collateral ligament (UCL) and the forearm flexor-pronator muscle (FPM) during repetitive pitching, and the factors that relate to the change of these tissues.

NUMBER OF SUBJECTS: Thirty.

MATERIALS AND METHODS: Thirty high school baseball players participated in this study (mean $\pm$ SD age, 16.6 ± 0.5 years). Each participant pitched 100 times (5 sets of 20 pitches). Medial elbow joint space gapping and the strain ratio of the UCL and FPM as stiffness of tissue were measured using ultrasound before pitching and after each 20-pitch set. The Friedman test was used to compare these parameters between before pitching and after each 20-pitch set. Furthermore, multiple regression analysis was used to investigate the factors that relate to the change rate of strain ratio.

RESULTS: The average of the maximum ball velocity in participants was 69.0 ± 3.6 mph. Medial elbow joint space gapping (millimeters) more than 60 pitches were significantly greater than that before pitching (before pitching, 4.40 ± 0.63 ; 60, 80, 100 pitches: 4.93 ± 0.67 , 5.08 ± 0.69 , 5.25 ± 0.73 ; $P < .05$). The strain ratio of the UCL after 100 pitches was significantly less than that before pitching (before pitching, 4.84 ± 1.70 ; 100 pitches, 3.59 ± 1.35 ; $P < .05$). In the strain ratio of the FPM, there was no significant difference after 100 pitching (before pitching, 0.57 ± 0.24 ; 100 pitches, 0.43 ± 0.18 ; $P = .07$). The factors that significantly relate to the change rate of UCL were the ratio of strain ratios (UCL/FPM) before pitching ($r = -0.526$, $P < .01$), the shoulder internal rotation range of motion (ROM) at 90° abduction ($r = -0.428$, $P < .05$), and the elbow flexion ROM ($r = -0.506$, $P < .01$). Multiple regression analysis demonstrated that the UCL/FPM strain ratio before pitching ($\beta = -0.385$, $P < .05$) and the elbow flexion ROM ($\beta = -0.352$, $P < .05$) were significantly and independently correlated with the change rate of UCL.

CONCLUSIONS: Medial elbow joint space gapping after 100 pitches increased compared to that before pitching, and that result was similar to previous studies. Although the stiffness of FPM did not change during 100 pitches, that of UCL significantly reduced after 100 pitches. Furthermore, the UCL/FPM strain ratio before pitching and the elbow flexion ROM were significantly related to the change rate of the UCL stiffness.

CLINICAL RELEVANCE: Because more than 100 pitches cause an immediate change in UCL, excessive repetitive pitching should be avoided to prevent UCL injury. Furthermore, (1) keeping the FPM hard against the UCL and (2) keeping the muscle volume large to avoid excessive elbow flexion ROM may prevent immediate changes in UCL during repetitive pitching.

SPL96

COMPARISON OF BLOOD FLOW RESTRICTION DEVICES AND THEIR EFFECT ON QUADRICEPS MUSCLE ACTIVATION

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PURPOSE/HYPOTHESIS: To determine the differences in acute muscle activa-

tion of the quadriceps during unilateral knee extension using traditional resistance exercise and 2 types of blood flow restriction (BFR) devices.

NUMBER OF SUBJECTS: Thirty-four healthy subjects (16 female) with at least 1 year of resistance training experience and no recent history of lower extremity neuromusculoskeletal injury.

MATERIALS AND METHODS: All participants completed three, randomized sessions of resisted knee extensions. Exercise sessions were: (1) control (C) at 80% of 1-repetition maximum (1RM), (2) regulated BFR at 30% 1RM using the Delfi Personalized Tourniquet System (R) and (3) standardized BFR at 30% 1RM using the B-Strong device (S). Session C involved 4 sets of leg extensions with a repetition (reps) progression of 8, 8, 6, and 6 at a self-selected cadence and 2 minutes rest between sets. Both BFR sessions used a reps sequence of 30, 15, 15, and 15 with a metronome paced cadence of 2 seconds for each concentric and eccentric contraction and 30 seconds of rest between sets. Isokinetic dynamometry (ID) was used to determine 1RM. Knee extension maximal voluntary isometric contraction (MVIC) was performed at 60° knee flexion via ID prior to each test session. EMG activity of the vastus lateralis, rectus femoris, and vastus medialis were recorded throughout each exercise session. EMG values were composed of the average of the middle 50% of reps (ie, reps 3-10 for the BFR conditions and reps 2-4 or 3-6 for the C condition) and calculated as percent activation normalized to MVIC. Numeric pain rating and rating of perceived exertion were reported for each exercise condition. A series of 2-by-3-by-3 (gender by training type by set) MANOVAs were conducted to examine effects on average and peak values of VMO, VLO, and RF muscle activity. Differences in NPRS and RPE between exercise conditions were determined by repeated measures ANOVA.

RESULTS: No significant differences ($P > .05$) in average or peak EMG activation were found between S and R sessions for any of the muscle groups; however, C sessions showed significantly greater average and peak EMG than both S and R ($P < .001$). Secondary findings revealed NPRS to be significantly greater in R sessions compared to S ($P < .001$) and C ($P < .001$), and in S sessions compared to C sessions ($P < .001$). RPE was significantly greater in the R sessions compared to the S ($P < .02$) and C ($P < .001$), and in S compared to C ($P < .02$). Results did not significantly vary by gender.

CONCLUSIONS: During isolated knee extension, both regulated and standardized BFR devices produced significantly less quadricep muscle activation when compared to traditional high resistance exercise. In addition, both BFR conditions resulted in greater self-perceived pain and exertion when compared to the traditional protocol.

CLINICAL RELEVANCE: These findings may influence selection of BFR devices for clinical practice. While muscle activation is similar between device types while patient reported pain and exertion vary significantly and may affect adherence to treatment and patient outcomes.

SPL97

CUFF FOR THE CUFF: BLOOD FLOW RESTRICTION FOR STRENGTHENING OF THE SHOULDER

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PURPOSE/HYPOTHESIS: Those undergoing orthopaedic surgery and/or experiencing periods of immobilization due to sports injuries are known to experience muscle atrophy along with decreased strength and function. Unfortunately, little can be done to minimize immediate postsurgical atrophy due to the inability to adequately load the injured limb(s). Blood flow restriction (BFR) therapy utilizes a specialized tourniquet cuff, restricting distal blood flow (50%-80% arterial occlusion) via compression. When combined with low-intensity exercise ($<30\%$ 1-repetition maximum), BFR has been shown to mimic/produce some of the same favorable effects as high-intensity exercise, but at a greatly reduced load (and subsequent reinjury risk) that can be performed in the early stages of rehabilitation. As BFR therapy is becoming popularized in sports rehabilitation, current therapy protocols are based on limited data from short-

term investigations and adequate longitudinal studies are lacking. More importantly, rehabilitation and injury prevention protocols for the upper extremity/shoulder are currently underdeveloped and limited beyond anecdotal reporting. While promising results have been reported for the use of BFR for upper body rehabilitation, no studies have evaluated the effects of BFR therapy on the rotator cuff, specifically. While proximal to the tourniquet cuff, previous review literature has proposed that enhanced motor unit activation of the proximal musculature may, in part, contribute to enhanced proximal benefit as muscles distal to the tourniquet become fatigued as a result of occlusion. Based on previous literature and clinical observations, we hypothesized that a combination of BFR and low intensity rotator cuff training would elicit greater increases in rotator cuff strength and endurance compared to standard low-intensity resistance training alone. Additionally, we hypothesized that BFR would elicit greater activation of the proximal shoulder musculature during acute exercise.

NUMBER OF SUBJECTS: Twenty-nine healthy, untrained adults (19 male: mean $\pm$ SD age, 31 ± 3 years; height, 178 ± 3 cm; weight, 80 ± 7 kg; 10 female: age, 30 ± 4 years; height, 169 ± 3 cm; weight, 79 ± 5 kg) were recruited, consented, and randomized into 2 groups (BFR-Rx, NoBFR-Rx). Participants were selected from the surrounding community who had not been performing more than 1 day per week of upper body resistance exercise.

MATERIALS AND METHODS: Groups performed 8 weeks of low intensity resistance training (2 per week) using 4 rotator cuff exercises: cable external rotation (ER), cable internal rotation (IR), dumbbell scaption, and sidelying dumbbell ER; 20% 1RM; 1 set/30 reps followed by 3 sets/15 reps (30 seconds of rest between sets, 2 minutes of rest between exercises, increased 1 lb of resistance each week if all repetitions achieved). For the final set of each exercise, participants performed repetitions to fatigue. All exercises were performed in a single limb followed by the contralateral limb. Order of limb training (dominant/nondominant) alternated every other session. For the BFR-Rx group, BFR was applied to using an automated tourniquet system (Delfi) that maintained 50% limb occlusion pressure during each exercise with pressure released between exercises. Using the BFR device, optimal limb occlusion pressures were reassessed and applied for every session for each individual participant. Maximal rotator cuff strength was assessed before and after 8 weeks of training. Strength assessment was performed by a trained physical therapist (blinded to treatment group) using a hand held dynamometer for the following: shoulder flexion, scaption, internal rotation, and external rotation (0° and 90°). Muscular endurance was assessed by recording the total achievable exercise volume (sets by repetitions by weight) that participants could achieve during each week of training. Shoulder and rotator cuff activation during acute exercise was assessed before and after training. All participants performed a single set to fatigue with and without BFR applied at 20% 1RM for the following: cable IR, cable ER, dumbbell scaption. Activation was assessed using wireless surface EMG (Delsys) placed on the anterior, middle, and posterior deltoid muscles as well as the infraspinatus, teres minor, and upper trapezius muscles. Site-specific lean muscle mass was measured in the whole arm and shoulder before and after training using DEXA (iDXA, GE). A group-by-time ANCOVA (covaried on baseline measures) repeated on time followed by a Tukey post hoc test was used to detect absolute and relative changes in strength (pre-post training), lean mass (pre-post training; DEXA, GE), and achieved weekly exercise volume (sets by reps by resistance). A 2-tailed paired-samples t test was used to detect differences in RC muscle activation (EMG, Delsys) recorded during ER and IR fatigue tests in all subjects. Type I error was set at $\alpha = .05$.

RESULTS: Significant improvements from baseline ($P < .05$) were found in maximal strength for dominant/nondominant scaption and external rotation (0°), dominant internal rotation (90°), and nondominant external rotation (90°). Strength improvements in dominant external rotation (90°) and nondominant internal rotation (90°) were greater in the BFR group.

Muscular endurance improvements were significant across all exercises, favoring the BFR group. Muscle mass was increased in both groups, but significantly higher for the BFR group in both shoulder lean mass and total arm lean mass. Muscle activation during exercise was also found to be greater in the middle deltoid and teres minor for the BFR group.

CONCLUSIONS: The present results indicate that BFR may be effective in shoulder and rotator cuff strengthening when applied during common rotator cuff exercises. This is inferred from (1) greater increases in maximal strength on primarily the dominant side; (2) greater overall increases in muscular endurance and achievable exercise volume; (3) greater increases in arm/shoulder lean muscle mass in the BFR training group. We hypothesize that the results are, in part, attributable to greater activation of deltoid and rotator cuff muscles observed during EMG testing.

CLINICAL RELEVANCE: The present results provide considerable support for utilizing BFR for preventative shoulder strengthening. These findings also provide support for future research on the utility of BFR for rehabilitation from both operative and nonoperative rotator cuff injuries. Lastly, further research is needed to determine how BFR-assisted rotator cuff strengthening may improve upper body performance during overhead activities or in the injured population.

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HIP STRENGTH PROFILES AMONG BANTAM, HIGH SCHOOL, JUNIOR, AND COLLEGIATE AMERICAN HOCKEY PLAYERS

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PURPOSE/HYPOTHESIS: Adductor strains are the most common noncontact musculoskeletal injury in hockey. An adduction-to-abduction strength ratio of 90% to 100% and adduction strength equal to the uninjured side have been proposed as suitable milestones for return-to-sport following groin injuries. Additional research found a seventeen-fold increase in the likelihood of groin strains if the adductor-to-abductor ratio was less than 80%. No research has investigated hip strength profiles across various levels of hockey players. The purpose of this study was to compare isometric hip adduction and abduction strength across various levels of play and factors that may contribute to groin strains.

NUMBER OF SUBJECTS: Eighty-seven.

MATERIALS AND METHODS: Seventeen bantam, 29 high school varsity, 22 tier 1 juniors, and 19 Division I NCAA collegiate players, mean age 17 years, were included. A questionnaire of demographic data, hockey and injury specific information was completed. Maximal hip isometric adduction and abduction strengths were quantified using a handheld dynamometer (MicroFET 2 by Hoggan Scientific) with external belt fixation. Data were normalized for respective teams prior to analysis.

RESULTS: No statistically significant differences were found between peak hip adduction and abduction isometric strength and playing level. There was no significant difference between unilateral strength and shooting hand or leg dominance. Athletes (34.5%) in this study reported a history of groin strains, but no difference existed in strength ratios. Three participants were found to have unilateral ratios of less than 80% (78.69%, 72.27%, and 69.41%), while 2 participants recorded bilateral strength ratios of less than 80% (right, 64.52%; left, 78.75%; right, 49.15%; left, 61.54%). Three of the 5 "at risk" participants had a history of groin strains. Of those with left sided adductor-to-abductor ratios of less than 80%, all reported being right leg dominant and shooting left handed. Mean hip adductor-to-abductor strength percentage ratios per level were also assessed with results as follows: Bantam, 121%; High School, 109%; Tier 1 Juniors, 111%; and Division I, 115%.

CONCLUSIONS: This is the first study to assess hip strength profiles across various levels of hockey play. Symmetry is illustrated between dominant and nondominant legs in hockey players with and without a history of groin strains. Data collected aligns well with previously established cross-sectional data from Australian football, with ratios of 103% in high school players, 107% in semi-professional players, and 113% in collegiate players.

This contradicts previously proposed milestones of obtaining adductor-to-abductor ratio of 90% to 100% prior to returning to hockey as adductor dominance was demonstrated in this study.

CLINICAL RELEVANCE: This study provides data supporting the ability to use the uninjured leg as a baseline for strength during return-to-sport progression following a groin injury as well as symmetry between dominant and nondominant kicking leg in hockey players across various levels of play. Further research is needed to determine accurate risk cutoffs in predicting groin strains through isometric strength testing.

SPL99

NORMATIVE DATA FOR THE NEUROCOM SENSORY ORGANIZATION TEST IN US MILITARY ACADEMY CADET BOXERS

Nathan Eric Henry

PURPOSE/HYPOTHESIS: To establish normative values for the SOT in a young, healthy, and active military population for use in future studies.

NUMBER OF SUBJECTS: Two hundred fifty-three.

MATERIALS AND METHODS: Two hundred fifty-three (70 female, 183 male) cadets in a boxing course at West Point, NY were enrolled. The participants were evaluated on the SOT using the NeuroCom Balance Manager (Natus Medical Inc, Seattle, WA). Participants performed the SOT and each condition, composite (COMP) score, and ratio score were recorded.

RESULTS: No significant differences were observed in SOT COMP scores between females (COMP, 76.67 ± 7.25) and males (COMP, 76.57 ± 7.77), nor between participants with history of concussion (COMP, 75.83 ± 7.90) versus those never concussed (COMP, 76.75 ± 7.57).

CONCLUSIONS: This study provides SOT reference values for young, healthy, active individuals, which will assist in the interpretation of individual scores for concussion diagnosis and recovery, as well as baseline data for future studies. These data of 17- to 23-year-olds fill the gap between currently available normative values of 14- to 15-year-olds and 20- to 59-year-olds.

CLINICAL RELEVANCE: This study is the first to provide normative values for the SOT in a young, active, healthy, military population. Sample size exceeds those used to provide the current normative values for all other age groups. These data may stand as a reference standard for military providers to allow meaningful comparisons in future studies and possibly against other devices.

SPL100

EFFECTS OF AN 8-WEEK CORE STABILITY PROGRAM ON ATHLETIC PERFORMANCE IN ADOLESCENT VOLLEYBALL PLAYERS

Ashley Marie Jefferson, Andrew Joseph Ford, Aaron Jacob Brown, Bryson Cain Platt, Paul Benedict Lonnemann, Norman Wayne Ayotte

PURPOSE/HYPOTHESIS: As volleyball becomes an increasingly popular sport for adolescent female athletes, more competitive, year-round participation is leading to repetitive stress on joints and muscles. With less recovery time, this may result in decreased performance and increased overuse injuries. Poor core stability is a modifiable risk factor among adolescent athletes. By increasing core stability, 1 would presumably increase postural and dynamic control and, therefore, increase athletic performance and decrease risk for overuse injuries of the shoulder, back, and knee. The purpose of this study is to determine the effects of an 8-week core stability program on athletic performance and injury prevention in female, adolescent volleyball players.

NUMBER OF SUBJECTS: Seventy-one healthy adolescent volleyball players (mean age, 13.72 years; height, 163.25 cm; weight, 58.55 kg).

MATERIALS AND METHODS: Participants were between 12 and 15 years old, currently healthy and able to fully participate in club volleyball. To improve compliance and reduce the risk of bias, whole teams were recruited for participation in the study. Three teams from each age division 13-15 were recruited and divided by age into a control group (CON) ($n = 26$), a control group with a supplemental strength and conditioning program

(CON-T) ($n = 20$) or the experimental group (EXP) ($n = 25$). The experimental group participated in a one-hour core stability program before or after their regular practice twice per week for 8 weeks. Baseline testing consisted of Y-Balance Test-upper quarter (YBT-UQ), Y-Balance Test-lower quarter (YBT-LQ), jump height (JH), and spike velocity (SV). Testing order was randomized and completed at baseline and 8 weeks. SPSS statistical software was used to complete a repeated measure analysis and descriptive statistics.

RESULTS: There was a statistically significant effect of time for all groups ($F_{2,68} = 61.11, P < .001$). Significant improvements in Left YBT-UQ composite was observed between the EXP and CON-T (6.1 ± 2.0 ; 95% CI: 6.0, 10.1) and between CON and CON-T (5.5 ± 2.0 ; 95% CI: 1.4, 9.5).

CONCLUSIONS: All 3 groups improved in core strength and athletic ability over 8 weeks showing significant, within group, positive changes. The experimental group made significant gains in core strength compared to the control-travel group. All other comparisons, though appearing to be greater in the experimental group regarding core strength, were not statistically significant.

CLINICAL RELEVANCE: This research contributes to evidence-based practice of prehabilitation and sports performance training to increase athletic ability of adolescent, female volleyball players. Clinicians can observe the benefits of using an 8-week program to increase core strength and stability, and using sport-specific exercise. Also, researchers can better understand which factors to analyze in future investigations that may result in the most remarkable positive or negative changes in athletic performance.

SPL101

STARTING BASEBALL PITCHING AGE IS CORRELATED WITH HUMERAL RETROTORSION IN PITCHERS WITH AN ULNAR COLLATERAL LIGAMENT INJURY

Sean Michael Kennedy, James Craig Garrison, Joseph Patrick Hannon, Kalyssa Creed, John E. Conway

PURPOSE/HYPOTHESIS: Humeral retrotorsion (HRT) and its relationship to baseball players with a UCL tear has previously been established in the literature. Recent published work has demonstrated a potential watershed age for HRT development. The purpose of this study was to investigate the relationship between HRT and participant reported starting pitching age in baseball pitchers with a UCL injury.

NUMBER OF SUBJECTS: Eighty-four baseball pitchers diagnosed with a UCL injury were divided into 2 groups based upon the median age at which participants began pitching. Thirty-three players reporting a starting pitching age ≥ 10 years old (group 1: mean $\pm$ SD age, 17.5 ± 2.1 years; height, 182.6 ± 8.1 cm; weight, 80.5 ± 14.9 kg; years of playing experience, 12.4 ± 2.6 ; age started pitching, 10.9 ± 1.3 years) were compared with 51 baseball pitchers reporting a starting pitching age < 10 years old (group 2: age, 17.3 ± 2.2 years; height, 185.2 ± 8.0 cm; weight, 83.4 ± 13.0 kg; years of playing experience, 12.5 ± 2.2 ; age started pitching, 8.5 ± 0.64 years). A previous study has identified 10 years of age as a potential watershed age for the development of HRT.

MATERIALS AND METHODS: Participants had a primary diagnosis of a UCL tear diagnosed by a fellowship-trained, board certified orthopaedic surgeon and confirmed via magnetic resonance imaging. Testing of HRT for participants was performed at the time of diagnosis of a UCL injury during the initial visit to the outpatient sports medicine facility. Participant's dominant limb retrotorsion (D HRT) and nondominant limb retrotorsion (ND HRT) were measured using a previously established diagnostic ultrasound technique. Two trials were completed for D HRT and ND HRT while the primary examiner was blinded from the measured HRT value. Independent t tests were run to compare mean group differences of starting pitching age, age at time of injury, D HRT, ND HRT, and humeral retrotorsion difference (HRTdiff).

RESULTS: There were no significant differences between groups in regards to age, height, weight or playing years experience. There was a statisti-

cally significant difference in participant reported starting pitching age (group 1, 10.9 ± 1.3 years; group 2, 8.5 ± 0.6 years; $P \leq .00001$). Significant differences between groups were noted for D HRT (group 1, $20.0^\circ \pm 9.4^\circ$; group 2, $14.5^\circ \pm 10.3^\circ$; $P = .015$) and for ND HRT (group 1, $38.6^\circ \pm 8.8^\circ$; group 2, $32.9^\circ \pm 9.5^\circ$; $P = .007$). No significant differences between groups were found for HRTdiff (group 1, $-18.6^\circ \pm 11.0^\circ$; group 2, $-18.5^\circ \pm 9.3^\circ$; $P = .940$).

CONCLUSIONS: Baseball pitchers with a UCL injury who reported a starting pitching age before 10 years of age demonstrated significantly greater D HRT and significantly less ND HRT when compared to UCL-injured baseball pitchers who reported a starting pitching age at 10 years old or later.

CLINICAL RELEVANCE: The results from the current study suggest humeral retrotorsion in baseball pitchers with a UCL injury is related to the age in which players began pitching. Osseous changes should be considered in the screening and treatment of baseball pitchers with a UCL injury.

SPL102

BASEBALL PLAYERS FOLLOWING ULNAR COLLATERAL LIGAMENT RECONSTRUCTION DEMONSTRATE DECREASED SHOULDER STRENGTH COMPARED TO HEALTHY CONTROLS

Brooks Klein, Joseph Patrick Hannon, James Craig Garrison, Kalyssa Creed, John E. Conway

PURPOSE/HYPOTHESIS: The purpose of this study was to examine shoulder external rotation (ER) and internal rotation (IR) strength in baseball players after ulnar collateral ligament reconstruction (UCLR) at time of release from medical care compared to healthy controls. We hypothesized that baseball players following UCLR would have no difference in shoulder strength when compared to healthy controls.

NUMBER OF SUBJECTS: Forty-three participants who were post-UCLR (mean $\pm$ SD age, 18.05 ± 1.69 years; height, 1.86 ± 0.06 m; weight, 87.3 ± 9.4 kg) and 43 healthy controls (age, 19.72 ± 1.58 years; height, 1.86 ± 0.07 m; weight, 87.0 ± 10.4 kg) participated. All participants played baseball at the high school or collegiate level. Participants in the post-UCLR group were at least 5 months from time of surgery (194 ± 30 days).

MATERIALS AND METHODS: Participants in the UCL group were identified during regularly scheduled visits to the participating physician and/or physical therapist. Once participants in the UCL group were discharged from medical care, objective measurements of shoulder strength were taken. Strength measurements were taken prior to the fall baseball season for participants in the control group. Isometric shoulder ER and IR strength measurements were performed using handheld dynamometer with the arm held to the side at 0° of shoulder abduction. All measurements were taken bilaterally and the means of throwing and nonthrowing arms for ER and IR in the UCL group were compared to the means of the throwing and nonthrowing arms in the healthy group. Independent t tests were used to calculate mean group differences for shoulder ER and IR strength between groups ($P < .05$).

RESULTS: No significant differences were found between groups for nonthrowing shoulder ER (UCLR, 116.8 ± 20.2 N; healthy, 110.1 ± 18.1 N; $P = .143$) or IR (UCLR, 149.9 ± 24.2 N; healthy, 149.9 ± 26.4 N; $P = .994$) strength. No significant difference was found between groups for throwing shoulder ER strength (UCLR, 117.9 ± 25.8 N; healthy, 116.5 ± 19.0 N; $P = .921$). However, baseball players post-UCLR produced significantly less force on shoulder IR compared to healthy controls (UCLR, 144.2 ± 27.8 N; healthy, 157.6 ± 27.1 N; $P = .023$).

CONCLUSIONS: Baseball players post-UCLR at time of release from medical care have lower throwing shoulder IR strength compared to healthy controls.

CLINICAL RELEVANCE: While throwing shoulder ER and IR strength deficits have been found at time of UCL injury, only shoulder IR strength deficits persist at time of release from medical care. Clinicians should include shoulder IR strengthening in rehabilitation for baseball players following UCLR to normalize throwing shoulder IR strength compared to healthy controls.

SPL103

THE INFLUENCE OF PAIN ON ROTATOR CUFF CROSS-SECTIONAL AREA

Dirk Jacob Kokmeyer

PURPOSE/HYPOTHESIS: Rotator cuff weakness is a common finding in patients with shoulder pain. Weakness may be a result of aging, neuropathy, full-thickness rotator cuff tearing, decreased voluntary activation due to inhibition, or muscle atrophy. Rotator cuff atrophy is not uncommon in the presence of a rotator cuff tear but can also be seen in aging populations and overhead athletes with intact rotator cuffs. The primary aim of this study was to compare the cross-sectional area (CSA) of the supraspinatus (SS) and infraspinatus (IS) muscles and SS tendon thickness between painful and nonpainful shoulders. Secondarily, we aimed to determine if there was a difference in SS and IS CSA between dominant and nondominant shoulders. Last, we explored the relationship of SS and IS CSA to rotator cuff endurance and isometric strength. We hypothesized that there would be a significant difference in the CSA between dominant and nondominant shoulders and between painful and nonpainful shoulders. Furthermore, we believed that age and weight would covary with muscle CSA. We also hypothesized that there would be a significant difference in muscle CSA, strength and endurance in painful and nonpainful shoulders based on chronicity of pain; however, we did not believe we would discover a difference in endurance and strength between nonpainful dominant and nondominant shoulders.

NUMBER OF SUBJECTS: Twenty-four subjects were recruited for this study. Twelve right hand dominant subjects with unilateral, right shoulder pain were recruited into the shoulder pain group. Subjects were excluded if they were found to have a full-thickness rotator cuff tear. Twelve healthy controls matched by gender, age, height and weight were recruited into the nonpainful control group.

MATERIALS AND METHODS: This was a cross-sectional study. Demographic information, the PENN shoulder score and the modified Constant score were collected at the time of testing. All subjects underwent a diagnostic ultrasound evaluation of bilateral shoulders to determine the CSA of the SS and IS muscles, and tendon thickness. Additionally, shoulder endurance and isometric strength were evaluated with hand-held dynamometry and the posterior shoulder endurance test (PSET).

RESULTS: Independent-samples t tests found no significant differences in age, height or weight between groups ($P < .05$). Two-by-two mixed-model analyses of variance (ANOVA) found no significant differences in SS and IS CSA and SS tendon thickness between painful and nonpainful shoulders, and between dominant and nondominant shoulders in all subjects ($P > .05$). However, there were significant differences shoulder strength and endurance between painful shoulders and nonpainful shoulders in the painful group and the painful shoulder in the shoulder pain group and the dominant and nondominant shoulders in the control group ($P < .05$).

CONCLUSIONS: This study showed that there is no significant difference in SS and IS CSA and SS tendon thickness between subjects with moderate shoulder pain and disability and nonpainful shoulders. Additionally, differences between dominant and nondominant shoulders were not found. The results of this study suggest that rotator cuff weakness in subjects with moderate shoulder pain and intact rotator cuffs is not due to decreased rotator cuff CSA.

CLINICAL RELEVANCE: Individuals classified with moderate tissue irritability of the shoulder may benefit more from interventions aimed at reducing pain than improving strength.

SPL104

DOES BLOOD FLOW RESTRICTION DURING SQUATTING IMPACT WEIGHT-DISTRIBUTION SYMMETRY IN HEALTHY INDIVIDUALS

Lukas Krumpl, Michael Rosenthal

PURPOSE/HYPOTHESIS: The purpose of this study was to determine the effect of unilateral and bilateral blood flow restriction (BFR), during weighted squatting, on symmetry of lower extremity (LE) weight distribution.

NUMBER OF SUBJECTS: Thirty healthy individuals (15 female) participated in the study.

MATERIALS AND METHODS: A within-subjects experimental design was used. Participants were required to have at least 6 months of LE resistance training or 1 year of level I or level II sports, and a minimum score of 2 on the FMS Deep Squat. Exclusion criteria included: LE injury in the past year, medical precautions to performing BFR exercise, or prior use of BFR. Participants completed 3 sessions of bilateral squatting with 5 to 7 days between test sessions. Weight used during squatting was 20% of 1.5 times the participants' body weight. Squats were performed on a 1.25-m Noraxon pressure platform with identical sets and repetitions (30, 15, 15, 15, with 30 seconds of rest between sets) at each test session. BFR sessions were conducted using the Delfi Personalized Tourniquet System. A self-paced 5-minute stationary bike warm-up was completed prior to test sessions. Session 1 included height and weight measurements, an FMS Deep Squat analysis, determining dominant LE, and performing the protocol without the use of BFR (control condition, C). Participants were then randomly assigned to unilateral (U) or bilateral (B) BFR at the second session, with the third session being the other BFR condition. Dominant versus nondominant average (Av) weight distribution and peak (Pk) vertical ground reaction forces (vGRF) were recorded using myoPRES-SURE software. Data were evaluated for statistical significance within and between conditions via SPSS using a repeated measures ANOVA. Pearson correlation coefficient analysis assessed the relationship between weight distribution and ground reaction forces.

RESULTS: A 1-way repeated-measures ANOVA analysis revealed a statistically significant difference in Av LE weight distribution between the C and U BFR conditions ($P = .026$). No significant differences in weight distribution were found between the C and B conditions, nor between U and B conditions. No significant differences in Pk vGRF were present between conditions. Pearson correlation analysis showed moderate positive relationships between the difference in weight distribution and the difference in vGRF ($r = 0.48-0.58$).

CONCLUSIONS: Squatting with unilateral BFR produced asymmetric LE weight-distribution with a shift in weight to the non-BFR extremity. Squatting with bilateral BFR produced LE weight distribution similar to squatting without BFR.

CLINICAL RELEVANCE: Utilization of unilateral BFR in squatting produces a weight shift to the non-BFR training LE and may contribute to an undesired movement pattern. Simultaneous BFR, on bilateral LE, negates the asymmetrical weight shift and should be considered a more appropriate method to promote weight bearing symmetry during LE BFR exercise.

SPL105

PREOPERATIVE HOP PERFORMANCE RELATED TO POSTOPERATIVE FUNCTION FOLLOWING HIP ARTHROSCOPY FOR FEMOROACETABULAR IMPINGEMENT SYNDROME

Chelseana Chantal Lahman, Kathryn Reid Martin, Lindsey Brown, Stephanie Di Stasi

PURPOSE/HYPOTHESIS: Functional performance measures are increasingly popular in physical therapy to predict patient outcomes; however, their preoperative utility remains unclear for athletes with femoroacetabular impingement syndrome (FAIS). The purpose of this study was to compare self-reported function after hip arthroscopy between those with and without optimal hop performance prior to surgery. We hypothesized that better preoperative hop performance would be associated with better postoperative patient-reported function.

NUMBER OF SUBJECTS: Thirty-five athletes with FAIS preparing for hip arthroscopy (18 female; mean $\pm$ SD age, 24 ± 10.1 years; BMI, 25.4 ± 5.7 kg/m²) participating in running, cutting, pivoting activities prior to symptoms of FAIS.

MATERIALS AND METHODS: Subjects completed the Hip Outcome Score Sports Subscale (HOS-S) and performed the single-leg hop (SLH) test on

their involved limb preoperatively and 6 months postoperatively. Maximum distance hopped, normalized to height, was used for analysis. Subjects were dichotomized into high (>0.70) and low (<0.70) performers based on their preoperative hop performance using previously published healthy control data. Frequency counts for athletes achieving >0.70 hop distance were reported. General estimating equations for a general linear model were used to test the interaction between time and baseline hop performance on postoperative HOS-S scores. If significant interactions were identified ($P < .05$) HOS-S scores were compared between groups at baseline, postoperative, and over time separately for each group. The minimal clinically important difference (MCID) for the HOS-S (6 points) was used to determine if subjects improved from preoperative to postoperative, and to compare differences between groups. The Patient Acceptable Symptomatic State (PASS; 75 points) was used to identify participants who achieved a satisfactory postoperative functional state.

RESULTS: Twenty-seven of the 35 subjects completed SLH testing preoperatively. Nine were lost to follow-up ($n = 8$) or did not complete a baseline HOS-S ($n = 1$). Of the remaining 18 participants, 72% were categorized as high performers prior to surgery. There was a significant interaction of time by hop performance for HOS-S scores ($P = .01$). Only the high performers demonstrated a significant improvement in HOS-S scores from preoperative (57.8 ± 20.1) to postoperative (77.0 ± 21.9 , $P = .005$), whereas the low performers did not demonstrate significant improvements (pre, 53.4 ± 21.7 ; post, 65.0 ± 27.0 ; $P = .51$).

CONCLUSIONS: Subjects with better hop performance prior to surgery demonstrated greater improvements in self-reported hip function than low performers. Although nonsignificant, both groups on average improved by at least the MCID on the HOS-S; high performers demonstrated greater improvements. Postoperative HOS-S for the high performers was on average 12 points greater than low performers. Only the high performers demonstrated a postoperative HOS-S average that exceeded the PASS value.

CLINICAL RELEVANCE: Despite low self-reported sports function, most subjects were high performers on the SLH test prior to surgery. Low preoperative hop distance may be related to persistent sports-reported sports limitations postoperatively.

SPL106

RUNNING READINESS SCALE AND INJURY IN COLLEGIATE TRACK-AND-FIELD ATHLETES: A PILOT STUDY

Lace Elly Luedke, Nickolas J. Freitag

PURPOSE/HYPOTHESIS: Track and field is one of the most popular NCAA sports, but track and field athletes have high rates of overuse injuries to the lower quadrant. The Running Readiness Scale (RRS) is a series of 5 clinical tests assessing lower extremity and trunk function initially established as a tool to help determine whether runners who were previously injured are ready to return to running. The purpose of this study was to determine if there was a difference in RRS scores in running athletes who experienced a lower quadrant injury during the track and field season and those who did not sustain an injury. We hypothesized that athletes with lower (ie, worse) RRS scores would have a higher risk of injury.

NUMBER OF SUBJECTS: Thirty-nine NCAA Division III track and field athletes in running, jumping and vaulting events (15 female, 24 male; mean $\pm$ SD age, 20.3 ± 1.3 years). Throwers were excluded.

MATERIALS AND METHODS: Athletes completed a survey on demographics and prior injury, and then had their RRS performance assessed at the start of their competitive season. The RRS consists of 5 one-minute tests with 30 seconds of rest between tests: vertical double-leg hops, prone plank, step-ups, single-leg squats, and wall sit. Step-ups and single-leg squats were performed for 30 seconds on each leg. Based on specified form elements, each test was rated pass or fail with possible cumulative RRS scores of 0 to 5 (5 is passing all tests). Ten athletes were each assessed by the 2 testers to calculate intertester reliability values. Athletes

were followed by the athletic training staff during the season for occurrences of lower-quadrant injuries that resulted in missing 1 or more practices or meets. *t* tests were used to assess mean differences of continuous variables between injured and uninjured athletes. Odds ratios (ORs) and 95% confidence intervals (CIs) were used to assess injury risk.

RESULTS: Interrater reliability values were substantial ($\kappa = 0.70$) for total RRS scores and ranged from moderate to perfect for individual tests ($\kappa = 0.41$ – 1.00). Sixteen athletes (41.0%) experienced a time-loss lower quadrant injury during the season. On average, injured athletes scored lower on the RRS (3.4 ± 1.0) than uninjured athletes (4.0 ± 0.6 , $P = .02$). Athletes with RRS scores of ≤ 3 had a higher risk of injury than those with scores of ≥ 4 even when adjusted for those with a history of prior injury that limited their participation for ≥ 7 days (OR = 8.03; 95% CI: 1.8, 35.7). For individual tests of the RRS, only athletes who did not pass the wall sit test had a significantly higher risk of injury (OR = 22.5; 95% CI: 1.1, 442.5).

CONCLUSIONS: Collegiate track and field athletes with RRS scores of ≤ 3 had a higher risk of lower-quadrant injury during the season than those with scores of ≥ 4 . Of individual tests, only the wall sit appears to be a significant predictor of injury. The small sample size and large CIs are limitations, but these preliminary findings support larger studies to verify the utility of the RRS as a screening tool.

CLINICAL RELEVANCE: Preseason screening with the RRS may be beneficial to identify running track and field athletes who may be at increased risk of lower-quadrant injury.

SPL107

SHOULDER ROTATION STRENGTH RATIOS IN COLLEGIATE OVERHEAD ATHLETES AT 3 ANGLES OF EXTERNAL ROTATION

Taylor Jon McWilliams, Jill Lauren Greenfield, Mark Russell Giveans

PURPOSE/HYPOTHESIS: Current literature suggests diminished strength ratios in overhead athletes are correlated to increased risk for injury. Despite normal strength ratios being poorly defined, acceptable ranges fall between 60% to 80% external rotation (ER) to internal rotation (IR) when using isokinetic devices, which are widely inaccessible to clinicians. Studies utilizing handheld dynamometers (HHD) to measure ER and IR strength have not assessed strength ratios in functional positions for overhead athletes. The purpose of this study was to determine normative values of the ER:IR ratio using a HHD at 3 rotation angles in healthy collegiate baseball and volleyball athletes that replicate a functional, overhead position, as well as to compare these ratios from side to side and between sports.

NUMBER OF SUBJECTS: Sixty-three athletes (28 baseball, 35 volleyball) were included with a mean age of 19.7 years (range, 18–22 years). Subjects were excluded for current shoulder pain or history of shoulder injury and/or surgery in the past year. All subjects with a history of shoulder pain, injury, or surgery more than 12 months prior must have returned to full, pain-free sport participation.

MATERIALS AND METHODS: Subjects half-kneeled with their elbow flexed to 90° and resting on a plinth in 90° of shoulder abduction (ABD). Strength measurements were randomized and taken at 3 angles of shoulder ER (90°, 60°, 30°) bilaterally. Subjects performed alternating IR and ER isometric contractions for 5 seconds each against a HHD in each of the 3 positions. The maximum value of 2 trials was recorded for IR and ER in all 3 positions.

RESULTS: The ER:IR strength ratios for each sport and for each side were all significantly different between 90°, 60°, and 30° of ER ($P < .001$), with 90° of shoulder rotation yielding the statistically lowest ratio for all conditions ($P < .001$). The ER:IR strength ratios were not significantly different ($P > .05$) between dominant and nondominant shoulders at the 3 positions of ER, with the exception of volleyball athletes at 0° having a higher ratio in the nondominant arm (63.5 versus 56.8, $P = .044$). There was no dif-

ference between baseball and volleyball athletes in the dominant shoulder ($P > .05$), yet volleyball nondominant shoulders had a higher ratio than baseball nondominant shoulder for all 3 positions ($P < .025$ for each).

CONCLUSIONS: In general, the ER:IR gradually increases as the shoulder approaches neutral rotation. However, the results demonstrate the necessity of measuring each of the 3 positions due to the statistically significant differences. With consideration of a small sample size, the ER:IR at 90° of ER was 52.0:63.5, at 60° was 85.5:96.0, and at 30° was 94.9:108.0 and were not statistically different between collegiate baseball and volleyball athletes or between the dominant and nondominant shoulders.

CLINICAL RELEVANCE: With normative data more clearly defined using a HHD, clinicians should be more confident in the interpretation of ER:IR strength ratios in overhead athletes.

SPL108

TIBIA STRESS DURING WALKING AND RUNNING IN FEMALE AND MALE RECREATIONAL RUNNERS

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PURPOSE/HYPOTHESIS: Sport and tactical athletes, especially females, experience high rates of bone stress injury (BSI). The tibia is a common site of BSI. Knowledge of tibia loads during walking and running in both sexes is needed to understand injury mechanisms and design safe running progressions. This study examined tibia loads during walking and running in males and females as a function of speed.

NUMBER OF SUBJECTS: Forty recreational runners (20 female, 20 male; >16 km/wk).

MATERIALS AND METHODS: Three-dimensional kinematic and kinetic data were collected while participants completed four 20-second speed conditions on an instrumented treadmill: preferred walk, preferred run, and $\pm 10\%$ preferred run speed. Internal tibia forces and moments across 10 stance phases were estimated using musculoskeletal modeling and input to a finite element (FE) model. To create subject-specific FE bone meshes, tibial bone geometry was obtained via MR imaging. Stance phase normal and shear stress were then estimated at the distal tibia; peaks were exported for analysis. A 2-factor MANOVA with repeated measures ($\alpha = .05$), partial eta-square effect sizes, and pairwise tests with Bonferroni adjustments for multiple comparisons quantified interaction and main effects of treadmill speed and sex. Bone strength indices, obtained from MR images, and normalized tibia forces and moments were compared between sexes using 1-factor ANOVAs ($\alpha = .05$).

RESULTS: An interaction effect was observed for peak tension ($P < .01$, $\eta_p^2 = 0.15$) and shear ($P < .01$, $\eta_p^2 = 0.33$). Both groups displayed greater tension and shear in running versus walking ($P < .01$) and in fast versus preferred running ($P < .01$). In females, shear was greater in preferred running versus slow running ($P = .03$). When shifting from a walk to a slow run, females displayed a greater increase than males in tension (72.9 MPa; 95% CI: 68.2, 77.5 versus 60.4 MPa; 95% CI: 54.2, 66.7) and shear (24.1 MPa; 95% CI: 17.6, 30.5 versus 6.99 MPa; 95% CI: 3.28, 10.7). Peak compression increased as speed increased ($P < .01$, $\eta_p^2 = 0.95$). Greater compression occurred in running versus walking ($P < .01$) and in fast versus preferred and slow running ($P < .01$). Torsional and bending strength indices were 38% and 40% lower in females than males, respectively ($P < .01$, $\eta_p^2 = 0.43$ – 0.67). Anterior-posterior and medial-lateral tibia forces were 16% to 68% greater in females ($P < .02$, $\eta_p^2 = 0.14$ – 0.41) and torsional and medial-lateral bending moments were 29% to 44% greater in females ($P \leq .01$, $\eta_p^2 = 0.15$ – 0.25).

CONCLUSIONS: Increasing running speed increased tibia stress. When shifting from a walk to a run, females displayed a greater increase in tibia stress than males. Females also exhibited low bone strength relative to males and disproportionately high tibia forces and moments. Smaller bone size relative to running related forces in females may contribute to increased tibia stress with running and the sex bias in tibia BSI.

CLINICAL RELEVANCE: Interventions to reduce injurious bone stress should focus on increasing bone strength through targeted exercise programs and/or regulating loads encountered during training. Female runners may need a slower progression when initiating a running program.

SPL109

ACCELERATED RECOVERY OF MUSCLE FUNCTION IN BASEBALL PITCHERS USING POSTGAME PHASE CHANGE MATERIAL COOLING

Michael John Mullaney, Malachy McHugh, Andrew Fink, Susan Kwiecien, Glyn Howatson

PURPOSE/HYPOTHESIS: There are few studies in the literature examining indices of recovery in baseball pitchers and, surprisingly, no studies have documented recovery of muscle function. Furthermore, no studies have examined interventions to accelerate recovery of muscle function on the days after a pitching performance. The purpose of this study were to document recovery following a pitching performance and determine if prolonged postgame phase change material (PCM) cooling to the shoulder and elbow accelerates recovery.

NUMBER OF SUBJECTS: Sixteen college pitchers.

MATERIALS AND METHODS: Strength, soreness and serum creatine kinase activity (CK) were assessed prior to and on each of the 2 days following pitching performances in 16 college pitchers. Pitchers were randomized to receive either postgame PCM cooling packs on the shoulder and elbow or no cooling (control). PCM cooling was applied inside compression shirts for 3 hours. Strength was assessed for shoulder internal rotation (IR), external rotation (ER), empty can test (EC) and grip.

RESULTS: Total pitch count was 60 ± 16 for 23 PCM cooling games and 62 ± 17 for 24 control games ($P = .679$). On the days following pitching strength was higher with PCM cooling versus control for IR strength (treatment effect, $P = .006$) and grip strength ($P = .036$). One day after pitching IR strength was $95\% \pm 14\%$ of baseline with PCM cooling versus $83\% \pm 13\%$ for control ($P = .008$) and $107\% \pm 9\%$ versus $95\% \pm 10\%$ for grip strength ($P = .022$). There was a trend for greater ER strength with PCM cooling (treatment effect, $P = .091$). EC strength was not impaired after pitching (time effect, $P = .147$) and was therefore unaffected by PCM cooling (treatment effect, $P = .168$). Elevations in CK and soreness were not different between treatments (treatment-by-time CK, $P = .139$; shoulder soreness, $P = .885$; elbow soreness, $P = .206$).

CONCLUSIONS: Prolonged PCM cooling protected against strength loss in shoulder IR and grip strength but did not affect CK levels or soreness. This is the first study to document impairments in muscle function on the days following baseball pitching, and the first study showing a novel intervention that accelerates recovery of muscle function in baseball pitchers.

CLINICAL RELEVANCE: PCM cooling packs placed in compression garments provide a practical means of delivering prolonged postgame cooling to baseball pitchers after they have departed the training room.

SPL110

DESCRIPTIVE STRENGTH AND RANGE OF MOTION IN YOUTH BASEBALL PLAYERS

Ross Makoto Nakaji, Lianna Marie Roberts, Kevin Michael McClenahan, Chase J. Perez, Scott Dickenson, Todd S. Ellenbecker

PURPOSE/HYPOTHESIS: To measure external (ER) and internal (IR) rotation range of motion (ROM) and isometric rotator cuff strength in youth baseball players 12 years of age and younger to compare between the dominant throwing arm (D) and the nondominant arm (ND).

NUMBER OF SUBJECTS: Fifty healthy youth male baseball players aged 5 to 12 years.

MATERIALS AND METHODS: All players were tested on a single day prior to the start of the season. ROM measurements were performed using a goniometer for IR and ER in the supine position with the shoulder in 90° of abduction (abd) with scapular stabilization. Isometric strength measure-

ments for IR and ER were collected in both neutral and 90° of abd with the use of a hand held dynamometer and recorded in pounds utilizing a "make" test. Descriptive statistics were obtained for all measures.

RESULTS: All data were analyzed as a single group (average age, 9.02 years). No significant difference in average total arc of PROM (ER + IR = total arc) on the D side compared to the ND side ($136.7^\circ \pm 12.7^\circ$ versus $134.3^\circ \pm 12.3^\circ$). There were statistically significant differences between ER ROM ($102.2^\circ \pm 7.7^\circ$ versus $96.8^\circ \pm 7.4^\circ$) and IR ROM ($34.4^\circ \pm 9.0^\circ$ versus $37.5^\circ \pm 9.5^\circ$) in D versus ND arms ($P < .001$ and $P = .006$, respectively). Mean ER strength in neutral (13.6 ± 3.4 lb and 12.8 ± 3.6 lb) and 90° deg abduction (12.3 ± 3.4 lb and 12.5 ± 4.3 lb) did not differ between D and ND arms, respectively. Mean IR strength in neutral (18.0 ± 6.0 lb and 15.7 ± 4.7 lb) and 90° abd (16.4 ± 5.6 lb and 15.0 ± 5.7 lb) was significantly greater in the D arm versus ND arm, respectively ($P < .001$ and $P = .001$).

CONCLUSIONS: These data provide descriptive information for clinicians who treat baseball players at very young ages. These data show sport specific adaptations at very young ages (5-12 years) and are similar to prior reports on adolescent, high school and professional baseball players regarding upper extremity ROM and rotator cuff strength.

CLINICAL RELEVANCE: Clinicians can expect to see, in a young healthy thrower's dominant arm, increased ER ROM and decreased IR ROM relative to nondominant arm with a symmetrical total arc of ROM bilaterally. Rotator cuff strength may show an increase in D arm IR strength while having symmetrical ER strength bilaterally. This characteristic profile of healthy overhead athletes can be used to guide evaluation interpretation in injured youth overhead athletes.

SPL111

ASSESSING THE EFFECTS OF PREVIOUS INJURY IN MILITARY PERSONNEL: IMPLICATIONS FOR SUBSEQUENT AND RECURRENT INJURY

Mikela Nylander-French, Ashley Lea, Ennea Dailey, Carolyn Killelea, Daniel Le, Mallory S. Faherty, Timothy Sell

PURPOSE/HYPOTHESIS: Military personnel are at significant risk for suffering a musculoskeletal injury (MSKI). Based on previous research, a history of MSKI has been identified as a risk factor for subsequent and recurrent injury. One potential explanation for this relationship may be due to persistent deficits in musculoskeletal and neuromuscular characteristics. The purpose of this study was to examine a cohort of military personnel to determine if individuals who have had a previous lower extremity (LE) injury demonstrate deficits in LE musculoskeletal and neuromuscular characteristics compared to the uninjured LE and a control group who has not suffered a LE MSKI. We hypothesize that military personnel with a recent history of injury would demonstrate deficits in dynamic postural stability, static postural stability, strength, and flexibility compared to their uninjured LE and to a control group.

NUMBER OF SUBJECTS: Sixty-two male, active-duty military personnel (mean $\pm$ SD height, 32.02 ± 2.81 cm; weight, 32.02 ± 2.81 kg). Ten of the 62 participants stated they had a LE injury within the past year.

MATERIALS AND METHODS: All participants had been cleared for duty prior to testing. A 1-year past medical history was collected through self-report guided by a Certified Athletic Trainer. Data were collected bilaterally and included dynamic and static postural stability, strength, and flexibility. Dynamic postural stability was measured during a single-leg landing task on a force plate. Static postural stability was assessed under eyes-open and eyes-closed conditions standing on a force plate. Strength tests included knee flexion/extension and ankle dorsiflexion/plantarflexion and ankle inversion/eversion. Flexibility tests included ankle dorsiflexion, gastrocnemius, active knee extension and straight leg raise. Results were compared between the uninjured group and injured group as well as between LE within each group. Data were assessed for normality. If normally distributed, within-group and between-group differences were assessed paired-samples t tests and/or a Wilcoxon signed-rank test. Significance of $P < .05$ was established a priori.

RESULTS: There was a significant difference between LEs for knee extension strength within the control group ($P = .019$). There was a significant difference between the injured LE and the uninjured LE in anterior/posterior dynamic stability within the injured group ($P = .029$). No significant differences were noted for between group differences.

CONCLUSIONS: Within the injured group there was significant difference between the noninjured leg and injured leg for 1 of the dynamic postural stability variables. There were no significant differences in dynamic postural stability, single-leg balance/static postural stability, strength, and flexibility found between the control group and injured group.

CLINICAL RELEVANCE: No significant difference between groups may indicate that injured military personnel are overall receiving proper rehabilitation training before returning to duty. The difference noted between the injured LE and uninjured LE in the injured group may indicate a need for more dynamic postural stability training within their rehabilitation program though. This information is important to make informative decisions on return to duty when military personnel have been injured so that they are at less risk for recurrent or subsequent injury. Opinions, interpretations, conclusions, and recommendations are those of the author and not necessarily endorsed by the Department of Defense, US Air Force, or US Air Force Special Operations Command.

SPL112

VALIDATION OF A NEW CLINICAL TEST: FUNCTIONAL ASSESSMENT OF SYSTEM TENSION IN OVERHEAD ATHLETES

Jesse Perry, Connor Burk, Jeremy Chiang, Steve Dischiavi, Chris M. Bleakley

PURPOSE/HYPOTHESIS: Overhead athletes require coordination, control, and mobility of the entire body. This is most evident during the early and late cocking phase of throwing, where the shoulder is in maximal horizontal abduction and external rotation, the trunk is rotated contralaterally, and the ipsilateral hip is extended. Adopting this position allows athletes to optimize myofascial tension allowing more efficient transition from potential to kinetic energy. A staple in rehab for overhead athletes includes high level exercises that incorporate interconnected muscle chains, but interestingly the viscoelastic nature of the muscle chains do not enter into the static assessment process. There is a need to develop a more holistic clinical test for shoulder ROM which reflects the complexity and 3-D nature of throwing. Therefore, the purpose of this study was to determine the reliability and validity of a new clinical test of shoulder ROM (FAST-OA) and to establish normative values in overhead athletes.

NUMBER OF SUBJECTS: Thirty-three healthy collegiate baseball players (mean $\pm$ SD age, 19.2 ± 1.2 years; weight, 86.1 ± 7.7 kg; height, 185.5 ± 5.39 cm).

MATERIALS AND METHODS: Participants were assessed for shoulder ROM (internal rotation, IR and external rotation, ER) using (1) traditional supine testing and (2) FAST-OA. During FAST-OA, athletes were positioned in supine, hook-lying with the test shoulder off the plinth. To recreate the late cocking position, the player's pelvis was passively rotated 90° contralateral to the tested arm (secured by strapping the knees around the plinth with a belt), with their back flat to the table. Positioning the test shoulder in 90° of shoulder abduction, a second tester moved the shoulder into maximal passive horizontal abduction, before assessing passive IR and ER ROM, using a bubble inclinometer placed on the ulnar styloid process. Mean differences and paired t tests ($P < .01$) were used to compare ROM values generated across tests. Intratester reliability of the FAST-OA was excellent (ICC = $0.95-0.97$) with MDC (90% CI) ranging from 7° to 9° .

RESULTS: Average shoulder IR values were higher during standard supine testing (dominant, $62.3^\circ \pm 12.1^\circ$; nondominant, $69.4^\circ \pm 12.9^\circ$) compared to FAST-OA (dominant, $39.0^\circ \pm 9.9^\circ$; nondominant, $49.7^\circ \pm 12.8^\circ$; $P < .001$). There were even greater differences between test results for ER (standard dominant, $128.2^\circ \pm 11.5^\circ$; standard nondominant, $115.7^\circ \pm 8.6^\circ$ versus FAST-OA dominant, $77.4^\circ \pm 15.0^\circ$; FAST-OA nondominant, $66.0^\circ \pm 15.0^\circ$; $P < .001$). The total arc of motion was significantly lower based

on the FAST-OA compared to the standard test for both dominant (MD, 73.0° ; 95% CI: $66.2^\circ, 79.9^\circ$; $P < .001$) and nondominant shoulders (MD, 72.1° ; 95% CI: $65.5^\circ, 78.8^\circ$; $P < .001$).

CONCLUSIONS: Collegiate baseball players demonstrated significantly less shoulder ER, IR, and tension arc when compared to standard supine testing.

CLINICAL RELEVANCE: Three dimensional positioning of the body to replicate throwing alters the tensional demands that is distributed across the body, ultimately diminishing end ROM of a baseball players throwing shoulder. While further analysis of the FAST-OA is needed, this accessible and easy to perform clinical test may provide useful information for injury prediction or performance potential in overhead athletes.

SPL113

LOWER EXTREMITY INJURY IS NOT ASSOCIATED WITH CONCUSSIONS IN FOOTBALL PLAYERS, REGARDLESS OF HEADS-UP TRAINING

Abigail Pinkerton, Ellen Shanley, Charles Alden Thigpen, Gil Gilliland, John Thorpe, Michael Kissenberth

PURPOSE/HYPOTHESIS: An estimated 1.6 to 3.8 million sports-related concussions (SRC) occur in the US annually. Troubling is that following SRC, athletes have 2.5 times greater odds of sustaining a lower extremity musculoskeletal (LE MSK) injury compared to athletes without concussion. While educational and prevention programs like US football heads-up (HU) educational program training in high school football has shown the ability to significantly lower concussion rate compared with players without HU training, it is unknown the influence on LE MSK injury. Therefore, the purpose of this study was to compare SRC and LE MSK injury rates in a group of high school athletes with and without HU training (NHU).

NUMBER OF SUBJECTS: A total of 2514 high school football players were monitored throughout their competitive season.

MATERIALS AND METHODS: Fourteen high schools (1818 athletes) who received US football HU training were compared to 10 high schools (696 athletes) who did not. At all schools, SRC and LE MSK injury time-loss injuries were documented by the athletic trainer. LE MSK injuries were included if they occurred within 60 days before or following the SRC. Cumulative incidence and incidence rate ratios (RR) were calculated for both groups with 95% confidence intervals (CI).

RESULTS: A total of 117 SRC (HU, 75; NHU, 42) and 393 LE MSK injuries (HU, 295; NHU, 98) were observed. The HU trained group had significantly lower concussion rate (4.1 versus 6.0 per 100 athletes) compared to NHU group (RR = 1.5; 95% CI: 1.1, 5.4). There was no significant difference in the incidence of LE MSK injury between the HU trained group (16.2 versus 14.1 per 100 athletes) and the NHU group (RR = 0.87; 95% CI: 0.7, 1.1). A total of 19 athletes sustained a LE MSK injury and SRC during season. There was no significant difference in the incidence of combined injury between the HU trained group (0.72 versus 0.86 per 100 athletes) and the NHU group (RR = 1.2; 95% CI: 0.46, 3.2).

CONCLUSIONS: Our results show that HU training is an effective in reducing the concussion rate in high school football athletes. In contrast to other reports we did not observe any association between concussion and LE MSK injury in our study or influence LE MSK injury rate. Future work is required to understand the association between initial injury recovery and subsequent injury risk.

CLINICAL RELEVANCE: Educational programs like heads up training appear to be an effective concussion injury reduction strategy without any adverse effects on LE MSK injuries and should be considered in high risk concussion sports.

SPL114

THORACIC OUTLET SYNDROME AND SPINOGLLENOID NOTCH ENTRAPMENT IN A HIGH SCHOOL BASEBALL PITCHER

Nicholas Keith Purcell, Megan Claire Graham, Albert Hergenroeder

BACKGROUND AND PURPOSE: Shoulder pain is a common musculoskeletal complaint in high school baseball players. Thoracic outlet syndrome and spinoglenoid notch entrapment are less common diagnoses for shoulder pain in this population. The literature is limited on physical therapy treatment for these conditions making it challenging to determine the most effective plan of care. This case study presents an effective approach of diagnosing and treating shoulder pain in a high school baseball pitcher that previously did not respond to 2 separate episodes of physical therapy over 1 year.

CASE DESCRIPTION: A 16-year-old high school male baseball pitcher presented with 1 year of right anterior and posterior shoulder pain after throwing that was sometimes accompanied with a feeling of heaviness. His pain occurs mostly after pitching but occasionally he experienced sharp pain in maximum external rotation position of the throwing motion. His velocity decreased 10 mph since the onset of pain and he was experiencing burning pain at rest in the right shoulder that radiated into his dorsal hand. After undergoing 2 episodes of physical therapy and an inconclusive shoulder MRI he was still experiencing pain with throwing.

OUTCOMES: Evaluation revealed normal cervical exam, visible atrophy present in the infraspinatus fossa, and exquisite tenderness of the infraspinatus near the spinoglenoid notch that reproduced his familiar shoulder pain. Positive special tests included Roos, radial nerve tension, first rib cluster, and pain with external rotation strength testing. Passive shoulder range of motion was within injury risk cutoff values for total arc of motion, GIRD, and flexion. Digital handheld dynamometry of right external rotation strength in 90° of abduction was 18 lb compared to 50 lb on the left shoulder. Initial physical therapy treatment included mobilization of the first rib, STM of the infraspinatus, and dry needling with electrical stimulation of the infraspinatus. The patient was initially instructed on self-mobilization of the first rib, radial nerve flossing, and sidelying external rotation strengthening. After 6 visits of physical therapy over 6 weeks the patient was able to start a throwing program after undergoing throwing mechanics evaluation. Video analysis of his throwing motion revealed excess horizontal abduction and extension during early cocking phase. External rotation strength improved to 48 lb and the patient returned to pitching without pain.

DISCUSSION: In this pitcher with thoracic outlet syndrome and spinoglenoid notch entrapment it was necessary to identify and treat proximal contributions to shoulder and arm pain prior to addressing strength limitations at the glenohumeral joint. Pitching is a violent motion and requires adequate mobility and stability through the entire kinetic chain in order to perform effectively. This case demonstrates an effective approach to address thoracic outlet syndrome and spinoglenoid notch entrapment and will help physical therapists better understand how to identify and treat impairments that lead to these conditions.

SPL115

REPORTING OF INJURIES AMONG HIGH SCHOOL CROSS-COUNTRY RUNNERS: IS ONE SEX TOUGHER THAN THE OTHER?

Mitchell John Rauha

PURPOSE/HYPOTHESIS: Multiple studies have reported a higher incidence of running-related injury (RRI) among female than male high school cross-country runners. One speculation for these findings is that females may be more apt to report their RRI than males. Thus, the purpose of this study was to examine if there were differences in reporting of RRI between female and male high school cross-country runners.

NUMBER OF SUBJECTS: Four hundred twenty-one athletes (186 female, 235 male) from 12 high school cross-country teams who competed during an interscholastic cross-country season.

MATERIALS AND METHODS: At baseline, all runners reported they were without any RRI symptoms. The runners were then prospectively followed for low back and lower extremity RRI during the season. Coaches recorded all RRIs using the Athletic Health Care System Daily Injury Report. At

the end of the season, the runners completed a questionnaire inquiring about RRI occurrence during the season. Relative Risk (RR) estimates and 95% confidence intervals (CIs) were used to determine associations between sex and runners' reports of RRI.

RESULTS: The coaches' reports in the DIRs indicated that females had a higher incidence of RRI (41.7%) than males (35.7%). Responses from the questionnaires indicated a higher percent of females (61.3%) than males (51.5%) incurred a RRI that affected their running during the season ($P = .05$). While females were more likely to report a shin RRI (RR = 1.41; 95% CI: 1.1, 3.0; $P = .02$), males were more likely to report a knee RRI (RR = 1.69; 95% CI: 1.1, 2.8; $P = .03$). Females were more likely to report a RRI causing time loss greater than 1 week from running (RR = 1.39; 95% CI: 1.1, 3.0; $P = .02$). No significant differences were found between females (95.6%) and males (95.9%) in reporting a RRI to the coach ($P = .58$). However, while most RRIs were reported within a few days of onset of symptoms, females were almost twice as likely (RR = 1.80; 95% CI: 1.1, 3.1; $P = .03$) to delay reporting their RRI pain symptoms 1 or more weeks to the coach than males. A higher percent of females (69.8%) than males (60.8%) reported returning to running with some pain from their RRI that affected their running ($P = .10$).

CONCLUSIONS: The findings indicate that the reporting of RRIs by competitive high school runners is similar between females and males. Females were more likely to delay reporting their RRI to their coach and also more apt to return to running with pain symptoms stemming from their recent RRI.

CLINICAL RELEVANCE: That the runners' reports of RRI were higher than those reported by the coaches suggests the true extent of RRI among high school runners may be underestimated. That females had a higher incidence of RRI, and their reporting of RRI to coaches was similar to males, suggests a need to determine what factors place females at higher risk of RRI. Of concern is that females were more likely to delay reporting their RRI to the coach. Since females had a higher percent of RRI that caused more time lost from running, it is possible that this delay contributed to these RRIs becoming more severe. This study indicates that current criteria to determine when a runner should return to running should be evaluated.

SPL116

EVALUATING THE RISK OF ANTERIOR CRUCIATE LIGAMENT INJURY IN HEALTHY SINGLE-SPORT AND MULTISPORT ADOLESCENT BASEBALL PLAYERS

Sandy Ross, Lindsay Ganter, Curtis J. Smith, Christopher Dietrich, Nicholas William Dietrich, Dalton Schumer, Tyler Nicholas Forbes, Emily C. Nieters

PURPOSE/HYPOTHESIS: The prevalence of noncontact anterior cruciate ligament (ACL) injuries among adolescent athletes has been well established in previous research with multiple risk factors including: sport specialization, poor mechanics during knee movement (excessive valgus), hip weakness, core weakness and limb asymmetry during hop tests. However, no research has analyzed the biomechanical differences between healthy single and multisport adolescent athletes and the risk of ACL injury. The purpose of this study was to determine if single-sport adolescent baseball players were at a greater risk for sustaining a noncontact ACL injury compared to their multisport counterparts using an objective movement analysis protocol.

NUMBER OF SUBJECTS: A prospective study was conducted using a convenience sample of ($n = 22$) adolescent baseball players (mean $\pm$ SD age, 15.3 $\pm$ 0.9 years; height, 1.8 m; weight, 71.2 kg). Participants were subdivided into single ($n = 12$) and multisport ($n = 10$) groups. Single-sport athletes played only organized baseball in the past year and multisport athletes played at least 1 additional sport.

MATERIALS AND METHODS: Outcome measures included an overall performance score using the standardized dorsaVi movement analysis system-

Athletic Movement Index (AMI) protocol which includes planks, squats, and single leg hop/plants. Overall performance score (ACL risk) and 2 subscores from the dorsaVi including core strength and knee total frontal range of motion (ROM) were recorded. Additional measures included distance components of the Cincinnati hop test and hip abductor and extensor strength with a handheld dynamometer (N/kg). Data were analyzed using a multivariate ANOVA and Pearson correlations ($P < .05$).

RESULTS: There was no significant difference between single and multisport groups for all outcome measures ($F = 0.866$, $P = .56$). There was a strong correlation between dorsaVi overall performance score and core strength ($r = 0.732$, $P < .001$) but no correlation with knee frontal ROM, hop test distance or hip strength. Knee frontal ROM during the dorsaVi AMI test was positively correlated with total hop distance ($r = 0.60$, $P = .003$).

CONCLUSIONS: Adolescent single and multisport baseball athletes performed similarly on the dorsaVi AMI test and may be equally susceptible to noncontact ACL injuries despite sport specialization. The correlational results of this study emphasized the importance of core strength and its potential role in promoting stability throughout the entire kinetic chain. The relationship between knee frontal ROM and hop distance implied that those with limited knee frontal ROM during movement had poorer performance on hop distance supporting the importance of knee flexibility with movement.

CLINICAL RELEVANCE: Given the current variable training regime for adolescent baseball players, sport specialization may not be associated with increased ACL injury risk. As more athletes elect to specialize in a single sport, future research should continue to investigate the training styles of athletes that could mitigate noncontact ACL injury risk even in the highly specialized athletic population.

SPL117

TRAUMATIC HIP DISLOCATION IN AN NCAA DIVISION I FOOTBALL PLAYER WITH OCCULT SEQUELAE: A CASE STUDY

Daniel Wingate Safford, Marisa Luisa Pontillo, Brian J. Sennett

BACKGROUND AND PURPOSE: Traumatic hip dislocation is an uncommon injury typically arising from high-energy axial impact, with only 2% to 5.5% occurring during sports activities. Posterior dislocations have been reported to represent 85% to 92% of all hip dislocations, generally occurring with the hip flexed and adducted. Associated local compounding injuries may include: fracture, femoral head cartilage damage, vascular or ligamentous injury, soft tissue disruption, and neural involvement, along with other lower extremity or trunk injuries, all of which may negatively impact prognosis. Sequelae of particular concern are avascular necrosis and posttraumatic arthritis, found to have incidences ranging from 11% to 40% and 19% to 55% respectively in posterior dislocations. This case study provides a rare example of traumatic posterior hip dislocation with occult sequelae requiring surgical intervention.

CASE DESCRIPTION: A 22-year-old NCAA Division I football defensive back experienced extreme left hip pain following contact during a game. The on-field medical team evacuated him to a nearby emergency room where radiographs revealed a posterior left hip dislocation, negative for fracture, and incidentally, mild femoral head CAM deformities bilaterally. The left hip was reduced and the patient was instructed to be non-weight bearing on the left lower extremity for 2 weeks, followed by progressive weight bearing with posterior hip precautions for 6 weeks. Magnetic resonance imaging of the left lower extremity indicated a grade 1 left medial collateral ligament sprain. The patient had a chief complaint of ongoing limited function and left hip, knee, and posterior thigh pain. Physical therapy evaluation 4 weeks after injury notably identified: tenderness to palpation in left hip soft tissues and medial left knee, (positive) left knee valgus testing, reproduction of pain with resisted left knee flexion, and limited left hip ROM and strength. Patient goals were unrestricted return to sport without fear of repeated dislocation.

OUTCOMES: Patient underwent 3 months of physical therapy care with progressive return to running, agilities, and lifting with emphasis on hip external rotation control during dynamic movements. The patient was asymptotically performing majority of noncontact sport activity, but did not complete the course of care and 7 months after injury returned to physician reporting left groin pain. Patient underwent magnetic resonance arthrogram revealing anterior labral tear, with osteochondral lesion and avascular necrosis of the femoral head. The patient opted for surgical arthroscopy of the left hip for a labral repair and femoral osteochondroplasty as recommended and initiated postoperative rehabilitation.

DISCUSSION: This case describes a relatively rare etiology of traumatic hip dislocation and management. It demonstrates the need for completion of a course of intensive physical therapy care at the Division I level along with the potential severe sequelae that have been associated with this type of injury and the appropriate diagnostic follow-up and intervention.

SPL118

ATHLETES DIAGNOSED WITH ANTERIOR AND POSTERIOR SHOULDER INSTABILITY DISPLAY DIFFERENT CHIEF COMPLAINTS AND DISABILITY

Ellen Shanley, Adam Daniel Lutz, Jared Hudspeth, Kyle Adams, Charles Alden Thigpen, John M. Tokish, Amit Moyama, Michael Kissenberth

PURPOSE/HYPOTHESIS: Anterior shoulder instability is a common complaint of young athletes. Posterior instability in this population is less well understood and the standard of care has not been defined. The purpose of the study was to compare index frequency, treatment choice, and athlete disability following an incident of anterior or posterior shoulder instability in high school and collegiate athletes.

NUMBER OF SUBJECTS: Fifty-nine high school and collegiate athletes ($n = 30$ athletes with anterior instability, $n = 29$ athletes with posterior instability) were included.

MATERIALS AND METHODS: Athletes suffering from a traumatic sport related shoulder instability episode during a team-sponsored practice or game were identified by their school athletic trainer (AT). Athletes were referred to the sports medicine physician or orthopaedic surgeon for diagnosis and initial treatment choice (operative versus nonoperative). Athlete's diagnosed with traumatic anterior or posterior instability that completed a full course of medical and rehabilitation treatment including pre and patient reported outcomes were included in the study. The frequency of shoulder instability was compared by direction, mechanism of injury (MOI) and treatment choice through chi square analyses and a repeated-measures analysis of variance was used to compare the functional outcomes by treatment type and direction of instability ($\alpha = .05$).

RESULTS: Athletes diagnosed with anterior instability were more likely to report a chief complaint of instability (70%), while those diagnosed with posterior instability reported a primary complaint of pain (96%) interfering with function ($P = .001$). The primary MOI (contact versus noncontact) and initial treatment choice for those sustaining anterior instability was similar to those with posterior instability (MOI, 77% versus 54%; $P = .06$; surgical treatment, 60% versus 72%; $P = .31$). When considering patient function, pre- and post-treatment Penn Scores were similar for all athletes diagnosed with instability whose initial course of treatment was operative ($P > .05$). In patients with a nonoperative course of care those diagnosed with anterior instability were initially significantly more disabled than those with posterior instability (32 ± 6.1 versus 58 ± 8.1 , $P = .001$). There were no differences in functional outcomes at discharge in those treated nonoperatively regardless of direction of instability ($P = .24$); however, change in Penn was significantly greater in those with anterior (61 ± 18.7) than those with posterior (27 ± 25.2) instability ($P = .002$).

CONCLUSIONS: Athletes with anterior instability appear to have different mechanisms and complaints than those with posterior instability. Among those that receive nonoperative treatment, athletes with anterior

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instability have significantly greater initial disability and change in disability than those with posterior disability during course of care. Future study is warranted to verify these results.

CLINICAL RELEVANCE: Treatment decisions for athletes with different directions of shoulder instability may be influenced by initial disability and primary complaint.

American Academy of Sports Physical Therapy Poster Presentation Abstracts SPO1-SPO137

The abstracts below are presented as prepared by the authors. The accuracy and content of each abstract remain the responsibility of the authors. In the identification number above each abstract, SPO designates an American Academy of Sports Physical Therapy poster presentation.

SPO1

ALTERED BIOMECHANICS DURING CUTTING IN DIVISION I FEMALE LACROSSE PLAYERS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Emma Alfred, Mary Mahon, Jeffrey B. Taylor, Anh-Dung Nguyen, Audrey E. Westbrook, Kevin R. Ford

PURPOSE/HYPOTHESIS: Women's lacrosse has quickly gained popularity which has led to greater attention towards injury incidence and prevention. The incidence of anterior cruciate ligament (ACL) injuries are increasing in women's lacrosse with higher rates compared to men's lacrosse. It has been reported that up to 30% of ACL reconstruction (ACLR) individuals go on to suffer a second injury. The purpose of this study was to compare hip and knee biomechanics between collegiate female lacrosse players with ACLR and those with no prior ACL injury (CTRL) during an unanticipated cut, which may increase the risk of secondary ACL injury.

NUMBER OF SUBJECTS: Twenty-six female lacrosse players, from the same Division I team, were included in this study consisting of 5 players with previous ACLR (2.1 ± 0.5 years).

MATERIALS AND METHODS: Each lacrosse team member completed a pre-season biomechanical screening where standard 3-D motion analysis techniques were used to capture hip and knee biomechanics during unanticipated cutting trials. An arrow was randomly displayed to the left or right which indicated the cutting direction. The ACLR involved limb was matched with the CTRL nondominant limb. Conversely, ACLR uninvolved limb was matched to CTRL dominant limb for statistical comparisons. Separate repeated-measures ANOVA (side by group) were used to identify differences in hip and knee biomechanics among ACLR/CTRL and side during cutting trials ($P < .05$).

RESULTS: Peak hip flexion angle during stance was significantly less (group main effect, $P = .005$) on both sides in ACLR (mean of both sides, 33.7° ; 95% CI: 26.9° , 40.6°) compared to CTRL (mean of both sides, 45.2° ; 95% CI: 41.8° , 48.5°). Similarly, peak knee flexion angle during stance was significantly less (group main effect, $P = .013$) on both sides in ACLR (mean of both sides, -50.8° ; 95% CI: -57.3° , -44.3°) compared to CTRL (mean of both sides, -60.3° ; 95% CI: -63.4° , -57.1°). Peak hip extensor moment was not statistically different between groups ($P > .05$). However, peak knee extensor moment had a statistically significant side by group interaction ($P = .018$). The involved limb had decreased knee extensor moment in ACLR (-2.15 Nm/kg; 95% CI: -2.58 , -1.72) compared to unin-

involved side (-2.73 Nm/kg; 95% CI: -3.17 , -2.29) and both nondominant (-2.37 Nm/kg; 95% CI: -2.58 , -2.16) and dominant (-2.54 Nm/kg; 95% CI: -2.76 , -2.33) sides in CTRL.

CONCLUSIONS: These results indicate female lacrosse players with previous ACL injury exhibit compensatory movement patterns that could contribute to greater risk of a secondary ACL injury. Decreased hip and knee flexion were found on both limbs of the ACLR group compared to the control. Additionally, the ACLR group exhibited a decreased knee extensor moment on the involved side compared to the control.

CLINICAL RELEVANCE: Quality of movement assessments should be performed during sport maneuvers after lacrosse players return to sport following ACLR. This information can be used by physical therapists to target neuromuscular and strength deficits.

SPO2

EFFECTS OF SPORTS SPECIALIZATION ON PERFORMANCE OF FUNCTIONAL TASKS IN ADOLESCENT ATHLETES

Alex Altenburger, Leslie Schein, Sarah Elizabeth Reinking, Aaron Provance, Gregory Walker, David R. Howell

PURPOSE/HYPOTHESIS: Sports specialization prevalence is increasing in the United States. Increased injury risk has been associated with early sports specialization in youth athletes, but the risk factors underlying increased injury risk are poorly understood. Poor neuromuscular control may be a risk factor for increased injury in youth athletes who are highly specialized. The purpose of this study was to investigate neuromuscular control among athletes with various levels of sport specialization. We hypothesized that highly specialized adolescent athletes would perform worse on a lateral step-down (LSD) test and Balance Error Scoring System (BESS) test compared to less specialized adolescent athletes.

NUMBER OF SUBJECTS: Twenty-nine healthy high school athletes undergoing a preparticipation physical examination.

MATERIALS AND METHODS: Athletes completed the LSD test, the BESS test, and a questionnaire describing their level of sport specialization on a 3-point scale (low, medium, and high) defined originally by Jayanthi et al. During the LSD test, participants were instructed to stand on 1 leg on an 8-inch box. On cue, participants lowered themselves to the floor, contacting their contralateral heel to the ground and then returned to starting position. Trials were completed for both dominant and nondominant legs. Participants were graded with scores ranging from 0 to 6, where higher scores reflect poorer neuromuscular control. Participants then completed the BESS test to assess static postural control. We examined LSD and bal-

ance performance between the sport specialization groups using ANOVA and Tukey post hoc comparisons.

RESULTS: There were 29 participants that completed the study. Of the 29 participants that completed the study, 45% were low sport specialization athletes, 28% were medium sport specialization athletes, and 28% were high sport specialization athletes. There were no significant demographic differences between groups. The high group had the highest LSD score on the nondominant limb compared to the low and medium groups, but these groups were not statistically different (mean $\pm$ SD, 2.9 ± 1.1 versus 2.6 ± 1.1 versus 2.7 ± 1.2 ; $P = .90$). However, the high group performed the BESS tandem stance with significantly fewer errors than the medium group (mean $\pm$ SD, 0.1 ± 0.3 versus 2.4 ± 0.3 ; $P = .04$).

CONCLUSIONS: Contrary to our hypothesis, we did not observe a significant difference in LSD performance between groups. However, the high group committed fewer errors on the BESS tandem stance than their less specialized counterparts.

CLINICAL RELEVANCE: Our study did not illustrate significant differences in neuromuscular control between highly specialized and medium or low specialized athletes. This may be secondary to the small sample size of this study. Higher scores on BESS tandem stance by the high sport specialization group may indicate increased balance performance for highly specialized athletes. Further research is warranted to assess whether neuromuscular control is contributing to the increased risk of injury in highly specialized athletes.

SP03

THE ASSOCIATION BETWEEN THE Y-BALANCE TEST AND THE DELOS POSTURAL PROPRIOCEPTIVE SYSTEM IN PROFESSIONAL BASKETBALL PLAYERS

Philip Albert Anloague, Shawn Windle, Grady Douglas Garno, Michael David Lewandowski, Caleb Dee Norton, Ryan Thomas Smerke, Sierra Nicole Speck, Jenna Marie Stoner, Aaron Robert Strausbaugh

PURPOSE/HYPOTHESIS: Lower extremity injury is common in professional basketball. The Y-Balance Test (YBT) and the Delos Postural Proprioceptive System (DPPS) have been purported to assess dynamic postural control and balance, which has been associated with injury in elite athletics. It has been reported that performance on balance assessments is influenced by many factors that include mobility, strength, and proprioception. The purpose of this exploratory study was to investigate the relationship between DPPS and YBT performance in professional basketball players. We hypothesize that performance on the YBT is associated with performance on the Delos.

NUMBER OF SUBJECTS: Thirteen professional basketball players (mean $\pm$ SD age, 25.5 ± 3.9 years; height, 2.00 ± 0.079 m; weight, 99.89 ± 12.38 kg; BMI, 24.66 ± 1.89 kg/m²).

MATERIALS AND METHODS: YBT and Delos Measurements were completed as part of preseason mobility screening prior to the 2018-2019 NBA season. The YBT is a low tech system that is based on the Star Balance Excursion Test. The DPPS is a hi tech proprioceptive training system that includes dynamic and static testing capabilities. A Friedman's ANOVA was used to investigate the differences between the Delos system and Y-Balance Test, using individuals scoring below 1 SD on both the static and dynamic Delos cutoff score (90) for both left and right lower extremities. The ICC was used to investigate the relationship between (right or left) dynamic and static Delos scores to scores on the respective Y-Balance Test.

RESULTS: The Delos Static and Dynamic tests for the right side were statistically different than the YBT composite scores. The ICC for the Delos static (right) score was -0.910 and the Delos dynamic (right) score was -0.999 with a 95% confidence interval from -7.127 to 0.962 ($F_{2,10} = 0.671$, $P < .001$). The Delos static and dynamic tests for the left side were statistically similar to the YBT Composite scores. The ICC Delos static (left) score was 0.800 and the Delos dynamic (left) score was 0.471 with a 95% confidence interval from -9.227 to 0.976 ($F_{2,4} = 1.041$, $P < .001$).

CONCLUSIONS: This exploratory study suggests that the direct correlation between the YBT and the DPPS should be further investigated. The YBT may be an assessment that is more sensitive to factors related to strength and mobility while the DPPS may be more representative of proprioceptive function.

CLINICAL RELEVANCE: Balance and mobility is influenced by many factors. Understanding the association between the Delos and Y-Balance can give clinicians a better understanding of the utility and value these assessments when working with elite athletes.

SP04

PARENTAL PERCEPTIONS INFLUENCE SPORT PARTICIPATION AND SPECIALIZATION IN YOUTH ATHLETES

Amanda Jo Arnold, Blake J. Cookmeyer, Mariam Jasmine Khansa, Cassie Mayer, Allison Ostendorf, Cody Stutson Lasiter, Alexandra Elizabeth Pfeifferle

PURPOSE/HYPOTHESIS: Youth sports have become a \$15 billion industry with athletes specializing in a single sport prior to the age of 12 years. Theories suggest that parental perceptions may impact youth sport participation and specialization; however, research is limited in this area. The purpose of this study was to assess and compare perceptions of sport participation and specialization in parents of specialized youth athletes and parents of nonspecialized youth athletes.

NUMBER OF SUBJECTS: One hundred twenty-five parents of youth athletes (aged 9-12 years).

MATERIALS AND METHODS: Parents of youth athletes completed an online survey assessing their perceptions of sport participation and specialization in South Louisiana. Athletes were classified as either specialized or nonspecialized based on criteria established by the American Academy of Pediatrics. Fisher's exact tests compared demographics, knowledge of sport specialization, and perceptions of sport participation between parents of specialized athletes and nonspecialized athletes. Odds ratios (OR) were calculated to examine parental perceptions and athlete specialization status.

RESULTS: Fifty-four parents had children who were classified as specialized athletes (43.2%). Parents who chose "concern for missing future sport-related opportunities" were >2 times as likely to have a specialized athlete when compared to those who did not (OR = 2.3; 95% CI: 1.0, 5.1; $P = .04$). Parents of specialized athletes were more likely to perceive that specialization positively impacted their children's future sport-related opportunities (58.0%, $P < .001$) and overall physical development (64.0%, $P = .03$).

CONCLUSIONS: Parental perceptions can influence sport participation patterns prior to adolescence. Parents of specialized athletes were more likely to perceive sport specialization as beneficial to their child's development and future in sport.

CLINICAL RELEVANCE: Parents' lack of knowledge surrounding the risks associated with youth sport specialization may be a contributing factor in its propagation. We, as healthcare providers, have an opportunity to educate parents and encourage them to make smart, safe decisions regarding their child's development and participation in sport.

SP05

MODE/INTENSITY OF PHYSICAL ACTIVITY DURING THE POSTACUTE PHASE OF SPORT-RELATED CONCUSSION: A SYSTEMATIC REVIEW

Barbara J. Baker, Kyle Walenta, Kevin Leo Vicari, Eric J. Koch

PURPOSE/HYPOTHESIS: The purpose of this systematic review was: (1) to investigate the most effective mode of physical activity during the postacute phase of SRC to optimize recovery and (2) to assess the most effective intensity of exercise during the postacute phase of SRC to optimize recovery.

NUMBER OF SUBJECTS: Two thousand sixty-eight records were identified through database searching. Nine studies were found to be eligible and were included in this systematic review.

MATERIALS AND METHODS: The Cumulative Index to Nursing and Allied Health Literature (CINAHL), PubMed, SPORTDiscus, and Web of Science databases were used to search the terms “brain concussion” AND “exercise” and variations of these terms. Inclusion criteria for the systematic review were as follows: (1) original research; (2) participants younger than 25 years old; (3) concussion as the primary source of injury; (4) intervention with specified intensity or mode of exercise following a concussion; (5) at least 1 group initiating exercise on average within 7 days following concussion. The evidence level for each included study was evaluated using the 2011 Oxford Center for Evidence-Based Medicine Guide. The methodological rigor of each included study was evaluated using a scale adapted from Medlicott and Harris.

RESULTS: Nine studies were found to be eligible and were included in this systematic review. The methodological quality of the literature was limited; 3 included studies were classified as moderately strong evidence and the remaining 6 studies were considered weak evidence. Six of the 9 studies used a cycle ergometer and 4 studies used a treadmill as their mode of exercise. Three studies utilized a low-intensity intervention, 4 studies utilized moderate intensity, and 8 studies incorporated some component of high intensity exercise.

CONCLUSIONS: Cycle ergometer and treadmill utilization were both found not to be aversive during the postacute phase of SRC, and thus therapists should consider an individualized approach to exercise mode prescription during this phase while carefully considering exercise intensity. Though the volume of literature at this time is limited, therapists should consider prescribing individualized, moderate intensity exercise when treating patients during the postacute phase of SRC.

CLINICAL RELEVANCE: therapists should consider prescribing individualized, moderate intensity exercise when treating patients during the postacute phase of SRC.

SP06

IS THERE A RELATIONSHIP BETWEEN STRIDE FREQUENCY AND OXYGEN CONSUMPTION DURING A FATIGUING RUN?

Nicole Baratta, Danielle Kreda, Tara Marie Porfido, Carrie Esopenko, Mary Jane Myslinski, Allison Mae Brown

PURPOSE/HYPOTHESIS: Runners typically select the most economical stride frequency in terms of energetic cost. Stride rate manipulation is commonly used to modify kinematic variables associated with running injuries; yet, larger modifications in stride rate have been shown to increase oxygen consumption (ie, VO_2) resulting in a decrease in running economy. To date, however, no study has examined stride rate changes and their relationship to VO_2 over the course of a run to fatigue, particularly when a runner is allowed to self-select and modify their running velocity. Therefore, we sought to determine whether stride frequency relates to VO_2 over the course of a run to fatigue. We hypothesized that as runners fatigued, they would demonstrate decreased stride frequency resulting in increased VO_2 .

NUMBER OF SUBJECTS: Sixteen uninjured recreational runners (10 male; mean $\pm$ SD age, 31.19 ± 5.54 years).

MATERIALS AND METHODS: Subjects performed a fatiguing run at their self-determined 10K pace with the ability to modify treadmill speed during the run. During the run, a metabolic unit was used to capture VO_2 values while a video camera was used to record a 2-D sagittal view of each participant. Video footage was used to quantify stride frequency at timestamps that were representative of 0%, 25%, 50%, 75%, and 100% of the run. Repeated measures analyses of variance were used to determine if there was a significant effect of time on stride frequency or VO_2 over the course of the run. Pearson correlations were computed to determine if there was a relationship between cadence and VO_2 at each timestamp.

RESULTS: Runners demonstrated an increase in VO_2 from the beginning to the end of the fatiguing run ($P < .001$). Increased stride frequency between 0% and 75% of the run was also shown ($P = .016$). However, no significant

changes in stride frequency values between all other timestamps ($P > .05$) nor a relationship between VO_2 values and stride frequency across all timestamps of the run were noted ($P > .05$).

CONCLUSIONS: As expected, runners demonstrated increases in VO_2 as a result of fatigue. They did not, however, demonstrate a decrease in stride frequency as was initially hypothesized. Rather, runners demonstrated increases in stride frequency occurring between the beginning and 75% of the run, but no changes between the beginning and 100% of the run. This is contrary to other studies that have found evidence of either increased or decreased stride frequency when fatigued. This may relate to the freedom that our runners had to modify their velocity during the run. Runners did not demonstrate any relationships between stride frequency and VO_2 .

CLINICAL RELEVANCE: Runners may be more likely to maintain preferred stride frequency when allowed to modify their running speed. Maintenance of this stride frequency is likely an attempt to maximize running economy in a setting where VO_2 naturally increases.

SP07

REHABILITATION AFTER A PATELLA-STABILIZING PROCEDURE WITH SUBSEQUENT ARTHROFIBROSIS DEVELOPMENT: A CASE REPORT

Patrick Barber

BACKGROUND AND PURPOSE: Postoperative rehabilitation protocols for patella stabilizing procedures have great variability. Factors causing variability including: the procedure performed, number of recurrent dislocations, structural abnormalities, tissue quality and patient's age. Taking all these factors into consideration as well as tissue-based healing timeframes guide postoperative rehab. Due to the risk of arthrofibrosis early referral to physical therapy is the gold standard. The purpose of this case report is to describe the successful management of a Medial Patellofemoral Ligament Reconstruction (MPFL-R) with Anteromedialization of Tibial Tuberosity (AMTTO) with subsequent arthrofibrosis development.

CASE DESCRIPTION: The patient was a 35-year-old woman with a history of 8 patella dislocations all treated with conservative management. She was referred to physical therapy 2 days postoperative MPFL-R with AMTTO. Rehabilitation was directed based off tissue healing timeframes and a progression of forces to promote and encourage healing. A comprehensive program was utilized including: therapeutic exercise, Low Load Long Duration (LLLD) stretching, neuromuscular re-education, gait training, Russian-Electrical Stimulation (NMES), cryotherapy and patient education. Despite early mobilization she had significant arthrofibrosis development; requiring a second lysis of adhesions/manipulation under anesthesia surgery 15 weeks postoperatively.

OUTCOMES: During the initial 15-week postoperative period she was in physical therapy 2 times/wk for a total of 27 visits. Despite the use of a comprehensive rehabilitation program she continued to have significant functional limitations. She demonstrated poor quadriceps control and a significant extensor lag noted with completion of a straight leg raise with NMES. Her ROM was noted at 0° to 90° ; based off tissue-healing timeframes her goal ROM should have been equal to the uninvolved knee. PROMIS pain interference score: 64, moderate symptoms and physical function score: 27, severe functional limitations. Lower Extremity Functional Scale (LEFS): 39/80. These amongst other factors prompted a lysis of adhesions/manipulation under anesthesia surgery. Over the course of 1 year she had 73 visits with physical therapy. She was able to return to work as a kindergarten teacher at 8 months postoperative from MPFL-R and AMTTO. At discharge her knee ROM was documented at 0° to 125° , an 8% quadriceps strength deficit assessed with hand held dynamometry (28.0 versus 34.5 lb). With unilateral hop for distance; 16% deficit noted on involved versus uninvolved side (32 versus 38 inches). PROMIS Physical Function Score: 50, within normal limits, Pain Interference Score: 44, within normal limits. Final LEFS score: 69/80.

DISCUSSION: A physical therapist working in an outpatient physical therapy clinic should be familiar with signs and symptoms consistent with arthrofibrosis as well as “at risk” patient populations. Management of complex postoperative cases that do not progress accordingly require a multidisciplinary team approach, considering basic science/tissue healing, neuromuscular re-education, LLLD/ Total End Range Time (TERT) considerations and most importantly patient education.

SP08

EFFECT OF LIMB DOMINANCE AND JUMP DIRECTION ON TIME TO STABILIZATION IN DIVISION III ATHLETES

Andrew Steven Bartlett, Robert E. Higby, Michaela I. Soules, Kelly Ann Maloney, Shannon Marie O'Malley, Brittney Nicole Mazzone

PURPOSE/HYPOTHESIS: The primary purpose of this pilot study was to determine the effects of leg dominance and jump direction (forward/lateral) as it relates to time to stabilization (TTS) in Division III collegiate athletes. The secondary aim of this study was to establish TTS norms for Division III collegiate athletes. It was hypothesized that there would be a significant interaction between limb dominance and jump direction as it relates to TTS.

NUMBER OF SUBJECTS: This study included 22 NCAA Division III collegiate athletes competing in soccer basketball, lacrosse, volleyball, and basketball (17 female). Participants were excluded if they had a prior lower extremity injury within 2 years or history of ankle sprains. Subjects were recruited via contact with local coaching staff.

MATERIALS AND METHODS: Participants completed an intake screen including the International Knee Documentation Committee Short Form (IKDC). Participants completed an established “step, step, hop” jump landing protocol using a single force plate under 4 conditions (1) forward, dominant limb, (2) forward, nondominant limb, (3) lateral, dominant limb, (4) lateral, nondominant limb. TTS was calculated as the time from landing to when the vertical ground reaction force remained $\pm 5\%$ of each individual's body weight. A 2-way ANOVA was utilized to assess differences in TTS for limb dominance and jump direction (forward/lateral).

RESULTS: Results concluded no significant interaction effect between TTS for leg dominance and jump direction ($P = .96$). There was a significant main effect of TTS for jump direction with mean difference of 0.15 (standard error, 0.064; $P = .023$). There was no significant main effect of leg dominance on time to stabilization ($P = .80$). The secondary aim established norms from this study and were as follows: forward (0.87 ± 0.26 seconds), lateral (1.01 ± 0.33 seconds).

CONCLUSIONS: The results of this study showed no significant interaction between leg preference and jump direction as it relates to TTS. However, data supports that direction of jump plays a factor in dynamic stability; it takes slightly longer to stabilize when jumping laterally as compared to forward. Future research should continue to expand on normative data and previous research on whether there is a correlation between TTS and lower extremity injuries (ie, ankle). Additional research can determine if TTS is an valid and reliable measure to determine if an athlete is appropriate to return to sport.

CLINICAL RELEVANCE: This study is the first study to identify and report forward/lateral norms for TTS in division III collegiate athletes. This is clinically important based on previous reports of longer TTS as a risk factors for ACL injury.

SP09

PROPRIOCEPTIVE ASSESSMENT TESTS FOLLOWING ANKLE SPRAINS: A SYSTEMATIC REVIEW

Michael Bertrand-Charette, Charline Dambreville, Laurent Bouyer, Jean-Sébastien Roy

PURPOSE/HYPOTHESIS: Ankle sprains are common musculoskeletal injuries

that are accompanied by deficits such as loss of functional ability and subjective instability. Regarding subjective instability, the persistence of sensorimotor deficits could explain the feeling of the ankle ready to give way. Since chronic instability can result from 3 types of deficits related to sensorimotor function (motor, sensory/proprioceptive and/or sensory processing), it is of utmost importance to identify the main cause of instability in clinical settings in order to treat adequately the sprain. Several tests have been developed to objectify the sensory or motor deficits that can be observed after ankle sprains. The goal of this study was to conduct a systematic review to determine which tests should be recommended to assess motor, sensory or sensory processing deficits at the ankle.

NUMBER OF SUBJECTS: Seventy-seven articles included.

MATERIALS AND METHODS: Seventy-seven articles on 8 categories of proprioceptive tests were found following a systematic review of 4 databases. Following critical appraisal, data on validity, reliability and responsiveness were extracted from the included articles and summarized.

RESULTS: The Star Excursion Balance Test (SEBT), Threshold for perception of passive movement (TPPM) and Joint Position Sense (JPS) were the most studied tests. Strong evidence supports the use of the SEBT as it is a functional test that discriminates between stable and unstable ankles while being reliable and responsive. Our findings suggest that there is moderate evidence that TPPM and JPS are valid and reliable tests, but their responsiveness has yet to be studied.

CONCLUSIONS: Since it is an easy-to-use functional test that gives valid, reliable and responsive information, the SEBT should be prioritized over the other tests to assess ankle function following ankle sprains. However, considering that demands on movement planning and sensorimotor integration are high during the execution of this test, the primary outcome might be more representative of the motor control aspect (ie, the ability to regulate or direct the mechanisms essentials to movement) than the sensory aspect (ie, proprioception) of human movement. Therefore, clinicians who want to assess global motor control, while having insights of proprioception, following ankle sprains should use the SEBT, while clinicians that want to focus on the sensory aspect of ankle instability should choose TPPM or JPS.

CLINICAL RELEVANCE: Identifying the best test to assess motor, sensory or sensory processing deficits at the ankle is of primary importance to adequately treat patients. The results presented in this up-to-date systematic review will therefore help clinicians in their decision-making process to select the most adequate test for patient follow-up in regard of their primary deficits (motor, sensory/proprioceptive and/or sensory processing).

SP010

EMERGING ROLE OF SPORT PHYSICAL THERAPISTS IN MENTAL HEALTH CARE

Steven Timothy Best, Jonathan Lewis Flower, Andy Krause

PURPOSE/HYPOTHESIS: Public, healthcare, and media attention regarding mental health disorder (MHD) awareness has increased in the last 5 years. Nearly 1 in 5, or 44 million, adults in the United States experience a mental illness in any given year. While 21% of Americans aged 13 to 18 years have experienced a severe MHD at some point during their lifetime. Current evidence suggests that 16% to 21% of student-athletes experience depression; however, this may be an underestimate secondary to perceived stigmatization of MHD in athletics. The NCAA published Mind, Body, and Sport to highlight the importance of student mental health and wellness, while attempting to erase the stigma related to athletes seeking management or treatment for MHD. While MHD have demonstrated a growing concern globally with a range of clinical signs and symptoms, there are no documented differences in prevalence discovered between the diagnosis of MHD in athletes versus nonathletes. Previous reports do indicate that athletes may seek psychotherapy less frequently. Additionally, athletes may be more susceptible to underdiagnosis and treatment of MHD compared to nonathletes where injuries, un-

expected athletic career termination, overtraining, and performance demands may increase the likelihood of development of MHD. A survey of sports medicine physicians revealed that over eighty percent of athletes treated for injuries also disclosed psychological issues related to that injury. Furthermore, injured athletes report higher levels of depression (33%) compared to noninjured athletes (27%). Physical therapists are identified as a member of the multidisciplinary team for treating injured athletes and they play a role in education, advocacy, research, direct intervention, and collaborative consultation to improve the overall health of the patient. However, evidence on the knowledge and competency of physical therapists with the identification and management of MHDs is not well established. Due to the paucity of evidence, the purpose of this study was to survey members of the APTA American Academy of Sports Physical Therapy regarding their level of knowledge, experience, and competency with the identification and management of patients with MHD.

NUMBER OF SUBJECTS: One hundred twenty-four physical therapists (56 male, 65 female, 3 not specified) with a mean $\pm$ SD age of 40.23 ± 11.34 years participated.

MATERIALS AND METHODS: A 22-item survey was developed and reviewed by a panel of practicing physical therapists involved in treating the athletic population, along with advanced knowledge in MHDs. The anonymous survey was then distributed via email to physical therapists who are members of the APTA American Academy of Sports Physical Therapy. The participants completed questions regarding demographic and clinical practice information, advanced credentialing, referral patterns, and screening tools used. The participants also completed a formal knowledge, experience, and competence assessment containing questions regarding MHD identification, diagnosis, and clinical decision making, using a 4-point Likert scale with anchors of 0, not at all to 4, very.

RESULTS: The reported average number of athletes seen per week was 11.1 ± 10.8 , where only 2.1 ± 3.5 athletes per week had a diagnosed MHD. Ninety-nine (79.8%) participants had advanced credentialing/specialty, where only 2 participants (1.6%) had advanced MHD training. Twenty-eight participants (22.3%) had a clinical policy and procedure for the management of athletes with signs and symptoms of MHD and only 52 (41.9%) participants used mental health screening/questionnaire tools in their everyday practice. Further, only 41 (33%) participants stated being/or have had been a member of an interprofessional team for the management of athletes with an MHD. The MEAN knowledge regarding MHDs was $52.0\% \pm 16.2\%$, where the average experience level was $40.8\% \pm 18.8\%$, and overall competency was $45.3\% \pm 20.2\%$. No significant differences were found for knowledge, experience, and competence between years of experience, gender, advanced MHD training, and advanced credentialing/specialties; all $P > .05$.

CONCLUSIONS: The data indicates the role of physical therapists as a member of a multidisciplinary team who supports the overall care and health of the patient. Data from our sample suggest that physical therapists, perhaps lack comprehensive knowledge, experience, and overall competence regarding the management of athletes with a diagnosed MHD; and the identification of signs and symptoms of MHDs. This is consistent with data on athletic trainers and team physicians previously reported in similar polling. Years of experience, sex, advanced MHD training, and advanced credentialing/specialties did not impact knowledge, experience, and competence in MHD management. The lack of advanced MHD training, along with limited use of screening tools and clinical policy and procedures for the management of MHDs further supports the need to improve future educational and training standards regarding MHD management, identification, and referral protocols.

CLINICAL RELEVANCE: The findings of this investigation supports the enhancement of learning, teaching, and practice standards regarding MHD identification and management. We subscribe to development and dissemination of continuing education activities related to patient mental health in clinical practice.

SP011

INTERRATER AND INTRATER RELIABILITY OF THE DROP VERTICAL JUMP ASSESSMENT

Emily Brooke Beyer, Rena Hale, Aaron Hellem, Allison Mumbleau, Nathan Schilatay, Timothy Hewett

PURPOSE/HYPOTHESIS: Noncontact injuries are common in sports as abnormal lower extremity joint mechanics can place athletes at risk for injury, such as an anterior cruciate ligament (ACL) tear. It is important to have reliable, feasible, cost-effective assessment tools to determine lower limb control and injury risk. The purpose of this study was to assess the inter and intratester reliability of a 3-tiered ACL injury risk rating criteria of the drop vertical jump using frontal plane 2-dimensional (2-D) motion capture.

NUMBER OF SUBJECTS: Twenty.

MATERIALS AND METHODS: A repeated measures design was utilized by 4 raters to independently view and score 20 male elite basketball athletes performing the drop vertical jump for 2-D video assessment. Athletes performed 2 to 3 practice repetitions and 3 official jumps using 2-D Dartfish cameras sampling at 60 Hz on tripods set to the height of the athletes' waist at 2 m away from the box in the frontal plane. Raters were provided a 3 tiered scoring criteria: 1 indicated no knee valgus, 2 indicated a slight wobble, inward motion of the knees, 3 was given if the athlete displayed knee collision, or large frontal plane knee excursion. They were instructed to rate knee valgus at 4 time points: (1) initial contact, (2) first landing maximum valgus, (3) second landing maximum valgus, and (4) point of maximum valgus from both jumps. The raters re-examined the same videos 1 month later blinded to their original scores. A fifth blinded investigator compared and analyzed the results.

RESULTS: Intratester reliability Fleiss kappa measure of agreement was substantial amongst all 4 raters at all scoring time points: initial contact (0.672), first landing (0.728), second landing (0.670), and peak valgus (0.662; $P < .001$). The intratester ICC values were good at initial contact (0.809), second landing (0.874), and max valgus (0.885). ICC values were excellent at first landing (0.914, $P < .001$). Interrater reliability Fleiss Kappa measurement scores were slight at initial contact (0.173), fair at max valgus (0.343), and moderate at first landing (0.532) and second landing (0.514, $P < .001$). Interrater ICC values were moderate at initial contact (0.588), excellent at first landing (0.919), and good at second landing (0.883) and max valgus point (0.882, $P < .001$).

CONCLUSIONS: When comparing scores of the drop vertical jump from 4 independent raters across 2 sessions, our study demonstrated substantial Kappa and good to excellent ICC intratester reliability. Interrater reliability demonstrated slight to moderate Kappa measurements of agreement and moderate to excellent ICC. Findings indicate that the proposed drop vertical jump assessment may be used for reliable identification of abnormal landing mechanics.

CLINICAL RELEVANCE: The DVJ ACL risk assessment is a fast, easy and cost effective method to screen athletes in the clinic or on the field. Our results demonstrate that the DVJ may be used for reliable identification of abnormal landing mechanics. The 3-tiered 2-D DVJ frontal plane assessment is repeatable and reliable for clinical use. For excellent reliability, patients should be scored by 1 individual. For moderate reliability between multiple raters, the first landing of the DVJ should be scored. Two-dimensional analysis reduces the need for software, cost, complexity and biomechanical tools to identify lower extremity movement quality.

SP012

ASSESSMENT OF THE AVERAGE PEAK TIMING OF KINEMATIC VARIABLES IN ADOLESCENT BASEBALL PITCHERS

Mark Andrew Boland, Ivan Joseph Mulligan, Joseph Steven Breisinger, Sean Donegan, Sydney Raine Lee, Kaitlyn Reese, Elizabeth Stiffler, Angela N. Tyke, Daniel C. Zambanini

PURPOSE/HYPOTHESIS: As pitching related injuries rise in adolescent baseball, it is crucial to identify the prevalence of both known reported and

measurable risk factors in adolescent baseball pitchers. The aim of the current study is to determine peaks in rotational kinematic variables among adolescent baseball pitchers as compared to previously collected data on collegiate and professional pitchers. In the current study, it is hypothesized that adolescent baseball pitchers will exhibit peaks in rotational velocities and ranges of motion earlier in the pitching cycle compared to collegiate and professional pitchers.

NUMBER OF SUBJECTS: Twenty-four.

MATERIALS AND METHODS: Twenty-four male pitchers (age, 9-16 years; mean $\pm$ SD age, 12.75 ± 2.02 years), recruited from a rural area in central Pennsylvania, participated in the study. Thirty-seven reflective markers were placed on each subject. Kinematic data were captured using an 8-camera VICON motion analysis system, with the pitching cycle identified as initial foot contact to ball release.

RESULTS: The average timing of peak trunk rotation range of motion in the 24 subjects occurred during $8.45\% \pm 12.72\%$ of the pitching cycle. Maximal pelvic rotation velocity took place at $33.26\% \pm 16.42\%$ of the pitching cycle and was shortly followed by peak trunk rotation velocity at $41.59\% \pm 9.27\%$ of the pitching cycle. The maximum shoulder external rotation range of motion occurred at $71.34\% \pm 6.61\%$ of the pitching cycle. Peak shoulder internal rotation velocity occurred last at $86.93\% \pm 6.45\%$ of the pitching cycle. Also, the average stride length, which was recorded in percentage of height of the subjects in this study, was $81.97\% \pm 4.57\%$.

CONCLUSIONS: The current study was able to identify the average peak timing of kinematic variables in the given subject population. The timing of these kinematic events may occur earlier in the pitching cycles of adolescent baseball pitchers versus collegiate or professional pitchers. The subjects within this study had stride lengths that were approximately 10% shorter than the accepted values for professional and collegiate pitchers. This finding suggests that a shorter stride length can cause adolescent pitchers to begin rotating earlier in the pitching cycle.

CLINICAL RELEVANCE: The study suggests that pitchers with a decreased stride length may exhibit peaks in kinematic variables occurring earlier in the pitching cycle.

SP013

SECOND ANTERIOR CRUCIATE LIGAMENT INJURY RATES AND ASSOCIATIONS WITH INDIVIDUAL COMPONENTS OF A RETURN-TO-SPORT ASSESSMENT

Tyler Donald Bolley, Darlene Yao, Jessica Kellum, Corey M. Snyder

PURPOSE/HYPOTHESIS: Limb symmetry on a battery of functional tests is a common clinical measure in rehabilitation following anterior cruciate ligament reconstruction (ACLR), serving as proxies for readiness to return to sport. The predictive capability of each test for determining likelihood of a second ACL injury is not well known. This study combines 18 established functional tests into a comprehensive return-to-sport assessment (RTSA). Associations and odds ratios for reinjury are determined using limb symmetry index (LSI), Y-Balance Tests (YBT), demographic data, and incidence of second ACL injury.

NUMBER OF SUBJECTS: Two hundred twenty-six individuals (51% female; mean $\pm$ SD age, 18.9 ± 4.0 years at RTS) after primary, unilateral ACLR who have completed an RTSA (9.4 ± 2.4 months post surgery).

MATERIALS AND METHODS: The RTSA included 18 tests: leg press (LP), eccentric hamstring strength (HS), tuck jump, YBT (anterior [YANT], posteromedial [YPM], posterolateral [YPL]), Drop-Jump, single hop (SH), triple hop (TH), crossover hop (CH), 6-m timed hop (TiH), lateral hop (LH), medial hop (MH), vertical jump (VJ), lower extremity functional test (LEFT), single-leg squat (SLS), burpees. Only tests that had bilateral differentiation between the limbs were included. LSI averaged values of 3 trials for each leg for LP, HS, SH, TH, CH, TiH, LH, MH, VJ, and SLS. Lowest bilateral difference across 3 trials was used for YANT, YPM, and YPL. Noncontact reinjury correlation and odds ratios with LSI, YBT, sex, age, and months

postsurgery at RTSA were examined through logistic regression using backward elimination as the variable selection method to derive the model.

RESULTS: Overall, there were 25 (11%) patients who returned for a subsequent ACL surgery. Of the 25, 20 individuals (14 [70%] female, 6 [30%] male) experienced a second noncontact ACL injury (10 ipsilateral, 10 contralateral). Of the 14 female athletes, 8 suffered a contralateral tear, 6 an ipsilateral tear. For males, 2 were contralateral and 4 were ipsilateral. The mean time from surgery to injury was 20.5 ± 9.8 months. Age, LP, YANT, and TiH were the only variables found to be statistically significant ($P = .013$, $P = .043$, $P = .027$, $P = .028$), with odds ratio of reinjury (OR) of 0.75 (95% CI: 0.58, 0.92), 0.97 (95% CI: 0.93, 0.99), 1.21 (95% CI: 1.02, 1.43), and 1.10 (95% CI: 1.01, 1.20), respectively.

CONCLUSIONS: The LSI scores of LP and TiH, as well as YANT and age have an impact on likelihood of reinjury. YANT has an OR of 1.21, indicating that a 1cm improvement in symmetry will decrease the likelihood of reinjury by 21%, holding all else constant; a 1% improvement in TiH symmetry provides a 10% decrease. Age and LP symmetry are inversely associated with likelihood of subsequent ACL injury. The LSI and YBT of the remaining tests in the RTSA were not found to be statistically associated with likelihood of reinjury.

CLINICAL RELEVANCE: Although LSI is a straightforward, quantitative measure, clinicians should not solely rely on it as a proxy for recovery of knee function. Many tests are often included in clinical assessments, but this study found only a few of the tests' quantitative measures have statistically rigorous associations with reinjury.

SP014

TIME TO ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION INFLUENCES RETURN TO SPORT THE FOLLOWING SEASON

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PURPOSE/HYPOTHESIS: Approximately 50 000 ACL injuries occur in US high school athletes each year. Previous research indicates varied rates of return to sport across all ACL injuries, and treatment type and timing. However, few studies have examined these variables in high school athletes. The purpose of this study is to determine if time to surgery and number of physical therapy visits impact the athlete's ability to return to sports.

NUMBER OF SUBJECTS: Seventy-nine (30 female, 49 male) high school athletes (average $\pm$ SD age, 15.9 ± 1.6 years) participated in the study.

MATERIALS AND METHODS: ACL injured athletes were identified by their school athletic trainer (AT) who confirmed they sustained their injury during a scholastic team-sponsored practice or game. Each athlete underwent ACL reconstruction and reported intention to return to sport at the time of surgery. ATs documented the date, mechanism, and sport of injury. Orthopaedic surgeons reported the type of surgery, graft type, date of surgery and clearance to return to sport. Patients participated in a standardized physical therapy program including a return to sport battery. Chi-square analyses and univariate ANOVAs were used to compare ability to RTS (yes or no) based on gender, graft type, delay to surgery and average physical therapy visits ($\alpha = .05$).

RESULTS: Of 79 scholastic athletes, 62 (75%) were cleared to return to their sport (9.0 ± 2.5 months) the following season while 17 did not return. Of the athletes, unable to return to sport, a significantly longer average time to surgery was noted (97 versus 47 days, $P = .005$). Athletes unable to RTS performed significantly fewer SLRs at 12 weeks (21 ± 12). There was no difference in gender ($P = .17$), graft type ($P = .7$), or PT visits ($P = .4$) when comparing those cleared versus those unable to RTS.

CONCLUSIONS: Athletes who had earlier surgical reconstruction of their ACL were more likely to return to sport the following season.

CLINICAL RELEVANCE: This study is novel in its ability to evaluate ACL the ability to return to sport in a scholastic population, based on gender, graft type, number of PT visits and delay in surgical stabilization.

SP015

RELIABILITY OF A QUALITATIVE SCORING SYSTEM OF TRUNK AND LIMB ALIGNMENT DURING A 45° CUT

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PURPOSE/HYPOTHESIS: Three-dimensional (3-D) motion analysis is considered the gold standard for evaluating human movement. However, its clinical utility is limited due to cost, operating expertise and lengthy postprocessing time. Numerous qualitative scoring systems, using videos, have been introduced to assess trunk and lower extremity (LE) alignment during functional tasks. Current literature reports that noncontact mechanisms account for up to 70% of all anterior cruciate ligament tears. However, it is unknown if a qualitative scoring system is a reliable method to evaluate cutting movement. The purpose of this study is to assess the interrater and intrarater reliability of a qualitative scoring system to evaluate trunk and LE alignment during a 45° sidestep cut. The subaim was to investigate the effect of interactive peer discussion on interrater reliability.

NUMBER OF SUBJECTS: Eight.

MATERIALS AND METHODS: A repeated-measures study design was used. Six raters (2 MDs, 2 PTs, and 2 ATs) independently viewed 10 videos, consisting of a 45° sidestep cut performed by 8 adolescent athletes (5 male, 3 female; age, 13-16 years). A clinically established checklist was given to examine quality of movement. The checklist evaluated 3 variables: trunk lean to the opposite direction of the cut, dynamic valgus on the weight bearing limb, and increased cut width. After the first round, an interactive peer discussion was held to discuss the checklist and movement quality observed. After a 1-week washout period, a second round evaluating the same 10 videos was performed. Following a 2-week washout period, a third round was performed to assess intrarater reliability. In each round video sequence was randomized to avoid memory bias. Intraclass correlation coefficient (ICC) and their 95% confident intervals (95% CIs) were calculated. Kappa agreement of each component was also measured. Values less than 0.50, between 0.50 and 0.75, between 0.75 and 0.90, and greater than 0.90 were defined as poor, moderate, good, and excellent reliability, respectively.

RESULTS: Interrater reliability for the first round was moderate (ICC = 0.565; 95% CI: 0.074, 0.866). Interrater reliability for the second round was moderate (ICC = 0.632; 95% CI: 0.100, 0.895). Intrarater reliability between the second and third round ranged from moderate to excellent (ICC = 0.589 and 0.910). Kappa measure of agreement ranged from good to excellent (κ = 0.74-1.00) for cut width and poor to excellent (κ = 0.29-1.00) for trunk lean. The variables of static and dynamic valgus varied from poor to excellent (0.07-1.00 and 0.00-1.00), respectively.

CONCLUSIONS: The results of this study showed moderate interrater reliability and moderate to excellent intrarater reliability of the qualitative checklist. Following the interactive peer discussion, slight improvements in interrater reliability were observed.

CLINICAL RELEVANCE: The findings indicate that this checklist may allow clinicians to standardize their assessment of trunk and LE alignment during a cutting task, however, more objective methods to evaluate multiplanar movements, such as genu valgum, may be warranted.

SP016

ASSESSMENT OF LANDING FORCES VIA A WEARABLE SENSOR IN FEMALE ATHLETES

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PURPOSE/HYPOTHESIS: Female athletes who exhibit high ground reaction forces (GRFs) and loading rates during landing are at greater risk for both

acute and overuse injuries. As a result, injury prevention programs often incorporate movement training to promote softer landings. Clinicians may benefit from the ability to capture GRFs, as it would allow them to assess changes throughout training and provide posttrial feedback to athletes regarding their performance. However, the force plates needed to capture GRFs are typically limited to laboratory settings. Fortunately, a body-worn sensor can also be used to indirectly assess GRFs by recording the accelerations these forces cause. However, there have been few attempts to validate this approach. The purpose of this study was to examine the relationship between impact accelerations recorded via a wearable sensor and the magnitudes and loading rates of the vertical GRF during landing. We also wanted to compare impact accelerations across landings with varying degrees of stiffness.

NUMBER OF SUBJECTS: Twenty-five uninjured female athletes.

MATERIALS AND METHODS: Following a warm-up, athletes completed double-leg drop landings from a 31-cm height using their typical technique. They then completed additional landings where they were instructed to land stiffly or softly. The order of the stiff versus soft conditions was randomized. During the landings, acceleration data were recorded via a sensor affixed to the right anterior superior iliac spine while a force plate simultaneously recorded GRFs. For each landing, the peak positive vertical acceleration ("impact acceleration"), peak vertical GRF, and loading rate of the vertical GRF were identified. The loading rate was calculated by dividing the peak vertical GRF by the time-to-peak vertical GRF. The Spearman rho correlation was used to examine the relationships between the impact accelerations and the peak vertical GRFs and loading rates for the trials in which the athletes utilized their typical technique. In addition, repeated measures ANOVA was used to compare impact accelerations among the typical, stiff, and soft conditions. Post hoc tests were conducted in the case of a significant omnibus test.

RESULTS: There was a strong, positive relationship between the impact accelerations and the peak vertical GRFs ($P < .001$, $r = 0.79$); however, there was not a relationship between the impact accelerations and the loading rates ($P = .57$, $r = 0.12$). The ANOVA results indicated that there were significant differences in impact accelerations among the conditions ($P < .001$). Impact accelerations were 15.4% lower for the soft trials ($P < .001$) and 16.7% higher for the stiff trials ($P < .001$), compared to the trials where the athletes used their typical technique.

CONCLUSIONS: Impact accelerations recorded via a pelvis-worn sensor are strongly related to peak vertical GRFs during landing and appear to be sensitive to changes in landing stiffness.

CLINICAL RELEVANCE: Wearable sensors may allow for the indirect assessment of landing forces within a clinical setting, which could be useful when training athletes.

SP017

THE RELATIONSHIP BETWEEN LEG-LENGTH INEQUALITY AND RUNNING INJURY

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PURPOSE/HYPOTHESIS: Past reports of leg-length inequality (LLI) prevalence >5 mm is approximately 50% in the United States; only approximately 20% exceed 10 mm. LLI has been associated with various knee injuries. In addition, the incidence of running-related injury is high (approximately 40%). Furthermore, the number of runners in the United States is increasing, which portends a greater prevalence of injury among this population. The Palpation Meter (PALM) has demonstrated excellent reliability and good validity for estimating LLI compared to radiographic measurement. The primary purpose of this study was to investigate the relationship between LLI, as measured via the PALM, and running injury. Our null hypothesis was that LLI would not demonstrate a statistically significant relationship with running injury.

NUMBER OF SUBJECTS: A purposive sample of 100 subjects was obtained. Inclusion criteria were runners aged 14 to 60 years who completed a run-

ning event ≥ 5 km. Subjects were excluded for any neurologic condition, active bone pathology, or body mass index ≥ 30 . Power analysis a priori indicated 69 subjects needed.

MATERIALS AND METHODS: Ethical approval for this study was approved by an Institutional Review Board. Injury within the previous 12 months was measured retrospectively by subject report via a questionnaire. LLI measurements using the PALM were performed solely by the principal investigator. The PALM was calibrated prior to application and a platform was used to standardize a level standing surface. Subjects were required to wear loose-fitting clothing during the measurement procedure and verbal cues for positioning were consistent. SPSS V ersion 25 was used for statistical analysis. Significance was set at $\alpha = .05$ and power ≥ 0.80 . Data for 91 subjects were included in final analysis. Chi-square tests for independence were used to test the hypotheses.

RESULTS: PALM calibration analysis revealed excellent validity for measurement of known distances and angles $<30^\circ$ (ICC = 0.99-1.00, $P < .01$). A chi-square test for independence revealed no significant difference in injury between groups with LLI ≥ 5 mm and <5 mm ($\chi^2 = 0.02$, $P = .88$). Past lifetime history of injury ($\chi^2 = 15.68$, $P < .01$) and running events ($\chi^2 = 3.09$, $P = .04$) revealed significant dependence with injury.

CONCLUSIONS: The null hypothesis failed to be rejected as there was no statistically significant relationship between LLI and running injury. Also, a past history of running-related injury and participation in multiple running events are significant risk factors for sustaining additional running-related injuries.

CLINICAL RELEVANCE: Correction of small LLI (<10 mm) appears to be unnecessary for reducing risk of running-related injury as the human body may be able to effectively compensate for small discrepancies. Runners with a past history of running-related injury are advised to consult a physical therapist prior to participation in running events, especially if planning to participate in multiple events annually.

SP018

CHILDREN DEMONSTRATE STRENGTH AND MOVEMENT-PATTERN ASYMMETRIES DURING A LATERAL STEP-DOWN TASK FOLLOWING PEDIATRIC ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Persistent strength deficits are reported among pediatric patients for more than 1 year following anterior cruciate ligament reconstruction (ACLR). However, the impact of persistent strength deficits on outcomes in this population has not been reported. As a first step for this work, the purpose of this preliminary analysis was to test the hypothesis that hip and knee strength would correlate with frontal and sagittal plane hip and knee kinematics during a single-leg lateral step-down task in patients after physal-sparing ACLR.

NUMBER OF SUBJECTS: Eight skeletally immature participants following primary, unilateral, physal-sparing ACLR (100% male; mean $\pm$ SD age, 11.4 $\pm$ 1.9 years; iliotibial band autograft; mean $\pm$ SD time from pACLR, 5.3 $\pm$ 2.2 months) as part of an ongoing longitudinal study.

MATERIALS AND METHODS: Sagittal and frontal plane kinematics were calculated using 3-D motion analysis during the lowering phase of a single-leg lateral step-down (4-inch box). Variables of interest included: peak knee flexion angle (PKFA), peak knee abduction angle (PKABA), peak pelvis drop (PPD), pelvis drop excursion (start of task to PKFA), and knee abduction excursion (start of task to PKFA). During the same testing session, isometric strength was evaluated for the hip abductors and extensors (JTECH Medical handheld dynamometer), and for the knee extensors and flexors (Biodex Pro System 4). Given the small sample size, between limb differences were compared with Wilcoxon signed-rank test and Spearman's rank correlation coefficients determined the association between strength and biomechanical variables ($\alpha = .05$).

RESULTS: During the task, PKFA was lower on the involved limb ($52.7^\circ \pm 7.2^\circ$) compared to the uninvolved limb ($59.9^\circ \pm 8.6^\circ$) ($z = -1.96$, $P = .05$), with a large effect size ($r = 0.5$). Regarding muscle strength, involved limb quadriceps strength was lower (60.7 ± 26.5 ft-lb) compared to uninvolved limb (72.2 ± 21.6 ft-lb) ($z = -1.960$, $P = .05$), with a large effect size ($r = 0.5$). There with no other statistical differences between limbs. On the involved limb, quadriceps strength and hamstring strength were positively correlated with PKFA ($r = 0.74$, $P = .04$ and $r = 0.88$, $P < .01$, respectively). Hip abductor strength was negatively correlated with PPD ($r = -0.81$, $P = .02$) and pelvis drop excursion ($r = -0.81$, $P = .02$).

CONCLUSIONS: Participants demonstrated strength and movement pattern asymmetries during a lateral step down 5 months following a pediatric ACLR. As hypothesized, significant correlations between strength and movement patterns in the involved limb were present. Further investigation of strength and movement patterns with a larger sample size is warranted in this patient population.

CLINICAL RELEVANCE: Following a pediatric ACLR, asymmetries in frontal and sagittal plane kinematics are observed during a lateral step down task and associated with hip and thigh strength. These preliminary data indicate that restoration of hip and thigh muscle strength is imperative to facilitate normalized movement mechanics in this patient population; however, further investigation is warranted.

SP019

ASSOCIATION BETWEEN WEARABLE INERTIAL SENSORS AND LABORATORY-BASED GROUND REACTION FORCE FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Peak vertical ground reaction force (vGRF) and instantaneous vGRF loading rate (vGRF-LR) during gait are associated with worse patient-reported outcomes and deleterious tissue changes related to osteoarthritis development following anterior cruciate ligament reconstruction (ACLR). A cost-effective, accessible method for measuring vGRF and vGRF-LR is needed to assess loading in real-world environments. The purpose of this study is to assess the association between accelerations derived from an inertial measurement unit (IMU) and vGRF and vGRF-LR during gait in individuals post ACLR.

NUMBER OF SUBJECTS: Ten individuals between 6 and 12 months following primary unilateral ACLR.

MATERIALS AND METHODS: Individuals walked for 5 minutes at their preferred speed on a force-measuring treadmill with RunScribe IMUs secured to the laces of each shoe. All vGRF data for each limb were normalized to body weight. The peak vGRF and peak vGRF-LR were extracted for each limb. RunScribe's proprietary algorithm calculated "impact g's," which was a measure of the peak vertical acceleration of the foot during stance. We used this as an estimate for acceleration experienced by the limb. A limb symmetry index [LSI = (involved/uninvolved) $\times$ 100] was calculated for each variable. Separate Pearson product-moment correlations (r) were calculated to determine the association of impact g's with peak vGRF and peak vGRF-LR.

RESULTS: For the uninvolved limb, we found significant correlations between IMU impact g's (1.62 ± 0.48 g) and both peak vGRF (1.15 ± 0.07 BW; $r = 0.64$, $P = .046$) and peak vGRF-LR (9.39 BW/s; $r = 0.64$, $P = .047$). For the involved limb, we found moderate but not statistically significant correlations between IMU impact g's (1.62 ± 0.62 g) and both peak vGRF (1.12 ± 0.07 BW; $r = 0.49$, $P = .14$) and peak vGRF-LR (9.35 ± 1.56 BW/s; $r = 0.53$, $P = .11$). For limb symmetry indices, we found no meaningful or significant correlation between IMU impact g's LSI (100.4 ± 25.9) and peak vGRF LSI (97.5 ± 2.1 ; $r = 0.08$, $P = .8$). Conversely, we found a moderate but not statistically significant correlation between IMU impact g's LSI and the peak vGRF-LR LSI (99.3 ± 5.3 ; $r = 0.53$, $P = .11$).

CONCLUSIONS: Our evidence suggests that impact g's from a shoe-based IMU are moderately correlated with peak vGRF and peak vGRF-LR in both limbs, though this relationship may be stronger in the uninvolved limb. Additionally, the LSIs from IMU impact g's and vGRF were not significantly correlated, which may be a product of the homogeneity in vGRF LSI across our sample. We suggest that interlimb symmetry may be interpreted differently when using an IMU compared to force plates.

CLINICAL RELEVANCE: IMU impact g's may be moderately correlated with laboratory measures of peak vGRF and vGRF-LR collected during gait following ACLR. IMUs appear to be a reasonable tool to assess gait clinically in this population. It is important for future research to determine if more heterogeneous peak vGRF LSIs are also reflected by IMU impact g's LSIs. It is also important to understand if IMU impact g's correlate with relevant clinical measures. These objectives will further aid in determining the utility of IMUs in post-ACLR management.

SP020

RELIABILITY OF SOMATOSENSORY TESTING AND KNEE ACTIVE JOINT POSITION SENSE IN ATHLETES WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Afferent input from the somatosensory system is important for optimal neuromuscular control of knee functional joint stability (FJS), particularly in those who have undergone anterior cruciate ligament reconstruction (ACLR). Thorough profiling of somatosensory function in individuals recovering from knee injury/surgery includes quantitative sensory testing (QST) and assessment of proprioception. The purpose of this study was to determine the intratester and intertester reliability of QST and proprioception test/variables in both lower limbs for athletes with ACLR.

NUMBER OF SUBJECTS: Following ethics approval and informed consent, 12 athletes (8 female, 4 male; mean $\pm$ SD age, 27.0 ± 3.0 years; height, 177.0 ± 13.7 cm; mass, 81.4 ± 22.9 kg) with a unilateral autogenous ACLR for ≥ 12 months, cleared for sport, and participating in level II sports or higher (Noyes Knee Sports Activity Rating Scale) participated.

MATERIALS AND METHODS: Study design was for repeated measures intra- and intertester between-day test-retest reliability involving 3 data collection sessions. Light touch, vibration sense, and pressure pain threshold (PPT) tests were performed at selected lower-limb sites, after which knee extension and flexion active joint position sense (AJPS) tests were administered. The adapted crossover hop for distance (ACHD) was included as a measure of knee FJS. For QST, Semmes Weinstein filaments were used for light touch testing, a biothesiometer for vibration sense testing, and a pain algometer for PPT testing. A smartphone and angle measurement application were used for knee AJPS testing. Intraclass correlation coefficients (ICC) were employed as the primary method to express test/variable reliability. Reliability (ICC) was defined as poor (0.00-0.25), fair (0.25-0.50), moderate to good (0.50-0.75), and good to excellent (>0.75).

RESULTS: Intratester ICC values ranged from 0.62 to 0.94 for light touch, 0.52 to 0.90 for vibration sense, 0.65 to 0.99 for PPT, 0.59 to 0.81 for AJPS, and 0.98 to 0.99 for the ACHD. Intertester ICC values ranged from 0.59 to 0.91 for light touch, 0.43 to 0.87 for vibration sense, 0.24 to 0.98 for PPT, 0.40 to 0.80 for AJPS, and 0.97 for the ACHD.

CONCLUSIONS: For both intratester and intertester reliability, ICC values consistently ranged from fair to excellent, with vibration sense testing demonstrating the lowest ICC values and the ACHD demonstrating the highest ICC values. Some light touch, vibration sense, PPT, and AJPS tests can be employed with confidence for intratester/intertester somatosensory profiling of athletes with ACLR. Other QST and knee AJPS tests should be utilized with caution due to the poor intratester/intertester reliability demonstrated by those tests.

CLINICAL RELEVANCE: This study offers a battery of QST and proprioception tests that can be used in a variety of research designs and clinical practice for somatosensory profiling of athletes with ACLR.

SP021

COMPARISON OF THE VARIABILITY OF HIP ADDUCTION ANGLE AND LIMB SYMMETRY IN YOUNG ATHLETES

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PURPOSE/HYPOTHESIS: The drop vertical jump (DVJ) task is often utilized to assess for risk factors that may lead to ACL injury. The test replicates the acceleration and deceleration aspect of sport activities that are commonly associated with ACL tears. It has been suggested that hip adduction motion contributes to knee valgus, which is associated with increased risk of ACL injury. Decreased neuromuscular control at the knee can be viewed through both ligament dominance patterns (knee valgus) and leg dominance patterns (side-to-side asymmetries). Kinematics during the DVJ have been highly studied; however, to our knowledge the variability of movement within youth athletes has not been explored. With the increasing trend of pediatric ACL injuries, it is important to determine if typical return to play testing methods are appropriate for adolescent populations. This study aimed to examine the hypothesis that there is increased variability in hip adduction angle and limb symmetry at initial contact during the drop vertical jump in younger adolescents. However, it is anticipated that the variability of both these measures decreases as age approaches skeletal maturity.

NUMBER OF SUBJECTS: Fifty.

MATERIALS AND METHODS: Fifty adolescent athletes, aged 12 to 17 years (average age, 14.1 years), performed the drop vertical jump from a 31-cm plyometric box. Each trial was recorded using video measurements and Noraxon Myomotion software for 3-D motion analysis.

RESULTS: Subjects from 12 to 14 years old demonstrated a higher range of hip adduction angles at initial contact. Hip adduction ranged from -6.6° to 19.4° on the right limb compared to -13.4° to 15.7° on the left. There was less variability in hip adduction angle from 15 to 17 years old with ranges from 0.4° to 10.6° on the right and -5.5° to 6.1° on the left. Participants between 15 and 17 years of age demonstrated higher degrees of hip adduction on the left limb compared to the right, which was the preferred limb for all subjects. Twelve year olds demonstrated increased variability of the degree of hip adduction between left and right, but 13-14-year-olds demonstrated the same trend as 15-17-year-olds with higher hip adduction on the left limb compared to the right.

CONCLUSIONS: These findings support our hypothesis that there is increased variability in hip adduction angles and limb symmetry in younger adolescents. These less predictable patterns in younger athletes (12-14 years) compared to high school age athletes could have implications in the way return to sport test results are analyzed.

CLINICAL RELEVANCE: With a high number of ACL injuries occurring in youth athletes and second reinjury rate of 23% in athletes under the age of 25 years who return to sports, it is important to determine appropriate criteria for safe return to play in the pediatric population. The variability in hip adduction within athletes from 12 to 14 years of age may limit the consideration of mechanics, such as dynamic knee valgus, within this age range when assessing for injury risk. This study addresses the need for continued research regarding return to play criteria for the younger, adolescent athlete.

SP022

ASYMMETRY AND DIFFERENCES IN STOP-JUMP TASKS IN INDIVIDUALS RETURNING TO SPORT FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Secondary ACL injury (ipsilateral graft or contralateral ACL) after ACLR is common following return-to-sport (RTS). Movement quality, including symmetry, is increasingly being recognized as an important consideration for RTS decisions. The purpose of this study was to examine lower extremity biomechanics during single-leg stop-jump (SLSJ) and double-legged stop-jump (DLSJ) tasks at the time of RTS. We hypothesized that asymmetry would not be present during the DLSJ task but present during the SLSJ task. We further hypothesized that the SLSJ task would place greater biomechanical demands on knee joint stability compared to a DLSJ.

NUMBER OF SUBJECTS: A total of 17 individuals (8 female, 9 male) participated in the study (mean $\pm$ SD age, 20.9 $\pm$ 6.5 years; height, 171.8 $\pm$ 9.7 cm; weight, 75.0 $\pm$ 18.4 kg). All subjects had undergone unilateral ACLR and were attempting to RTS.

MATERIALS AND METHODS: Biomechanical testing was performed after clearance for RTS (10.4 $\pm$ 1.9 months post ACLR) and included a 16-camera motion analysis system and 2 force plates. Individuals performed 3 SLSJ (bilateral) and DLSJ tasks. The tasks began at a distance of 40% of the participant's height from the force plate. Following the initial landing, participants immediately jumped as high as possible and landed back on the force plate. Knee flexion and valgus angle at IC and maximum value; maximum vertical (vGRF) and posterior ground reaction force (pGRF); maximum knee valgus and flexion moment; and peak proximal anterior tibia shear force were calculated. A 2-way ANOVA (task and leg) was calculated followed by pairwise comparisons (*t* tests) to examine bilateral differences and significant differences between tasks for the involved side. Statistical significance was set a priori at $P < .05$.

RESULTS: The 2-way ANOVAs resulted in statistical significance ($P < .05$) for knee flexion angles, ground reaction forces, and maximum knee valgus angle. The pairwise comparisons demonstrated that individuals landed in less ($P = .049$) maximum knee flexion on the involved side (56.6° $\pm$ 16.6°) compared to the uninvolved side (66.5° $\pm$ 10.4°) during the SLSJ task. Knee flexions angles (maximum; $P < .001$) and at IC ($P < .001$) were significantly lower during the SLSJ tasks (maximum, 56.6° $\pm$ 16.6°; IC, 15.7° $\pm$ 7.23°) compared to the DLSJ task (maximum, 84.5° $\pm$ 10.9°; IC, 26.6° $\pm$ 8.6°). Individuals landed with greater peak vGRF ($P < .001$; 321.7% $\pm$ 71.2% versus 209.1% $\pm$ 57.8 % body weight) and peak pGRF ($P = .004$; 80.8% $\pm$ 22.8% versus 58.0% $\pm$ 19.1 % body weight) during the SLSJ tasks as compared to the DLSJ tasks.

CONCLUSIONS: Differences in maximum knee flexion angle on landing were observed between the involved and uninvolved knees despite symmetry in all other variables. The SLSJ tasks did result in lower knee flexion angles, higher vertical ground reaction forces, and greater deceleration forces than the DLSJ task which would place greater demand on knee joint stability.

CLINICAL RELEVANCE: Assessment of movement quality should include both single-leg and double-leg tasks given the greater demands placed on knee joint stability during the SLSJ task. The bilateral symmetry observed in the majority of variables would potentially indicate a recovery of movement characteristics; although, caution in the interpretation of these results is warranted given the small sample size and the lack of movement assessments prior to RTS and prior to ACLR.

SP023

INCREASED PAIN IS NOT RELATED TO REDUCED KNEE JOINT LOADING IN WOMEN WITH PATELLOFEMORAL PAIN

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PURPOSE/HYPOTHESIS: Altered patellofemoral joint (PFJ) stress is thought to contribute to the etiology and persistence of patellofemoral pain (PFP). However, the relationship between PFJ pain exacerbation and lower-limb

movement patterns in individuals with PFP is unclear. We hypothesized that changes in lower-limb movement patterns would be related to change in pain status in individuals with PFP after a pain exacerbation protocol.

NUMBER OF SUBJECTS: Fifty-seven women (mean $\pm$ SD age, 22.0 $\pm$ 3.0 years) with chronic PFP; worst visual analog scale (VAS) pain (out of 100) in last week: 52.1/100 $\pm$ 16.2; duration of symptoms, 53.5 $\pm$ 47.1 months.

MATERIALS AND METHODS: Lower limb biomechanics were sampled using standard 3-D motion-capture procedures during instrumented stair ascent before and after a pain exacerbation protocol. The pain exacerbation protocol consisted of ascending and descending a flight of 7 steps a total of 15 times with a backpack load equivalent to 0.35 of each participant's bodyweight. Pain before and after the pain exacerbation protocol was rated on a 0-to-100-mm VAS scale. Peak PFJ stress was estimated using a musculoskeletal model that accounted for cocontraction of the quadriceps, hamstrings and gastrocnemius. Relative ankle, knee, and hip contributions to the total support moment impulse were also calculated. Dependent *t* tests ($\alpha = .05$) and Cohen's effect size (*d*) analyzed the change in PFJ stress, hip, knee, and ankle support moments from before and after the pain exacerbation protocol. Change scores were calculated for all variables as the difference between baseline and postexacerbation protocol values. Spearman rank correlations ($\alpha = .05$) assessed relationships between change in pain VAS and change in biomechanical variables after the pain exacerbation protocol.

RESULTS: Baseline VAS pain: 15.9 $\pm$ 22.5. After the pain exacerbation protocol, VAS Pain increased by 24.0 $\pm$ 18.0 mm ($P < .001$, $d = 0.96$); peak PFJ stress decreased 0.20 $\pm$ 0.31 mPa ($P < .001$, $d = -0.96$); knee support moment decreased 3.8% $\pm$ 5.5% ($P < .001$, $d = -0.46$); and hip support moment increased 3.9% $\pm$ 8.4% ($P < .001$, $d = 0.33$). No change in ankle support moment ($P = .87$) occurred. Changes in pain, support moments, and PFJ stress were not correlated ($P = .10-.96$).

CONCLUSIONS: After the pain exacerbation protocol, the distribution of the total support moment shifted to the hip and away from the knee, resulting in reduced PFJ stress. Despite an increase in VAS pain after the pain exacerbation protocol, changes in assessed lower limb mechanics were not associated with changes in VAS pain.

CLINICAL RELEVANCE: Pain exacerbation in women with PFP resulted in increased reliance on the hip and reduced reliance on knee loading during a stair ascent task. This altered coordination pattern was not related to change in pain status. Other factors, such as kinesophobia, may require further investigation to better understand altered movement patterns in individuals with acute exacerbation of existing PFP.

SP024

COMMON MUSCULOSKELETAL IMPAIRMENTS IN POSTPARTUM RUNNERS WITH PAIN: AN INTERNATIONAL DELPHI STUDY

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PURPOSE/HYPOTHESIS: Commonly, postpartum runners report musculoskeletal pain with running. Because of inadequate research, little is known about the origin and pain-related classification. This study is the first attempt to understand the musculoskeletal impairments that these runners present with. The objective of this Delphi survey was to gather expert consensus on the common characteristics of reported impairments in postpartum runners that have musculoskeletal pain.

NUMBER OF SUBJECTS: One hundred seventeen experts were invited to complete the survey. Forty-five experts completed round I of the survey and 41 completed rounds II and III.

MATERIALS AND METHODS: A web-based Delphi survey was conducted and was composed of 5 impairment categories: strength, range of motion, alignment and flexibility impairments, as well as risk factors for pain in postpartum runners.

RESULTS: The strength impairments that reached consensus were abdominal, hip and pelvic floor weakness. The range of motion impairments that

reached consensus were hip extension restriction, anterior pelvic tilt and general hypermobility. The alignment impairments that reached consensus were a Trendelenburg sign, dynamic knee valgus, lumbar lordosis, overpronation and thoracic kyphosis. The flexibility impairments that reached consensus were laxity in abdominal wall, and tight hip flexors, lumbar extensors, iliotibial band and hamstrings. The risk factors for pain in postpartum runners were hip pain, decrease exercise tolerance, pain during pregnancy, too much too soon, life stressors, and pelvic floor trauma.

CONCLUSIONS: This study presents a framework for clinicians to understand postpartum runners. Future cohort studies should consider investigating these impairments presenting in postpartum runners in order to assist with providing a clinical framework and rehabilitation guidelines that may be unique to this population.

CLINICAL RELEVANCE: Women are returning to running postpartum. However up to 35% are reporting lumbopelvic pain; despite these statistics to our knowledge there are no return to running recommendations that have been investigated. The primary aim of this Delphi study was to identify impairments that contribute to pain with running in the postpartum population. Synthesizing the response of the experts on the Delphi survey provide an initial understanding of which impairments contribute to pain in postpartum runners, which deserve further study, and which impairment may have face validity for transfer to a clinical environment.

SP025

EFFECTS OF A SEASON OF AMERICAN FOOTBALL ON ECCENTRIC HAMSTRING STRENGTH

Zachary Ross Christopherson, Kyle Beatty, John Steele, Robert Zarzour, Yuji Katsuta, Timothy Sell

PURPOSE/HYPOTHESIS: Hamstring strain injuries (HSIs) are a common musculoskeletal injury in American football (AF) and can result in impaired performance and lost time from competition. These injuries occur when the eccentric load exceeds the hamstring's eccentric strength threshold. Factors that decrease this threshold may contribute to HSI. Fatigue in hamstring muscles is suggested to contribute to decreased eccentric hamstring strength. This relationship has been well studied over the course of a practice or competition. However, there is a paucity of research on changes in eccentric hamstring strength over the course of a season. The primary purpose of this study was to evaluate the effect of a season of AF on eccentric hamstring strength. We hypothesized that throughout the course of a season the additive effects of exercise would result in decreased eccentric hamstring strength at the end of the season compared to the preseason, especially among the players who received the most playing time during competitions.

NUMBER OF SUBJECTS: Thirty-eight Division I male AF athletes divided into 2 groups. High (H) number of plays ($n = 21$) were players who logged greater than 100 plays during games over the course of the season. Low (L) number of plays ($n = 17$) were those who logged less than 100 plays during games over the course of the season. There was no statically significant difference between groups in age (mean $\pm$ SD H, 22.0 ± 1.0 years; L, 21.5 ± 1.1 years), height (H, 74.7 ± 2.4 inches; L, 74.3 ± 2.1 inches), or mass (H, 243.0 ± 50.0 lb; L, 230.3 ± 41.0 lb).

MATERIALS AND METHODS: Participants were excluded if they did not complete both baseline and postseason testing. All eligible participants underwent baseline testing prior to the start and at the end of the 2017-2018 season. Each participant followed the same Nordic testing protocol (3 maximal effort repetitions) on the Nordbord Hamstring Testing System (Version 1.0; Vald Performance, Queensland, Australia). The maximum and average pull forces were calculated bilaterally and used in the analysis. Statistical analysis included a 2-way ANOVA (group and test session) followed by t tests to examine differences between time points for each group and between each group at each time point. Statistical significance was set a priori at $P < .05$.

RESULTS: None of the 2-way ANOVAs resulted in statistical significance but 1 of the 16 t tests did ($P = .048$). The H group saw a significant differ-

ence between preseason (396.81 ± 11.3 N) and post season (443.8 ± 20.1 N) eccentric strength for left average pull force.

CONCLUSIONS: Overall, based on the majority of the result we did not see any difference between groups at either time points or within groups between time points.

CLINICAL RELEVANCE: It does not appear that the number of plays over the course of a season of AF changes eccentric hamstring strength. There should be some caution when interpreting the results of this study due to the small sample size, effects of in season training programs for those who play less and loss of follow-up due to attrition.

SP026

RETURN TO SPORT AND SUBSEQUENT ANTERIOR CRUCIATE LIGAMENT INJURY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION WITH CONTRALATERAL PATELLAR TENDON GRAFT

William Claussen, K. Donald Shelbourne, Tinker Gray, Rodney Benner

PURPOSE/HYPOTHESIS: Return to sport rates following anterior cruciate ligament (ACL) reconstruction varies greatly and early return to sports is considered to be a risk factor for ACL graft tear. We hypothesized that subsequent ACL tear rate to either knee will not be different based on time of return to sport with contralateral patellar tendon autografts.

NUMBER OF SUBJECTS: Two thousand one hundred thirty.

MATERIALS AND METHODS: Between 1998 and 2013, 2130 patients underwent primary ACL reconstruction using a contralateral patellar tendon graft, had no bilateral ACL injury at time of surgery, and were prospectively enrolled into a long-term outcome study. Patients followed postoperative rehabilitation to restore full and equal ROM and strength before returning to sport. Postoperative stability was recorded using KT1000 arthrometer testing of manual maximum difference between knees. Patients reported pre/postoperative level of sport participation, as well as timing of return to sport based on self-reported activity survey. Subsequent ACL injury to either knee within 5 years of surgery was recorded. Injury rates were evaluated based on time of return to sport before or after 6 months postoperatively and correlation of time of return to activity to the time of injury was calculated.

RESULTS: Of patients meeting criteria for the study, 1386 patients (65%) had complete activity rating survey data, and 89% of patients were able to return to presurgery level of sport. KT1000 arthrometer testing showed a mean manual maximum difference between knees of 1.9 ± 1.3 mm, with 91% of patients having <3 -mm difference. Of the 1386 patients, 618 (45%) were <18 years old, 394 (28%) were 18 to 25 years old, and 374 (27%) were >25 years old. In total, 758 patients returned to sport at <6 months postoperatively, and 628 patients returned at ≥ 6 months postoperatively. Overall, 93 (6.7%) suffered subsequent ACL graft tear and 68 (4.9%) suffered subsequent contralateral ACL tear in the first 5 years postoperatively. Subsequent graft tear rate was 7.7% in patients who returned to sport at <6 months and 5.6% in patients who returned at ≥ 6 months postoperatively, which was not statistically significantly different ($P = .124$). Subsequent contralateral ACL tear rate was 5.3% for patients who returned to sport before 6 months and 4.5% in patients who returned to sport at >6 months after surgery ($P = .482$). The subsequent graft tear and contralateral ACL tear rates within the age groups of <18 years, 18 to 25 years, and >25 years was not statistically significantly different (all, $P > .21$). There was no correlation between time of return to sport and subsequent ACL graft tear ($r = -0.1082$, $P = .6911$) or subsequent contralateral ACL tear ($r = -0.8691$, $P = .7847$).

CONCLUSIONS: ACL reconstruction using a contralateral patellar tendon graft reliably restores stability to the knee, and 89% of patients returned to presurgery level of sport.

CLINICAL RELEVANCE: The subsequent ACL graft tear rate or contralateral ACL tear rate was not statistically significantly different based on return to sport at <6 months or ≥ 6 months postoperatively. Furthermore,

there was no correlation of time of return to sport and time of subsequent injury.

SP027

INCREASED LOWER EXTREMITY INJURY INCIDENCE AND PARTICIPATION TIME LOSS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN ELITE COLLEGIATE ATHLETES

Daniel Garrett Cobian, Demitra R. Philosophos, Jennifer L. Sanfilippo, Bryan C. Heiderscheit

PURPOSE/HYPOTHESIS: Anterior cruciate ligament (ACL) rupture and subsequent reconstruction (ACLR) can be a devastating injury for collegiate athletes, contributing to persistent neuromuscular and neurocognitive impairments and often truncating an already short athletic career. The effect of ACL injury and surgery on risk of future lower extremity (LE) injury and time loss in high-level, competitive athletes is not well defined. The purpose of this study was to analyze the impact of ACLR on sport participation and risk of future LE injury in NCAA athletes by comparing LE injury incidence and time loss prior to ACL rupture and in the season following return to sport (RTS) after ACLR. We hypothesized athletes post-ACLR would have a higher incidence of LE injury with greater time loss in the year following RTS.

NUMBER OF SUBJECTS: Fifty-six Division I athletes (mean $\pm$ SD age, 20.3 $\pm$ 1.5 years; BMI, 26.4 $\pm$ 4.1 kg/m²; 26 female) competing in basketball, crew, football, ice hockey, soccer, track, volleyball, and wrestling.

MATERIALS AND METHODS: A review of medical and sport participation records was performed with data from 2010-2019 and both injury incidence and the percentage of time missed due to LE injuries before ACL rupture and after ACLR was calculated. Athletes were excluded if they: did not participate in collegiate practices or NCAA sanctioned competitions prior to ACLR; had exhausted eligibility; did not RTS after ACLR; or had a previous ACLR and did not have a full year of participation between the 2 surgeries. Rate ratios (RR) with 95% confidence intervals (CI) were used to compare pre and post-ACLR LE injury incidence and days missed due to LE injury.

RESULTS: Nine athletes were excluded due to lack of preoperative participation data and 5 athletes were excluded because they exhausted eligibility and did not RTS. 4 athletes had eligibility remaining post-ACLR but were excluded as they never RTS or suffered an ACL rerupture before they were cleared to RTS. The 38 included athletes who did RTS did so at an average $\pm$ SD of 9.4 $\pm$ 2.6 months post surgery. The time-loss LE injury rate per 100 days of participation was 0.154 presurgery and 0.254 postsurgery (RR = 1.65; 95% CI: 0.94, 2.90; P = .083). Pre-ACLR injury, athletes missed an average of 4.2 days/100 days of participation due to LE injury compared to 13.3 days/100 days post-ACLR (RR = 3.15; 95% CI: 2.86, 3.47; P < .001). Pre-ACLR injury, athletes missed an average of 37.1 days per LE injury compared to 52.4 days post surgery. There were 7 knee injuries prior to ACLR (36.8% of all injuries) compared to 21 knee injuries post-ACLR (63.6% of all injuries). Of the 38 included athletes, 4 reruptures (all contralateral) occurred (10.5%), all within 12 months of initial ACLR.

CONCLUSIONS: Collegiate athletes who return to collegiate sports following ACL injury and surgery have a greater risk of subsequent LE injury and time-loss due to injury.

CLINICAL RELEVANCE: ACL injury can inhibit sports participation and increase risk of future LE injury. Subsequent research initiatives will evaluate the relationships between LE neuromuscular function, movement mechanics, and injury risk post-ACLR to help guide rehabilitation efforts in this population.

SP028

BIOMECHANICAL RISK FACTORS OF ANKLE SPRAIN BASED ON POSITIONAL DEMANDS OF COLLEGIATE LACROSSE PLAYERS

David Collier, Audrey E. Westbrook, Kevin Mullen, Jeffrey B. Taylor, Anh-Dung Nguyen, Kevin R. Ford

PURPOSE/HYPOTHESIS: Ankle sprains are a commonly reported injury across all collegiate sports with lateral ankle sprain as the primary classification in 85% of cases. The most common mechanism of injury is excessive and rapid ankle inversion, producing high levels of force through the anterior talofibular ligament. Greater ankle inversion has been linked to increased ankle injury risk. The rapid growth in women's lacrosse has led to greater attention in injury prevention and rehabilitation. Like other cutting/pivoting sports, ankle sprains are prevalent in women's lacrosse and may differ based on positional demands of the sport. The purpose of this study was to identify positional differences in ankle inversion during a cutting task in women's lacrosse players.

NUMBER OF SUBJECTS: Nineteen female Division I lacrosse players volunteered to participate in this study (mean $\pm$ SD height, 163.8 $\pm$ 5.4 cm; mass, 62.3 $\pm$ 4.5 kg).

MATERIALS AND METHODS: Each participant was instrumented for standard 3-D motion analysis and performed an unanticipated cutting task over an embedded force platform consisting of a jump stop followed by a 45° cut in the direction of a randomly displayed arrow. Players were grouped according to their position: defenders (DF, n = 9), midfielders (MF, n = 5), and attackers (AT, n = 5) and frontal plane landing biomechanics of the ankle analyzed using their dominant limb. Differences between groups in ankle inversion angle, moment, velocity, and range of motion (ROM) were examined using a repeated-measures ANOVA (P < .05).

RESULTS: A main effect of position was found for each dependent variable: peak ankle inversion angle (P = .013), moment (P = .024), velocity (P = .014), and ROM (P = .025). Specifically, post hoc analyses identified that attackers had significantly greater peak ankle inversion angle compared to midfielders (AT, 21.29° $\pm$ 4.4°; MF, 11.32° $\pm$ 4.5°; P = .004) as well as greater peak inversion moment (AT, 23.16 $\pm$ 13.4 Nm; MF, 10.02 $\pm$ 2.5 Nm; P = .015), peak inversion velocity (AT, 201.03°/s $\pm$ 60.1°/s; MF, 110.15°/s $\pm$ 41.9°/s; P = .004), and inversion ROM (AT, 20.18° $\pm$ 3.6°; MF, 13.37° $\pm$ 3.0°; P = .008) compared to midfielders. Defensive players also had significantly greater peak ankle inversion moment compared to midfielders (DF, 21.80 $\pm$ 5.0 Nm; MF, 10.02 $\pm$ 2.5 Nm; P = .014), though no significant interactions were observed for other ankle measures.

CONCLUSIONS: Significantly greater ankle inversion mechanics were observed in offensive players compared to midfielders during an unanticipated cutting task in highly active lacrosse players. This movement pattern, consistent with ankle injuries, in combination with the positional demands of the sport may increase the risk of ankle sprain.

CLINICAL RELEVANCE: Given the popularity of lacrosse and the frequency of sport related ankle injuries, it is critical to understand positional risk of injury and specific movement patterns relative to player position. This allows physical therapists to create ankle-specific training and rehabilitation protocols for athletes depending on the demands of their specific position on the lacrosse field.

SP029

THE EFFECTS OF PATELLAR TENDINOPATHY ON EXPLOSIVENESS IN DIVISION I BASKETBALL PLAYERS: A PILOT STUDY

Zachary Charles Collins, Sarah Benson, Sam Methot, Nick DiMarco, Srikant Vallabhajosula, Shefali Mathur Christopher

PURPOSE/HYPOTHESIS: To investigate the effects of patellar tendinopathy (PT) on explosiveness, dynamic stability, and tendon morphology in Division I basketball players. Hypotheses: (1) participants with a history of PT would perform worse on performance tests of explosiveness and dynamic stability and (2) would show no difference in tendon thickness on ultrasound imaging.

NUMBER OF SUBJECTS: Twelve.

MATERIALS AND METHODS: Participants were tested for explosiveness and stability. Explosiveness was measured using the Reactive Strength Index (RSI): a drop-jump task onto an inground force plate. Stability was mea-

sured using the Dynamic Postural Stability Index (DPSI) requiring the participants to jump over a hurdle and land on 1 foot on a mobile force plate and regain stability. Participants also underwent ultrasonographic imaging; 2 images (proximal and distal anterior-to-posterior [AP]) were taken of each patellar tendon using European Society of Musculoskeletal Radiology guidelines. Groups were compared using independent-samples *t* tests ($\alpha < .05$).

RESULTS: Participants with a history of PT performed significantly worse on the RSI, but showed no statistical differences on DPSI performance. Differences in RSI were found between groups on ground contact time (GCT), but not flight time or jump height. Participants with a history of PT showed significantly greater AP thickness at the proximal tendon.

CONCLUSIONS: College basketball players with a history of PT may show an increased tendon thickness, but only near the proximal insertion. This injury didn't show a significant effect on long-term performance on the DPSI, but may affect explosiveness. The authors propose that the long-term effects of PT are not seen in the DPSI because it does not require a complete stretch-shorten-cycle. The tendon must store energy to achieve static stability, but is not required to release the energy explosively, as is demanded in basketball activities. Further research is needed to determine the ability to restore the explosiveness to the patellar tendon, and utilization of the RSI as part of a PT risk assessment or return-to-sport testing.

CLINICAL RELEVANCE: PT is a common overuse injury seen in up to 32% of elite basketball players. Basketball requires explosive movements which demand tendons to store and release energy repeatedly, putting them at risk of overload. Studies have not investigated the lasting effects of PT on measures of stability and explosiveness. The results of this study could help guide the later stages of rehab for PT, focusing on returning the explosiveness of the tendon. The RSI may be a valuable tool for physical therapists to assess the athletes' explosiveness preseason and during rehabilitation.

SPO30

CLINICAL DECISIONS TO GET A STRUGGLING ATHLETE BACK ON THE FIELD: A CASE REPORT

Katherine Irene Collinsworth, Noel M. Goodstadt

BACKGROUND AND PURPOSE: Patellofemoral pain (PFP) is a common sequelae of anterior cruciate ligament reconstruction (ACLR) with patellar tendon grafts. PFP can be managed with taping and exercise modifications, allowing the patient to continue to progress towards postoperative goals. Quadriceps muscle (QM) atrophy and persistent weakness, as long as 2 years postop, is another complication following ACLR to which PFP can contribute. Weakness of the QM has implications on function and is argued to impact risk of retear. As a result, return to sport (RTS) guidelines to determine an athlete's readiness emphasize the limb symmetry index (LSI) of the QM. If not monitored QM weakness can persist and prevent achievement of criterion-based guidelines. Strict RTS criteria can hold back an athlete, while not using guidelines can lead to sequelae delaying RTS. The purpose of this case report is to describe the RTS clinical decision making in a collegiate athlete's struggle due to highly irritable PFP and persistent QM weakness post ACLR.

CASE DESCRIPTION: Patient is a 19-year-old female Division I soccer player who sustained a contact ACL injury. She underwent ACLR, using a patellar tendon bone-tendon-bone autograft. She presented 5 months post-surgery after attempting to return to running and plyometrics under the care of her sports medicine team. She presented with complaints of severe PFP, and a QM LSI of 32%. Treatment focused on NMES in conjunction with OKC and CKC QM exercise with management strategies for PFP. To assess progress, monthly isometric strength tests were performed. Testing repeatedly exacerbated her PFP, resulting in inconsistent progression of strength and a change in testing was needed. Strength testing was switched to isokinetics at 9 months postop and determined an LSI of 45%. All other return-to-running criteria were achieved. Knowing her MD cleared her, all other criteria achieved, time postop, and no pain led

to the decision to deviate from the guidelines. We reinitiated running and plyometric progression to facilitate unilateral strength, power and RTS.

OUTCOMES: At 13 months postop, her QM LSI increased to 73% of the contralateral limb and all hop tests were >95%. Based on these results the decision was to begin a progression back to sport.

DISCUSSION: This case details the RTS clinical decision making for a Division I soccer player with multiple postop complications from too rapid a progression post ACLR. Understanding the evidence that the QM is an insufficient independent risk factor with respect to RTS ability and rate of retear informed the clinical decision to change how we progressed the patient. Due to peripheral adaptations, this patient may never achieve full quadriceps strength, and this could have prevented her from making it back to soccer. By deviating from typical guidelines, we were able to return her to team preseason training while still working on strength gains and minimizing irritability.

SPO31

SPORT-SPECIFIC OCULOMOTOR PERFORMANCE DIFFERENCES AMONG COLLEGIATE ATHLETES

Tyler Jason Cooperman, Quintin Davis, Geoffrey Hart, Jacob Anthony Klemme, Colby Alexander Kulig, Edward William Milisits, Ethan A. Hood

PURPOSE/HYPOTHESIS: Oculomotor performance is a fundamental function for excelling in many sports. Saccadic eye movements, smooth pursuit, and reaction time play a vital role in being successful as an athlete. The purpose of this study was to quantify differences in oculomotor performance between ball and stick sport and nonball and stick sport Division III collegiate athletes. We hypothesized as oculomotor functional demands varies between sports, differences will exist in baseline oculomotor performance specific to ball and stick versus non-ball-and-stick sports. Significant differences among the varying sports may suggest the need for sport-specific training programs to improve oculomotor performance.

NUMBER OF SUBJECTS: One hundred twenty-eight NCAA Division III athletes.

MATERIALS AND METHODS: One hundred twenty-eight participants, 79 ball-and-stick athletes (BS) (baseball, $n = 23$; softball, $n = 11$; men's lacrosse, $n = 30$; and women's lacrosse, $n = 15$), 49 non-ball and stick (NBS) (men's track and field, $n = 17$; women's track and field, $n = 7$; men's cross-country, $n = 18$; women's cross-country, $n = 7$; mean $\pm$ SD age, 19.3 ± 1.19 years). Each athlete completed oculomotor performance testing via a circuit. The King-Devick (KDT) assessed saccadic eye movements via timed reading of numbers on standardized cards during 1 warm-up round and 2 test trials. The Eye-Guide Focus (EG) assessed smooth pursuit during 1 trial using infrared camera fixation on the eye's pupil while visually tracking a figure-of-eight on an iPad screen. The Online Reaction Time Test (ORTT) assessed reaction time by clicking a stoplight cue on a laptop computer during 5 averaged trials.

RESULTS: There was no significant difference between BS and NBS scores for any of the 3 oculomotor performance assessments. Interrater reliability for the KDT was found to be significant with a high intraclass correlation coefficient. Moderate correlation was found between KDT and ORTT performance.

CONCLUSIONS: Our findings do not support the hypothesis that there are differences in oculomotor performance between athletes that participate in ball and stick sports and those that do not. Sport alone may not be an appropriate predictor of an athlete's oculomotor performance. Further research is needed to evaluate other possible predictors of oculomotor performance.

CLINICAL RELEVANCE: Establishing individual preseason baseline oculomotor scores for screening purposes is more sensitive than age matched or sport specific scores to identify oculomotor abnormalities due to the high performance variability among individuals. These findings support individual oculomotor performance screening used to detect abnormality after injury like concussion rather than standardized scores. These findings suggest oc-

ulomotor system training should be individualized to the participant rather than the sport they play. Future studies should include larger, randomized, and more diverse sample sizes and higher tier athletes.

SP032

CLINICAL MANAGEMENT OF FINGER FLEXOR PULLEY INJURIES: A SYSTEMATIC REVIEW

Logan J. Couce, Meagan Fairchild, Victoria Banner Vice, Thomas Sheahan, Tyler Logan Cope, Corey B. Simon

PURPOSE/HYPOTHESIS: Closed finger flexor pulley (CFFP) injuries first emerged as a clinical phenomenon in the 1980s with the introduction of sport climbing. As the popularity of climbing grows, so too does the prevalence of CFFP injuries. To our knowledge, no recent studies have summarized the existing literature on ideal clinical management of CFFP injuries.

NUMBER OF SUBJECTS: Two hundred forty-five subjects across 13 studies.

MATERIALS AND METHODS: Using PRISMA guidelines, we performed a systematic review across 6 electronic databases over a 15-year period. Methodological quality of included studies was assessed using the Modified Downs and Black instrument. Studies were included if population included rock climbers, community dwelling individuals, or both; and at least 1 intervention targeted CFFP injuries.

RESULTS: Of the 4835 studies extracted, 13 were eligible for inclusion. Three studies evaluated conservative interventions such as active range of motion and progressive loading via therapeutic exercise. Seven studies assessed surgical interventions such as direct pulley repair via onlay graft. Three studies considered a mix of both surgical and conservative interventions. Overall, both conservative and surgical interventions were beneficial for outcome measures that included range of motion and return to sport. However, all studies were case-based design, and thus qualitative assessment revealed an overall high susceptibility of bias. In addition, the majority of studies suffered from small sample sizes along with significant variability in both intervention parameters and choice of outcome measures.

CONCLUSIONS: Clear trends in current clinical management of CFFP injuries can be seen across the available literature for both conservative and surgical interventions. While a growing emphasis on conservative management has emerged for CFFP injuries, surgical intervention also appears to be indicated in certain cases. However, future studies must employ more rigorous experimental designs to adequately assess the efficacy of both conservative and surgical interventions for CFFP; and better inform specific intervention parameters across the healthcare spectrum.

CLINICAL RELEVANCE: To our knowledge, our systematic review is the first to comprise the latest available literature on CFFP management. In doing so, we identify preliminary indication of successful physical therapy interventions either unique to or in combination with surgery. CFFP injuries appear to be successfully managed conservatively, with patients typically returning to prior levels of sport with minimal functional deficits. However, some CFFP injuries may still require surgical intervention, and indications for either conservative versus surgical interventions remain unclear. CFFP injuries have incrementally rose with the popularity of rock climbing, but as we show here, both community-dwelling patients and other athletes (eg, baseball players) also present to physical therapy with CFFP. It's important that physical therapists acknowledge both the increased prevalence of CFFP injuries, and also the lack of rigorous research for CFFP management.

SP033

KNEE BUCKLING ASSOCIATED WITH FUNCTIONAL MOVEMENT DISORDER POST MULTIPLE PATELLAR TENDON SURGERIES: A CASE STUDY

Cemre Crowley, Jacob M. Jansen, Ian J. Kremenich, Karl F. Orishimo, Takumi Fukunaga, Malachy P. McHugh, Stephen J. Nicholas

BACKGROUND AND PURPOSE: Functional movement disorder (FMD), which is characterized by uncontrollable movement patterns such as buckling,

is not a common diagnosis in sports physical therapy. However, patellar tendon injuries are widely seen in rehabilitation, and FMD may manifest as a result of psychophysiological factors. The purpose of this case study is to explain techniques employed in the management of knee buckling in a patient with a diagnosis of FMD after multiple knee surgeries.

CASE DESCRIPTION: A 23-year-old female field hockey player was diagnosed with quadriceps weakness and activation failure after multiple surgeries: partial fat pad and plica excision in August 2016, patellar tendon repair in December 2016, patellar tendon debridement in May 2017, patellar tip debridement in November 2017, and patellar tendon reconstruction with allograft in March 2018. The patient reported first episode of knee buckling after the first surgery and physical therapy initial evaluation was done after the last surgery. At the time of evaluation, the patient demonstrated increased muscle tremors with quadriceps activation, inability to ambulate and transition from stand to sit without knee buckling, and used bilateral axillary crutches and a knee brace locked in extension.

OUTCOMES: The treatment consisted primarily of hip, knee and core strengthening, Russian stimulation of quadriceps as well as isokinetic strengthening. Strength in open kinetic chain improved over the course of the treatment and quadriceps tremors lessened; however, the patient was not able to progress to closed kinetic chain strengthening due to knee buckling. After multiple visits to physiatrists and neurologists, the patient was diagnosed with FMD. Further evaluation was performed via functional electromyogram testing, while having the patient hold a squat at a 60° angle. After a few seconds of holding the squat the patient had a momentary buckling and regained postural control with assistance. Prior to buckling there was markedly decreased activation of vastus lateralis (VL) and medialis (VM), and VL stayed relatively unchanged during buckling on the involved side. Paradoxically, the noninvolved side demonstrated deactivation of the quadriceps during buckling, and reactivation of all quadriceps muscles after buckling. Subsequent rehabilitation consisted of eccentric quadriceps strengthening and mirror training with quad sets, straight leg raise, long arc quads, supine leg press and sit to stand using TRX as well as continued hip muscle strengthening. At this point, the patient was able to ambulate using a single crutch with normal gait pattern lasting a few hours to half a day. Patient has seen a psychiatrist and will undergo inpatient multidisciplinary care to treat persisting symptoms.

DISCUSSION: In summary, it is important to recognize the symptoms of FMD in a sports physical therapy setting. A multidisciplinary treatment approach needs to be implemented. Eccentric strengthening and mirror training may be useful to treat patients with FMD presenting with buckling after surgery.

SP034

ISOKINETIC QUADRICEPS STRENGTH LIMB SYMMETRY INDEX AND HOP TEST PERFORMANCE 2 YEARS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Adam Michael Culiver, Christin Marie Zwolski, Jennifer Perry, Laura C. Schmitt

PURPOSE/HYPOTHESIS: Isometric and isokinetic quadriceps limb symmetry index (LSI) is often used in comparison to single-leg (SL) hop LSI among patients following anterior cruciate ligament reconstruction (ACLR). Isokinetic strength testing more closely simulates the muscular demands of SL jumping; however, hop performance differences based on isometric versus isokinetic quadriceps LSI are rarely investigated. The purpose of this study was to test the following hypotheses; (1) patients with greater isokinetic quadriceps LSI will demonstrate greater hop symmetry, and (2) will report higher function compared to patients with higher isometric quadriceps LSI.

NUMBER OF SUBJECTS: Fifty-four participants (mean $\pm$ SD age, 22.76 $\pm$ 3.89 years; 27 female) following primary ACLR were tested 27.53 $\pm$ 7.26 months after surgery. All participants were medically cleared for full activity.

MATERIALS AND METHODS: Participants performed isometric (at 60° knee flexion) and isokinetic (60°/s) quadriceps strength testing (Biodex Pro System 4) on both lower extremities. At the same testing session, participants completed a SL hop test battery (single hop, triple hop, cross-over hop, and 6-m timed hop) on each limb. Patient-reported function was evaluated with the Knee injury and Osteoarthritis Outcome Score (KOOS). LSI (percent) was calculated using (involved limb/uninvolved limb) $\times$ 100% for quadriceps peak torque and hop test battery measures. Participants were dichotomized into groups based on their quadriceps strength LSI. Those with isometric strength LSI greater than isokinetic strength LSI were put into a group (IM, $n = 30$) and those with isokinetic strength LSI greater than isometric strength LSI into a second group (IK, $n = 24$). Independent t tests were used to determine group differences on hop test LSI and patient reported function.

RESULTS: Group IK had a significantly higher LSI on single hop (99.0% versus 94.1%, $P = .034$), triple hop (98.4% versus 93.4%, $P = .018$), and crossover hop (99.3% versus 94.4%, $P = .029$) tests compared to the IM group. No statistical significance was found between groups on any KOOS subscale ($P > .05$). Although not statistically significant, a 10.6 ± 5.8 -point difference (82.9 versus 72.3, $P = .071$) was found on the KOOS quality of life (QoL) subscale.

CONCLUSIONS: Participants with a higher isokinetic quadriceps strength LSI jump with a more symmetric hop test profile than those with a higher isometric quadriceps strength LSI, but these differences are likely not clinically meaningful. Between group differences of 10.6 ± 5.8 on the KOOS QoL was not statistically significant but exceeds the established minimal detectable change (MCD) of 7.00 to 7.21.

CLINICAL RELEVANCE: This information may be used by clinicians to help develop training methodology for optimizing quadriceps muscle performance. Patients exhibiting a greater isometric quadriceps strength LSI may benefit from velocity based strengthening whereas those with greater isokinetic quadriceps strength LSI may benefit from heavier resistance training.

SP035

REHABILITATION OF AN ADOLESCENT ICE HOCKEY GOALIE FOLLOWING BILATERAL ACETABULAR LABRAL REPAIRS: A CASE REPORT

Derek Joseph Dathe, Glen Walter Rowell, Robert Scott Van Zant

BACKGROUND AND PURPOSE: The biomechanical demands of an ice hockey goaltender can give rise to impingement at the hip joint from the repetitive nature of each stride and save preparation, promoting tearing of the labrum and chondral lesion formation. There is limited research available about the rehabilitation for adolescent ice hockey goalies, specifically following bilateral acetabular labral repairs. The case report describes the physical therapy treatment from initial evaluation to discharge, and successful return to prior level of competition.

CASE DESCRIPTION: This retrospective case report describes the therapeutic intervention of a 15-year-old male ice hockey goalie referred to outpatient physical therapy 4 days post bilateral arthroscopic femoral head-neck osteoplasty and labral repair. The patient presented initially with severely impaired ambulation requiring the use of bilateral axillary crutches. Bilateral anterior hip pain was rated as 5/10, described as dull and local without radiation. Initial bilateral hip PROM was: flexion 115°, extension 0°, IR 25°, ER 25°. Initial hip strength via manual muscle testing recorded bilateral hip extension and abduction to be 4/5. Initial LEFS score was 14/80. He attended 26 therapy sessions over the course of an 18-week period. Treatment interventions included therapeutic exercise, neuromuscular re-education and manual therapy.

OUTCOMES: At 26 weeks post surgery, the patient had full return of AROM, strength and resolution of pain. At time of discharge bilateral hip AROM was: flexion 125°, extension 20°, IR 45°, ER 45°. Bilateral hip strength at discharge was 5/5 for all movement planes, and LEFS was 80/80. At discharge the patient had resumed skating 2 times per week, pain free. He

was able to fully return to his previous level of competitive play 5 weeks after discharge (23 weeks from surgical date).

DISCUSSION: The results of this case report demonstrates the physical therapy protocol that allowed for the successful competitive return of an adolescent ice hockey goalie following bilateral acetabular labral repairs.

SP036

A COMPARISON OF BONE DENSITY AND RUNNING KINEMATICS BETWEEN HIGH SCHOOL AND COLLEGIATE RUNNERS

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PURPOSE/HYPOTHESIS: Cross-country running is a popular sport for high school and collegiate athletes, although approximately one third of these athletes sustain running-related injuries that prevent them from participating in their sport. Recent evidence has shown a difference in the kinematics of high school and young adult recreational runners using 2-dimensional (2-D) kinematics. No study has compared running kinematics of high school and collegiate cross-country athletes and any potential risk factors related to kinematics in these populations. Additionally, calcaneal bone mineral density (BMD) was measured to investigate the effect of previous running experience on BMD. The purpose of this study was to use 2-D video analysis to compare sagittal plane kinematic variables between high school and collegiate cross-country runners and to further assess the effect of previous running experience on BMD.

NUMBER OF SUBJECTS: Thirteen high school cross-country runners (8 female, 5 male; mean $\pm$ SD age, 14.75 ± 0.75 years) and 8 collegiate cross-country runners (4 women, 4 men; mean $\pm$ SD age, 19.75 ± 1.3 years) participated in the study.

MATERIALS AND METHODS: Using a bone densitometer, each athlete had their calcaneal bone density properties measured including speed of sound (SOS), bone ultrasound attenuation (BUA), and stiffness index (SI). Participants ran shod on a treadmill at their preferred running speed, wearing reflective markers on selected lower extremity landmarks. Video data were recorded using a single high-speed camera at 240 frames/s, and assessment of 7 sagittal plane kinematic variables for each runner was performed by a single experienced rater. Vertical ground reaction force and loading rates were calculated based on a published prediction equation. A series of t tests using an alpha of .01 were used to determine if significant differences existed between the high school and collegiate cross-country athletes and for all 7 kinematic variables, predicted average loading rate and vertical ground reaction force, and for calcaneal BMD.

RESULTS: There were no differences between right and left kinematic or BMD measures, therefore left and right limbs were combined. The collegiate runners had significantly higher BMD measures of SOS ($P < .001$), BUA ($P = .001$), and SI ($P < .001$). However, the high school runners all had BMD measures within predicted age-based norms. The collegiate runners had a higher running speed ($P = .002$) but there were no differences in sagittal plane kinematics between the high school and collegiate runners other than the collegiate runners had significantly greater hip extension at toe-off ($P < .001$). The collegiate runners had a higher vertical ground reaction force ($P = .006$) but no difference in average loading rate between the 2 groups.

CONCLUSIONS: These results support that physical activity has a positive effect on calcaneal BMD, with all runners having BMD at or above predicted age norms, and greater BMD with greater running experience. The results also show no differences in running kinematics between high school and collegiate runners other than in hip extension, and all mean 2-D kinematic values are consistent with kinematic norms for running based on 3-D kinematic studies.

CLINICAL RELEVANCE: BMD appears to be positively affected with running. Further research should investigate the possible relationship between running kinematics, BMD, and injury risk in high school runners. The utilization of 2-D kinematic assessment for running gait analysis in the

clinical setting is feasible and more affordable when compared to 3-D kinematic and kinetic analysis.

SP037

HEALTH-RELATED CONSEQUENCES OF BONE STRESS INJURY IN ADOLESCENTS AND YOUNG ADULTS

Abigail Donahue, Margaret Marshall, John David Willson, Stacey A. Meardon

PURPOSE/HYPOTHESIS: Adolescents and young adults are at unique risk for physical activity related injury, including bone stress injury (BSI), due to dramatic musculoskeletal growth and development. Fifteen percent of active youth experience sport/exercise related BSI during a time considered to be a window of opportunity to build bone. Musculoskeletal injury in active populations profoundly affects quality of life (QOL) and activity participation. However, a comprehensive review of BSI effects on QOL and participation is lacking. To address this gap, we conducted a systematic literature search and review to identify what is known and what remains uncertain in the literature about QOL and participation following BSI.

NUMBER OF SUBJECTS: Of the 2818 articles identified, 32 met the inclusion criteria for qualitative and quantitative synthesis (13 prospective, 14 retrospective, 3 case series, and 2 systematic reviews) of QOL ($n = 4$) and participation ($n = 28$) outcomes.

MATERIALS AND METHODS: Using predetermined search terms, the MEDLINE/PubMed database was searched, with no publication date restrictions, for articles reporting BSI and QOL and/or participation measures. Following a comprehensive search, articles were screened by title and abstract for eligibility. Only articles that included individuals with lower extremity BSI in the sample population and outcomes related to QOL and participation were eligible for review. General review articles, consensus statements, and case studies were excluded from analysis. Article inclusion was verified by 2 investigators. Included studies were stratified for analysis based on reporting of QOL and participation outcomes. Study type, sample population, and participant age were recorded. QOL and participation outcomes were extracted. Standardized difference of the means effect sizes were calculated for QOL outcomes using reported means and standard deviations to identify the magnitude of effect BSI has on QOL metrics. Average time loss and prevalence of activity discontinuation with 95% confidence interval (CI) were also calculated.

RESULTS: Studies examined either sport ($n = 28$) or military ($n = 4$) populations. The most common age groups examined were adolescents ($n = 18$) and young adults ($n = 31$). Studies ($n = 4$) reported the following QOL were affected by BSI: short- and long-term changes in emotional health and physical functioning (effect size, 0.83), depression (effect size, 0.80), anger (effect size, 0.77) and vigor (effect size, 0.50). In studies examining participation ($n = 28$), time loss from activity participation averaged 77 days (95% CI: 64, 142) and 17% (95% CI: 10%, 27%) of participants discontinued activity participation.

CONCLUSIONS: BSI is associated with marked decline in QOL and severe time loss or discontinuation of activity participation. The prevalence of impaired QOL is not well reported. Future analyses will expand to additional databases and include quality assessment.

CLINICAL RELEVANCE: Both short- and long-term QOL and participation may be markedly impaired following BSI. Clinicians should screen for and address these issues in addition to physical rehabilitation strategies postinjury.

SP038

THE RELATIONSHIP BETWEEN HIP STRENGTH, SPORT-SPECIFIC ASSESSMENTS, AND SPORT PERFORMANCE IN FEMALE VOLLEYBALL PLAYERS

Elizabeth Ann Myers

PURPOSE/HYPOTHESIS: Contact with another player is the cause of less than 25% of volleyball injuries. Sports medicine personnel attempt to miti-

gate athlete injury by teaching proper skill performance and providing progressive training. While natural athlete talent cannot be discounted, training programs designed to reduce injury may also enhance athletic performance. The purpose of this study was to examine the relationships between hip strength, sport-specific assessments, and sport performance.

NUMBER OF SUBJECTS: Nineteen NCAA Division I female volleyball players (mean age, 19.4 years; range, 18-21 years).

MATERIALS AND METHODS: Participant hip external rotation (ER) and abduction (ABD) were measured using a handheld dynamometer and recorded to the nearest 0.10 kg. Vertical jump, vertical hop, and video assessment of hop form was performed using the Optojump testing device. Jump and hop height were recorded to the nearest 0.10 cm. Two reviewers rated hop form by scoring patella position, iliac crest level, and trunk position on a 0-2 scale with higher scores indicating poorer form. Disagreements were discussed until consensus was made. Scores were summed to create a composite hop score. Participants' injuries and kills and blocks per set from the season were recorded.

RESULTS: Composite hop scores were significantly correlated with each subcomponent. Patella position was the most highly correlated (dominant, $r = 0.754$; nondominant, $r = 0.830$; $P \leq .001$) with composite hop scores. Dominant patella position was significantly negatively correlated with ABD ($r = -0.638$, $P = .004$) but not correlated with ER ($r = -0.413$, $P = .088$). Nondominant patella position was significantly negatively correlated with ER ($r = -0.582$, $P = .011$) but not correlated with ABD ($r = -0.119$, $P = .637$). Hop and jump height were not correlated with hip strength. Kills and blocks per set were not correlated with hip strength, hop height, jump height, or hop form. No injuries occurred.

CONCLUSIONS: Composite hop scores were highly correlated with each subcomponent. For the dominant limb, greater ABD strength resulted in better hop form. For the nondominant limb, greater ER strength resulted in better hop form. Hop and jump height were not correlated with hip strength. Sport performance was not correlated with any assessments performed.

CLINICAL RELEVANCE: Given that patella position was highly correlated with composite hop scores, clinicians may choose to solely examine patellar position when evaluating hop form. More ideal hop form was related to greater hip strength. To improve hop form, clinicians should address both frontal and transverse plane hip strengthening in addition to performing traditional neuromuscular control drills. Since hop form did not affect hop/jump height or number of kills/blocks per set, training to improve hop mechanics may not improve performance in sports such as volleyball. However, such training may reduce higher-risk positioning, thereby decreasing risk of injury.

SP039

FUNCTIONAL MOVEMENT ASSESSMENTS AND INJURY RISK: A FOLLOW-UP STUDY IN DIVISION I MALE SOCCER PLAYERS

Katherine Maureen Fester, Jacqueline Ellen O'Neil, Alexa Maria Paganini, Dylan James Pearce, Rami M. Said, Jean Fitzpatrick Timmerberg

PURPOSE/HYPOTHESIS: Soccer is one of the most widely played sports in the world with high rates of injuries being reported. A soccer player produces and absorbs an enormous amount of force during an athletic event and weakness and asymmetries may predispose them to injury. Functional movement assessments are commonly used tools to identify athletes' risk of injury, but those proposed in the literature are limited to generalized movement patterns and few assessments are sport specific. Previous findings in the literature found that scores on multiple functional movement assessments, including some sport specific, may provide a better insight into increased risk of injury in this population. The purpose of this follow-up study was to explore the utility of using a battery of assessments that are sport specific to (1) see how assessment scores change over time and (2) to analyze the relationship between the battery of assessments and the relative risk of subsequent injury.

NUMBER OF SUBJECTS: Thirty-eight Division I male soccer players between the ages of 17 and 23 years (mean $\pm$ SD age, 19.7 ± 1.67 years) participated in this study.

MATERIALS AND METHODS: During the soccer preseasons of 2017-2018 and 2018-2019, players performed a 1-time assessment of the following functional movement assessments: Active Straight Leg Raise (ASLR) and Overhead Deep Squat (ODS) components of the Functional Movement Screen (FMS), Y-Balance Test (YBT), Weight-Bearing Dorsiflexion range of motion (WBDF), Single Leg Deadlift (SLDL), and an Anterolateral Leap. During the subsequent soccer seasons, injuries sustained and time lost from athletic participation were recorded.

RESULTS: Between 2 subsequent soccer seasons, 15 injuries occurred among 10 players, accounting for 364 hours lost from participation in practices/games. The majority of the injuries involved the foot and ankle (40%), hip (13.3%), and knee (13.3%). FMS squat scores significantly increased ($P = .03$) while WBDF on both the right ($P < .01$) and left ($P < .01$) decreased during over the season. Increased injury risk was associated with players who measured $<30.1^\circ$ of DF on either ankle (RR = 5.02; 95% CI: 2.73, 9.24). When examining the results of 2 or more assessments, if players presented with $<30.1^\circ$ of WBDF on either ankle combined with >4 -cm difference between each lower extremity on the YBT in the anterior direction or an FMS ASLR component score of <2 , risk of sustaining an injury in the subsequent seasons was greater than 5 (RR = 5.16; 95% CI: 2.19, 12.12) and 6 (RR = 6.33; 95% CI: 3.48, 11.53) times more likely, respectively. Similarly, players with an FMS Squat component score <2 , >4 -cm difference on the YBT between each lower extremity in the anterior or posteromedial direction, and $<30.1^\circ$ of DF were approximately 6 times more likely to sustain an injury in the following season (RR = 5.8; 95% CI: 3.30, 10.19).

CONCLUSIONS: While combining several sport specific functional assessments may further identify players at risk, a significant reduction in WBDF appears to have a stronger impact on relative risk for future lower extremity injury.

CLINICAL RELEVANCE: Identifying players who perform poorly on specific functional movement assessments may prove beneficial to developing an injury risk profile of athletes and reducing the injury risk.

SP040

DESCRIPTION AND PREDICTORS OF INJURY IN CLUB-LEVEL ULTIMATE FRISBEE PLAYERS

Joshua Gellert

PURPOSE/HYPOTHESIS: Ultimate Frisbee, or Ultimate, is a rapidly growing, self-refereed, noncontact sport that is played competitively in men's, women's, and coed leagues. Identification of injuries sustained by these athletes and potential risk factors are a prerequisite of developing therapeutic interventions. Recent studies have described the lifetime concussion prevalence among Ultimate players, injury reporting patterns in the collegiate setting, and the type of injuries incurred in the tournament setting. Currently, there are no studies that describe the prevalence or predictors of injury during a season of club-level Ultimate.

NUMBER OF SUBJECTS: Forty-four.

MATERIALS AND METHODS: A voluntary, prospective survey was given to 3 local club-level Ultimate teams (women's, men's, coed) before and after the 2018 season. Teams consisted of 28 members. Information collected included prior injuries, injuries during the season, missed time in prior/current season, nagging injuries, days/week spent training, and questions to determine Cincinnati Knee Score. Associations were determined by linear correlation (R^2) and statistical difference was determined with t test ($P < .05$).

RESULTS: Forty-four preseason and 41 postseason surveys were completed; 43/44 (98%) players had previous Ultimate-related injuries and 26/41 (63%) players were injured during the season. Time missed during the previous and current season was correlated with the presence of a nagging lower extremity injury ($R^2 = 0.83, 0.94$). We also found a negative

correlation between time missed during the previous season and days/week spent weight training ($R^2 = 0.92$) and a negative correlation between Cincinnati knee scores and time missed during the season ($R^2 = 0.7$). Notable differences in the types of injuries incurred by female versus male players during the season included males having more ankle, lower-leg, and knee injuries while females having more upper-leg injuries.

CONCLUSIONS: In this study, we gave a prospective survey to 3 club-level Ultimate men's, women's, and coed teams before and after the 2018 season. Nearly all Ultimate players (98%) came into the season with a history of previous Ultimate-related injury and a majority (63%) were injured during the season. The presence of a nagging lower extremity injury was associated with time missed in the previous and current season ($R^2 = 0.83, 0.94$). Additionally, we found correlations between the amount of weight training and Cincinnati knee scores with time missed ($R^2 = 0.92, 0.70$). Finally, we found the prevalence of certain lower extremity injuries differed between female and male players. With this study, we identify the injuries these athletes are at risk for and possible predictors of injury.

CLINICAL RELEVANCE: This study is the first to describes the prevalence and risk factors of injury during a season of club-level Ultimate Frisbee.

SP041

A MULTIFACETED APPROACH IN THE HEALING OF A STRESS FRACTURE IN THE FEMALE ENDURANCE ATHLETE

Sarah Rose Glick, Megan Mcleod, Michele Alexandria Raya, Luis Alejandro Feigenbaum, Jeff Ruiz

BACKGROUND AND PURPOSE: Stress fractures are very common in female collegiate athletes. Low bone mineral density (BMD), menstrual dysfunction, and dietary restriction/energy deprivation are risk factors for stress fracture and are elements of the female athlete triad. Due to this overlap of risk factors, it is crucial to address biomechanical deficits, energy depletion/potential overtraining syndrome, and psychosocial influences on the recovery and treatment of an athlete. The purpose of this study is to demonstrate the importance of a multifaceted approach in the recovery of a collegiate female athlete with a tibial stress fracture.

CASE DESCRIPTION: This case study involves the recovery process of a collegiate female cross country runner diagnosed with a tibial stress fracture. She presented with running form deviations which included overpronation of feet bilaterally, poor pelvic rotation with apparent hip drop bilaterally, increased bilateral femoral internal rotation and increased knee valgus. She demonstrated poor left quad neuromuscular control with occasional knee hyperextension during gait cycle, poor glute strength (Hip MMT 4-/5) and poor core endurance (front plank, 38 seconds). Further findings included decreased subtalar mobility and decreased ankle dorsiflexion (open chain dorsiflexion: right, 7° ; left, 4° ; closed chain tibial excursion test right, 4.8 inches; left, 3.2 inches). She was amenorrheic, had a low percentage body fat (13.4%), and an insufficient caloric intake. Lab studies portrayed low iron stores (35 ng/mL ferritin) and decreased BMD (DEXA lumbar Z score, -1.2). Outcome measures were chosen to incorporate influence from internal and external stressors. These measures, the Profile of Mood States (POMS) and the Athlete Stress and Recovery Questionnaire (ASRQ), were indicative of high anxiety, stress, fatigue and depression (POMS, 59; ASRQ, 24).

OUTCOMES: Physical therapy included a regimen to correct the noted biomechanical deficits, blood flow restriction training (BFRT) to aid in muscle activation and allow for strength training with decreased loads, mid-range stability exercise, running gait training, and cross training (hydroworks, bicycle, Alter-G, swimming). Bone stimulation and other modalities were also utilized. Despite physical therapy, nutritionist and sports psychology involvement, at 3 months the athlete continued to present with delayed healing. She was cleared to return to sports after 6 months. Outcome measures were given again and the athlete reported improved quality of life, sleep, and nutrition.

DISCUSSION: There is a high prevalence of the female athlete triad and stress fractures among collegiate runners. The current case study demonstrates the importance of a biopsychosocial approach in the systemic healing of an athlete who presented with a tibial stress fracture, the female athlete triad, elevated POMS and ASRQ outcome measure scores and delayed healing. Therefore, a holistic, multidimensional approach should be considered in the recovery of a female athlete with a stress fracture.

SPO42

MANAGEMENT OF TWIN ATHLETES WITH JUVENILE OSTEOCHONDRITIS DISSECANS: A CASE SERIES

Amit Gohil, Paul Michael Eckrich, Airelle Onnolee Giordano, Tara Jo Manal

BACKGROUND AND PURPOSE: Juvenile Osteochondritis Dissecans (JOCD) has a low incidence of 2.3/100 000 and is commonly diagnosed in patients 13 to 21 years old. Postoperative management of OCD has been reviewed but not with reference to using criterion based rehabilitation to optimize return to sport outcomes in youth athletes. The purpose of this case series is to discuss the case of twin athletes treated for OCD lesions and the rehabilitation progression to their respective sports.

CASE DESCRIPTION: Twin sisters, each diagnosed with an OCD lesion of the medial femoral condyle were evaluated following surgical fixation 6.5 months apart. The patients each had a history of knee pain with MRI findings of OCD lesion. Both were treated with arthroscopically assisted open reduction internal fixation of the lesion. Immediate post-operative treatment goals included restoring knee ROM within recommendations, effusion management, non-weight-bearing (NWB) quad strengthening and neuromuscular electrical stimulation (NMES). After 3 months, each patient returned to full weight bearing (WB) with gait and strengthening. Intermediate phase goals included normalizing gait, minimal to no effusion, full ROM, and quadriceps index (QI) $\geq 80\%$. Treatment included quadriceps strengthening, gait training, restoring full ROM, and NMES. Initial focus on was NWB strengthening with later progression to WB quadriceps strengthening using effusion to determine response to load. At 6 months, both twins met criteria to begin a running progression including: no or minimal effusion, full knee ROM, QI $\geq 80\%$. After meeting intermediate phase goals, Twin 1 progressed to late stage rehabilitation which included a gradual return to plyometrics, and agilities. Goals for late stage rehabilitation included: QI $\geq 90\%$, minimal to no effusion, full ROM, and $\geq 90\%$ limb symmetry index (LSI) on 4 single-leg hop tests. After meeting late stage goals, ballet-specific rehabilitation included a progressive loading regimen with single leg jumps and landing emphasizing neuromuscular control and reduced dynamic valgus. Twin 2 has been successfully completing a running progression that began unweighted and has progressed to running up to 2 miles on a treadmill. Upon completion, late stage rehabilitation will include progressive loading to return to functional goals of basketball, soccer, and ice hockey.

OUTCOMES: Both patients had KOS ADLs scores $>90\%$ at 9-month follow-up. Twin 1 successfully returned to ballet using criterion-based rehabilitation. Twin 2 met objective criteria to begin running progression without complications with intent to return to level 1 sports once cleared by her surgeon.

DISCUSSION: In this case series 2 youth athletes returned to sport and/or running without complication. Criterion based rehabilitation should be used while respecting tissue healing time frames to optimize outcomes. These outcomes are comparable to 1 other study evaluating return to sport in male twins with OCD lesions.

SPO43

UTILIZATION OF A CRITERION-BASED REHABILITATION PROGRAM IN A PATIENT WITH TRAUMATIC THIGH COMPARTMENT SYNDROME AND FASCIOTOMY

Daniel Matthew Goldstein

BACKGROUND AND PURPOSE: Compartment syndromes of the anterior thigh after blunt trauma in the absence of femur fracture is rare for adolescent athletes and standard of care remains operative decompression/fasciotomy. Lack of consensus regarding postoperative rehabilitation and progression of return to sport exists following this procedure. The purpose of this case report is to describe the criterion-based rehabilitation, return to sport, and outcomes in a high-level, adolescent basketball player.

CASE DESCRIPTION: The patient is a 16-year-old high school shooting guard who sustained multiple traumatic collisions to his right quadriceps while playing basketball. He subsequently hit his quadriceps on a table 2 days later after most recent trauma, resulting in a significant increase in pain/swelling to the area. He was initially seen in an Urgent Care center where his right quadriceps midportion circumferential measurement was 5.5 cm greater than left and referred to a local Emergency Department where he underwent an emergent fasciotomy. He arrived to outpatient physical therapy (PT) 5.5 weeks post fasciotomy with complaints of right thigh pain, limited hip abduction and external rotation strength, trace volitional quadriceps contraction, and limited active and passive knee flexion range of motion (ROM) on right lower extremity. Initial therapy interventions focused on stretching and soft tissue mobilization to regain ROM, use of neuromuscular electrical stimulation (NMES) for quadriceps activation, and progressive resisted core and hip strengthening in both open and closed kinetic chains. Late-phase rehabilitation progressed to include plyometrics and agility training as well as return to sport exercises with goal of return to basketball activities prior to his Amateur Athletic Union season.

OUTCOMES: The patient was seen for a total of 13 visits over 7 weeks in physical therapy. At initial evaluation the patient scored a 51/80 on LEFS, reported 2/10 pain in his right quadriceps, trace quadriceps contraction on right, and 4-/5 manual muscle strength in hip abduction, extension, and external rotation, and demonstrated a difference of 11° of knee flexion active ROM. After 7 sessions, the patient achieved 92% quadriceps index and 103% hip abductor index as measured via HHD, at which time he was advanced to plyometric and agility-based training. He also reported no pain, had full ROM actively, and demonstrated 7 errors with use of Tuck Jump Assessment. After 13 sessions the patient improved from initial evaluation LEFS score to 79/80 which is significant based upon minimal clinically important difference (MCID) for the LEFS, enhanced his quadriceps and hip abductor indexes to $>100\%$ with use of HHD, and refined his Tuck Jump Assessment from 7 errors to 4 errors which is below the empirical cutoff of 6 errors requiring further jump training. He also improved his Functional Hop Test score to greater than 90% limb symmetry with all testing¹ and was returned to all basketball activities without restrictions. Therefore, through a criterion-based progression, he was able to return to full function while being objectively cleared to return to basketball without restrictions nor limitations.

DISCUSSION: This case study demonstrates the effective utilization of a criterion-based return to sport progression of an adolescent basketball player, through significant improvement to his functional outcomes, lower extremity strength, pain rating, knee range of motion, and functional hop testing to allow for return to full basketball activities without restrictions. Traumatic anterior thigh compartment syndromes are rare, particularly in the absence of femur fracture, and this case study demonstrates how functional outcome measures and objective assessment can be applied to guide physical therapy progression of an adolescent athlete with return to sport decisions.

SPO44

POSTURAL STRENGTHENING AND EDUCATION TO MANAGE A COMPETITIVE HOCKEY PLAYER WITH SYMPTOMATIC THORACIC OUTLET SYNDROME

Nicole Brody Gomes, Jennifer Golda Flug-Atwood, Thomas Carlyle Windley

BACKGROUND AND PURPOSE: Thoracic Outlet Syndrome (TOS) is a disorder related to arterial, venous, or neurogenic compression in the cervi-

cal region but can occur without radiologic or electrophysical abnormalities, which is considered symptomatic TOS. This can occur due to poor posture (forward head/rounded shoulders), or repeated shoulder trauma, as seen with hockey players. Often, neurogenic or symptomatic TOS can be treated conservatively, as exercise is beneficial in 50% to 90% of TOS cases, allowing athletes to return to preinjury activity levels. This should include scapular control, manual therapy, shoulder strengthening, and scalene/pectoral stretching. This case demonstrates the benefit of periscapular strengthening and postural education to manage symptomatic TOS in a competitive hockey player.

CASE DESCRIPTION: A 15-year-old male hockey player presented to physical therapy with bilateral shoulder pain, numbness, tingling and coldness in his hands exacerbated by reaching overhead or playing hockey. He displayed an upper-cross syndrome with poor posture, pectoralis minor length of 11 cm bilaterally and periscapular strength of lower trap (L/R, 17 N/17 N), middle trap (L/R, 17 N/24 N), and rhomboids (L/R, 60 N/33 N). The numbness and coldness in his hands was recreated with Adson's, Roos, and Military Brace tests. He had decreased and painful shoulder AROM bilaterally (R/L flexion, 150°/155°; abduction, 140°/146°; functional ER T3/T1, and functional IR PSIS/PSIS), and L sided shoulder strength deficits with flexion (L/R, 93 N/113 N), abduction (L/R, 61 N/97 N), and internal rotation (L/R, 157 N/202 N). His FOTO Shoulder Survey score was 69%. His practice schedule limited therapy visits to once per week. Treatments included periscapular and rotator cuff strengthening, postural education, anterior chest/shoulder stretching, and soft tissue mobilization, with extensive home exercise mimicking in-clinic program with a focus on postural awareness.

OUTCOMES: The patient was seen for 6 visits in 6 weeks. At discharge, his FOTO Shoulder Survey score was 95%. He had improved shoulder ROM and L shoulder and periscapular strength raw values: flexion (L/R, 115 N/118 N), abduction (L/R, 112 N/110 N), internal rotation (L/R, 179 N/160 N), lower trap (L/R, 57 N/58 N), middle trap (L/R, 49 N/40 N), and rhomboids (L/R, 121 N/117 N). He also had negative TOS tests and resolution of numbness, tingling and coldness in his hands. He was educated to continue his home program to maintain improvements and to use more appropriate sitting postures when at school or riding in the car. He returned to pain free hockey participation.

DISCUSSION: This case highlights the importance of assessing posture in sport and daily activities when treating TOS. Prolonged time spent in a rounded shoulder posture while playing hockey 7 d/wk and slumping when sitting may have contributed to the initiation of his symptoms. Addressing the upper-cross syndrome and his strength and ROM deficits led to resolution of his TOS symptoms, allowing him to return to his prior level of function.

SP045

ROLE OF FUNCTIONAL ELECTRICAL STIMULATION IN RETURNING AN INJURED DIVISION I SWIMMER TO COMPETITION

Margarita Gonzalez, Noel M. Goodstadt

BACKGROUND AND PURPOSE: Shoulder instability (ShI) is common in swimmers and can be part of the multifactorial pathology of swimmer's shoulder. Slower activation and weakness of the scapular stabilizers and middle trapezius (MT) weakness in young swimmers has been implicated in ShI. The use of functional electrical stimulation (FES) has been successful in patients post cerebrovascular accident and in a case series for posterior ShI. To the best of our knowledge there is no evidence of FES for shoulder rehabilitation in swimmers. The purpose of this case study is to describe the use of FES on a Division I swimmer injured 2 months before season.

CASE DESCRIPTION: Patient presented with bilateral shoulder pain, worse on the right after a motor vehicle accident. Examination was significant for right anterior ShI and adverse neural tension of the median and ulnar nerves. She presented with high levels of pain, scapular and rotator cuff weakness, and was unable to swim. Treatment included scapular and ro-

tator cuff (RC) strengthening and modalities for pain. Due to slow progress and preseason time constraints, the plan of care was altered after 4 visits to add scapular retraction taping. Pain improved for ADLs, but continued to limit her ability to swim. FES was added to visits 7 to 10 consisting of 2 synchronized channels, a trigger, and was set to 50 pps, 300 microseconds, with a 1-second ramp-up time.

OUTCOMES: The Disabilities of the Arm, Shoulder and Hand (DASH) score was the primary outcome measure. Pain, scapular and shoulder strength, and ability to participate in swimming were secondary outcomes. Data were collected at initial evaluation and 4 weeks, 10 weeks, and 20 weeks of PT. DASH scores significantly decreased from 59.8 to 20.8, 7.5, and 2.5, respectively. DASH sports module decreased from 100 to 62.5, 31.25, and 0, respectively. Pain levels decreased from 6-9/10 to 0-2/10 after 4 weeks. Full RC and deltoid strength recovered after 4 weeks; however, MT and lower trapezius (LT) did not until week 20. A return to swim program started week 4 and she competed in the first meet at week 7.

DISCUSSION: Exercise programs addressing scapular control in addition to RC and deltoid strength have demonstrated significantly better functional outcome scores in patients with multidirectional ShI. Scapular retraction taping is used in treatment for pain relief and may help improve scapular neuromuscular control. Due to the short time frame prior to start of season and insignificant results in the first 6 visits, treatment was altered to achieve the patient's goal. After consultation with a mentor, the decision was made to add FES to enhance muscle activation of scapular stabilizers, as FES to LT has been shown to increase acromiohumeral distance, which may have aided in pain free exercise. FES was only used for 4 sessions, and in conjunction with exercise and tape was effective in improving the patient's function and pain. Patient successfully returned to swimming even though strength had not fully recovered, and she achieved a personal best by the end of the season.

SP046

RELIABILITY AND VALIDITY OF CLINICAL MEASURES OF ASSESSING RUNNING STEP RATE

Eric Todd Greenberg, Christos Kostas Mouzakitis, Giuseppe Antonio Sposito, Anthony Joseph Joe, Dano Andrew Norceide, Ryan James Merrihue

PURPOSE/HYPOTHESIS: Real-time counting is a practical clinical measure to assess step rate, though it is unknown as to which modes are most reliable and valid. The purpose of this study was to evaluate the reliability and validity of various clinical methods of assessing running step rate. It was hypothesized that using a tally counter for 30 seconds will increase counting accuracy and will be inversely related to both running speed and step rate.

NUMBER OF SUBJECTS: Ten; 3 raters.

MATERIALS AND METHODS: Ten healthy subjects (mean $\pm$ SD age, 23.2 $\pm$ 2.5 years) instrumented with a previously validated running watch were video recorded for 90 seconds while running on treadmill at 3 different running speeds: preferred, +15% preferred, and -15% preferred. Three raters, blinded to subject, specific running condition, and one another, simultaneously viewed each video and assessed running step rate using 8 counting methods derived from combinations of 3 factors: (1) with or without a tally counter; (2) 1 or 2 legs, and (3) 30 or 60 seconds. Simple calculations were performed to normalize all counting conditions to number of steps per minute (spm). The same protocol was then repeated 1 week later. Appropriate ICCs assessed the interrater and intrarater reliabilities. Mean error, absolute mean error, and ICCs assessed the validity and accuracy of each counting condition. Since the running watch has been validated in previous literature, it was utilized as the reference standard for step rate validity.

RESULTS: All 8 counting conditions had good to excellent intrarater (ICC = 0.87-1.00) and interrater (ICC = 0.80-0.98) reliability, except for using a tally counter with bilateral foot strikes for 60 seconds (ICC = 0.60-0.79 and 0.45-0.75, respectively). When compared to the running watch, all

counting methods had good to excellent agreement ($ICC = 0.82-0.96$), except the tally counter for 30 seconds on both legs ($ICC = 0.45$) and right leg only ($ICC = 0.74$) conditions. Raters overestimated step rate on average for all counting conditions compared to the running watch with mean errors ranging from 1.9 to 10.1 spm. Additionally, error was compounded for all the 30-second conditions (4.0-10.7 spm) compared to their respective 60-second conditions (2.1-4.2 spm). There were no associations between mean absolute errors and treadmill speed ($r = -0.02$ to 0.27) or step rate ($r = 0.06-0.25$).

CONCLUSIONS: When technological instrumentation such as a running watch are not available, counting running step rate is both reliable and valid regardless of running speed or magnitude of step rate, except when using a tally counter for 30 seconds. However, to enhance accuracy, counting should be performed for 60 seconds as 30-second conditions compounded measurement error. Because these counting measures tend to overestimate step rate, prescriptive increases based on these methods should be made more conservatively (5%-7.5%).

CLINICAL RELEVANCE: Running step rate is a common metric used to assess running technique. Increasing running step rate by 5% to 10% of a runner's preferred can decrease stresses to the lower limb and assist in the management of running related injuries. This study provides clinicians with valid, inexpensive, and time efficient options for assessing running step rate in a clinical setting.

SP047

LIMB SYMMETRY IS NOT ENOUGH: ESTABLISHMENT OF HEIGHT-NORMALIZED HOP DISTANCES WITHIN HEALTHY YOUTH ATHLETES

Elliot M. Greenberg, Julie Ann Dyke, Michael Scott Karl, Anne Leung, J. Todd Lawrence, Theodore J. Ganley

PURPOSE/HYPOTHESIS: Most experts recommend utilizing single leg hop tests to help determine an athlete's readiness to return to sports after anterior cruciate ligament reconstruction (ACLR). A limb symmetry index $LSI = (\text{involved limb}/\text{uninvolved limb})$ utilizing a criteria of $\geq 90\%$ is typically required by most contemporary protocols. However, limb symmetry may underestimate continued postoperative deficits due to performance declines within the uninvolved limb after ACLR. Additionally, LSI criteria may not accurately identify those at risk of repeat injury, and do not help determine if a patient is volitionally lowering their uninvolved limb effort in order to achieve a better LSI . Comparing height normalized hop distances to uninjured controls has been suggested as an additional criteria to better recognize performance deficits and effort after ACLR. The purpose of this study was to characterize single-leg hop test performance in a large group of healthy youth athletes and determine the relationships of sex or age on hop performance.

NUMBER OF SUBJECTS: Three hundred forty.

MATERIALS AND METHODS: This was a cross-sectional study of healthy youth athletes between the ages of 8 and 14 years, who were currently participating in organized sports. Using their dominant leg, each subject performed a triple hop (TrH) in which they quickly hopped on 1 leg 3 times achieving maximal linear distance, while holding their balance after the last hop. Distance from starting line to the heel was recorded in centimeters. Each subject's hop distance was normalized to body height and served as the dependent variable. A 2-way ANOVA was utilized to determine any effects of age and sex. A priori alpha was set at $P \leq .05$.

RESULTS: A total of 340 subjects (184 male; mean $\pm$ SD age, 10.9 ± 1.5 years) were included in the analysis. Across the entire sample, mean TrH distance was 2.2 times body height. ANOVA demonstrated no differences for main effect of sex (mean TrH/height: males, 2.2; females, 2.1; $P = .212$). Main effect of age was significant ($P < .001$) with Bonferroni post hoc analysis indicating 13-year-olds normalized TrH distance (2.6 times body height) was greater than all other age groups (8 years, 1.9; 9 years, 2.0; 10 years, 2.1; 11 years, 2.2; 12 years, 2.3). The 12-year-old performance was significantly greater than 8-9-year-olds only (2.3 versus 1.9-2.0).

CONCLUSIONS: When normalized to body height, TrH performance increases significantly around the ages of 12 to 13 years. This large cohort study shows that regardless of sex, young athletes aged 8 to 11 years can be expected to TrH approximately 2 times body height, while athletes near age 13 should have TrH values of 2.6 times body height.

CLINICAL RELEVANCE: Due to postoperative deconditioning within the healthy limb, the use of age-matched hopping norms in addition to LSI may offer better determination of recovery or effort. As performance changes with age, future research should focus on establishing normative performance in older subjects.

SP048

ACUTE CHANGES IN SAGITTAL PLANE KINEMATICS WHILE WEARING A NOVEL BELT DEVICE DURING TREADMILL RUNNING

Eric Todd Greenberg, Micah C. Garcia, Juliana Galante, William Gregory Werner

PURPOSE/HYPOTHESIS: Somatosensory feedback is a form of augmented feedback used in walking retraining in neurological populations, however its utility in running gait retraining is less feasible due to the greater associated speeds. The purpose of this study was to examine temporal-spatial and sagittal plane kinematic changes while wearing a novel running belt device designed to alter stride characteristics. The belt is worn around the waist and connected to foot stirrups by elastic tubing. It is hypothesized that the belt will facilitate an increased step rate and knee flexion angle at initial contact (IC), as well as a reduction in center of mass (COM) vertical displacement and tibial and foot inclination angle at IC.

NUMBER OF SUBJECTS: Ten.

MATERIALS AND METHODS: Ten healthy runners (mean $\pm$ SD age, 28.26 ± 2.75 years) ran at their preferred speed on a treadmill with and without the use of a commercial running belt device within a repeated measures study design. Temporal-spatial characteristics and sagittal plane knee and ankle kinematics were recorded with high-speed motion analysis instrumentation. Descriptive statistics and 1-tailed Wilcoxon signed-rank tests were used to compare unbelted and belted running conditions. Dependent variables included step rate, COM vertical displacement, and right limb sagittal plane kinematics of tibial inclination at IC, foot inclination angle at IC, knee flexion angle at IC, peak knee flexion during stance phase, and knee excursion from IC to peak stance phase knee flexion. To control for type I errors, a Bonferroni correction was applied and the level of significance was set at $P = .007$.

RESULTS: Average preferred treadmill running speed was 3.15 ± 0.56 m/s. Compared to the unbelted condition, COM vertical displacement ($z = -2.083, P = .003$), tibial inclination angle at IC ($z = -2.803, P = .003$), and knee excursion during stance phase ($z = -2.701, P = .003$) significantly decreased in the belted condition by 12.7%, 34.7%, and 14.9%, respectively. Additionally, knee flexion angle at IC statistically increased ($z = -2.803, P = .003$). No differences were measured for step rate ($z = -0.351, P = .363$), foot inclination angle at IC ($z = -2.090, P = .018$), or peak knee flexion in stance phase ($z = -1.172, P = .121$).

CONCLUSIONS: Running with the belt device facilitated changes in COM vertical displacement and sagittal plane limb posture at IC. This device may be a viable treatment option as a supplement to more traditional modes of gait retraining to promote changes in running technique in those with specific biomechanical profiles.

CLINICAL RELEVANCE: The results of the current study are relevant for interdisciplinary professionals working to increase performance or manage injuries in runners. This belt can act as a training adjunct for runners with specific running movement profiles that include excessive vertical displacement of COM and an extended knee and more inclined tibia at IC. Despite multiple strategies to facilitate changes in running technique, the device can provide additional somatosensory feedback to those runners not responding to other forms of gait retraining.

SP049

ARE PATIENT OUTCOMES AND TREATMENT METRICS DIFFERENT BASED ON IRRITABILITY IN SHOULDER INSTABILITY PATIENTS?

Logan John Gudde, Ellen Shanley, Carlos Gonzalez, Caitlin Ludington, Adam Daniel Lutz

PURPOSE/HYPOTHESIS: Previous research has compared PROs after surgical versus conservative, nonoperative treatment for shoulder instability. Additionally, studies have highlighted effective rehabilitation programs for patients with shoulder instability managed conservatively. However, no research to this date has examined differences in follow-up PROs and episode-level treatment metrics between levels of baseline irritability for patients with shoulder instability treated conservatively. The purpose of this study was to examine differences in follow-up PROs and episode-level treatment metrics between levels of baseline irritability for patients with shoulder instability treated conservatively.

NUMBER OF SUBJECTS: Fifty-two patients treated nonoperatively for shoulder instability. Patients were included in the study if they had a primary complaint of shoulder instability and excluded if they presented with previous shoulder or cervical surgery, or neurological involvement.

MATERIALS AND METHODS: Demographic information and episode-level treatment metrics (CPT codes, visits, and PROs) were extracted from the ATI registry. Patients were classified at baseline with low, moderate, or high irritability using published criteria. The primary PRO used in this study was the Penn Shoulder Score (Penn). Additional episode-level treatment metrics calculated for each group were number of visits, units, and skilled (active + manual). Statistical analysis was conducted using a one-way ANOVA with Tukey post hoc testing ($\alpha = .05$).

RESULTS: There was a significant difference between each of the 3 irritability groups for initial Penn score: low (74.2 ± 15.7), moderate (59.8 ± 13.3), high (35.8 ± 14.5). The high irritability group (71.4 ± 21.0) had a significantly worse final Penn score compared to the low (86.4 ± 18.2 , $P = .03$) and moderate (87.3 ± 11.7 , $P = .05$) irritability groups; no difference existed between the moderate and low irritability groups. The high irritability group had significantly more visits (18.5 ± 10.5 versus 12.4 ± 4.3 , $P = .02$), total units billed (83.2 ± 56.4 versus 52.4 ± 21 , $P = .03$), and skilled units billed (72.8 ± 45.4 versus 47.6 ± 17.6 , $P = .03$) when compared to the low irritability group; no other differences were identified.

CONCLUSIONS: When comparing each level of irritability, the high irritability group reported significantly worse final Penn Shoulder Scores than the other 2 groups and required more physical therapy visits and billed units. The low and moderate irritability groups appear to be similar in outcomes and fidelity metrics.

CLINICAL RELEVANCE: This study demonstrates that highly irritable patients with shoulder instability may require increased treatment intensity and resources when treated conservatively. Future research should focus on treatment strategies to improve outcomes for these patients.

SP050

AN INVESTIGATION OF KINETICS AND DYNAMIC POSTURAL STABILITY IN COLLEGIATE CROSS-COUNTRY RUNNERS

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PURPOSE/HYPOTHESIS: Injury rates for NCAA cross-country runners between 2009 and 2014 were 4.7-5.9/1000 athlete exposures. Loading rates have been shown to be altered in runners with musculoskeletal injury, and have also been shown to be risk factors for bony injury. Dynamic postural stability index (DPSI) has been shown to be increased in injured runners, although it has not been commonly examined in this population. Our purpose was to (1) explore differences in loading rates in injured legs and uninjured legs of NCAA Division I runners, (2) investigate the relationship between loading rates and DPSI, and (3) identify musculoskeletal variables that are related to loading rates and DPSI.

NUMBER OF SUBJECTS: Twenty-eight Division I collegiate cross-country athletes were recruited and classified into 3 injury classifications: Injured leg on an injured runner (II), uninjured leg on an injured runner (UI), and uninjured leg on an uninjured runner (UU). Injury was defined as any previous injury within the last 3 years to the lower extremity that resulted in any amount of time away from sport and required attention from a medical provider/athletic trainer.

MATERIALS AND METHODS: Inversion, eversion, and dorsiflexion strength were measured via handheld dynamometry. Ankle range of motion (ROM) was assessed via active dorsiflexion and gastrocnemius length. For DPSI, athletes jumped over a hurdle onto a force plate and landed on a single leg. DPSI was calculated for the first 3 seconds after landing. Loading rates were collected with the athlete running over a force plate at a standardized pace. Three trials were collected per leg for DPSI and loading rate. A 1-way ANOVA was performed to determine differences between groups. Pearson's correlation coefficient was used to determine relationships between variables.

RESULTS: Dorsiflexion ROM was significantly greater in II ($11.7^\circ \pm 3.6^\circ$) than UU ($8.6^\circ \pm 3.1^\circ$, $P = .013$). Vertical average loading rates were significantly greater in UI (55.9 ± 22.3 BW/s) compared to UU (37.9 ± 13.9 BW/s, $P = .046$); Vertical instantaneous loading rates were also significantly greater in UI (69.2 ± 19.0 BW/s) compared to UU (50.5 ± 13.5 BW/s, $P = .029$). Average braking loading rates (BALR) were highest for UU (18.3 ± 8.7 BW/s), followed by II (11.9 ± 9.3 BW/s) and UI (10.3 ± 7.9 BW/s), although post hoc analysis showed no differences between groups. DPSI had positive moderate correlations with BALR ($r = 0.40$, $P = .005$) and instantaneous braking loading rates ($r = 0.42$, $P = .003$) and ankle dorsiflexion ROM ($r = 0.54$, $P < .001$) in all runners.

CONCLUSIONS: Loading rates are altered in the uninjured extremity of runners with previous injury compared to runners with no history of injury. Braking rates were found to be correlated with DPSI in all runners, which indicates single-leg stability may be related to regulation of braking rates during running.

CLINICAL RELEVANCE: Rehabilitation for running injuries should address the possibility of bilateral deficits due to compensatory gait. Ankle strength and range of motion should be addressed due to their influence on single leg stability, and subsequently, braking rates. The relationship between balance and kinetics should be explored by further research.

SP051

QUADRICEPS STRENGTH CALCULATIONS TO IDENTIFY INDIVIDUALS WHO ARE AT RISK FOR SECOND ANTERIOR CRUCIATE LIGAMENT INJURY

Joseph Patrick Hannon, James Craig Garrison, Sharon S. Wang-Price, Shiho Goto, Angel Grondin, Jim Bothwell, Curtis Bush

PURPOSE/HYPOTHESIS: Restoring quadriceps strength continues to be a point of emphasis following anterior cruciate ligament reconstruction (ACL-R). How we define "restored" has changed over time from 80% limb symmetry index (LSI) to, 90%, to 100% as an acceptable cut off. Some have suggested other comparisons that include comparison to the uninjured preoperative limb, which is known as a measure of the estimated preinjury capacity (EPIC). Others have suggested that comparison to healthy controls may be a more accurate measure. Therefore, the purpose of this study was to examine the ability of 4 different quadriceps strength metrics (traditional LSI, EPIC, comparison to controls, normalized quadriceps strength to body mass (QBM)) to discriminate between those athletes who subsequently re-injured their ipsilateral or contralateral ACL following primary ACL-R.

NUMBER OF SUBJECTS: One hundred one ACL injured participants were enrolled in this study at time of initial injury. Of the 101, 90 participants were enrolled preoperatively (EPIC). Sixty-three participants were matched to healthy controls for age, sex, limb, and sport and were used for comparison. Of the 101 enrolled in the study, 15 went on to injure their ipsilateral or contralateral limb. All participants were level 1 athletes who sustained a

primary ACL injury and underwent ACL reconstruction with either a bone-patellar tendon-bone graft or hamstring graft. Participants were tested following their initial injury, but prior to surgery and again at time of return to sport (RTS) testing and then followed after release to assess for reinjury. **MATERIALS AND METHODS:** All participants completed isokinetic quadriceps strength testing on the Biodex Multi-Joint Testing and Rehabilitation System. Participants performed 5 consecutive concentric contractions at 60°/s on the uninvolved limb followed by the involved limb. Four strength calculations were completed based on the quadriceps strength recorded. (1) Quadriceps LSI at time of RTS [(Involved/uninvolved) × 100]. (2) Estimated preinjury capacity calculations (EPIC) [(Involved (RTS)/Uninvolved (initial) × 100]. (3) Quadriceps strength compared to controls [(ACL-Involved/Control-limb matched) × 100]. (4) QBM. For Quadriceps LSI, EPIC, and comparison to controls a cutoff score of greater than 90% was used to group participants into 2 groups (>90%, good; <90%, poor). For the normalized QBM calculation, a cutoff score of 2.0 NM/KG was used to dichotomize participants into 2 groups (1, good; 2, poor). This cutoff score was based on the average normalized QBM of the healthy control group.

RESULTS: Cross-tab chi-square analysis was completed to determine the number of individuals who met or did not meet each quadriceps measure grouped by those who reinjured or did not reinjure. None of the 4 measures were able to significantly discriminate between those who went on to reinjure versus those who did not reinjure: (1) Quadriceps LSI ($\chi^2 = 3.07, P = .08$); (2) EPIC ($\chi^2 = 0.386, P = .535$); (3) Comparison to controls ($\chi^2 = 0.002, P = .964$); (4) QBM ($\chi^2 = 0.109, P = .741$).

CONCLUSIONS: While quadriceps strength is undoubtedly an important measure following ACL-R, it alone was unable to discriminate between those who sustain a second ACL injury and those who do not. In this cohort, none of the 4 measures was significantly better than the other.

CLINICAL RELEVANCE: Continuing to utilize a cluster of RTS tests and a variety of quadriceps strength measures is likely indicated to have a better understanding of a patient's readiness to return to sport.

SP052

SEX DIFFERENCES IN PATELLOFEMORAL JOINT KINETICS WHILE WALKING WITH HEAVY LOAD CARRIAGE

Brittany Hanser, Brent Ruby, Alexis Doult, Lexi Klawitter, Kelly Christensen, Richard W. Willy

PURPOSE/HYPOTHESIS: Female Cadets have 2.23-fold greater risk of experiencing patellofemoral pain (PFP) versus male Cadets. Load carriage is expected during basic combat training and the prescribed amount of load carriage is universal regardless of biological sex or body mass. Quadriceps weakness is a risk factor for PFP in the military. Females have lower quadriceps strength, even when normalized to body mass. We hypothesized: (a) females will experience greater increases in patellofemoral joint (PFJ) kinetics with added heavy load carriage (33 kg); (b) lower baseline quadriceps strength and body mass will relate increases in PFJ kinetics with load carriage.

NUMBER OF SUBJECTS: Thirty-four healthy, well-trained individuals with load carriage experience (17 male: mean ± SD age, 26.8 ± 4.3 years; 17 female: age, 23.8 ± 4.6 years).

MATERIALS AND METHODS: Isometric quadriceps strength was assessed via dynamometry. Three-dimensional motion data were sampled during instrumented treadmill walking (1.35 m/s) with/without load carriage. PFJ stress (mPA) was estimated via a musculoskeletal model. Peak PFJ stress and PFJ stress loading rate were assessed via separate ANOVAs (Sex by Load; $\alpha = .05$). Standard mean difference (SMD) determined the magnitude of between group differences. Linear regression analysis ($\alpha = .05$) assessed relationships between body mass and quadriceps strength with PFJ kinetic change scores calculated with and without added load carriage.

RESULTS: Females were lighter (male: weight, 78.9 ± 6.8 kg; female, 64.3 ± 8.1 kg; $P < .001, d = 1.57$) and with less quadriceps strength (male, 323.9

± 77.0 Nm; female, 210.9 ± 32.7 Nm; $P < .001, d = 2.06$). Significant interactions were found for peak PFJ Stress (No load: male, 2.1 ± 0.6 mPa; female, 2.0 ± 0.6 mPa; load carriage: male, 2.8 ± 0.9 mPa; female, 3.4 ± 1.0 mPa; $P < .001$; SMD, 0.83) and PFJ stress loading rate (No load: male, 22.2 ± 9.9 mPa/s; female, 18.7 ± 10.0 mPa/s; load carriage: male, 28.8 ± 12.0 mPa/s; female, 34.5 ± 12.8 mPa/s; $P = .001$; SMD, 0.85) indicating that females experienced greater increases in PFJ kinetics with added load carriage versus males. The regression was not significant for peak PFJ stress. However, quadriceps strength was a significant predictor ($r = -0.45, P = .01$) of the change PFJ stress loading rate across the entire sample between no load carriage and the added load carriage, while body mass was not retained in the regression model.

CONCLUSIONS: Females experienced greater relative increases in PFJ kinetics versus males and quadriceps strength was related to the change score for PFJ stress rate, albeit not for peak PFJ stress. Underscoring the potential importance of optimizing quadriceps strength in this sample, the bottom quartile for quadriceps strength (7 female, 1 male) exhibited 3-fold greater PFJ stress loading rate changes compared with the top quartile (8 males) ($P = .006, d = 0.73$) with the added load carriage.

CLINICAL RELEVANCE: Females experienced greater increases in PFJ kinetics with load carriage. Individuals with weaker quadriceps experienced greater relative increases in PFJ stress loading rate with load carriage. Optimizing quadriceps strength may be a strategy to minimize PFJ loading rate increases that occur with heavy load carriage.

SP053

PREDICTORS OF QUALITY-OF-LIFE 2 YEARS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION AND RETURN TO SPORT

Kayla Harris, Christin Marie Zwolski, Matthew Peter Ithurburn, Staci Thomas, Mark Vincent Paterno, Laura C. Schmitt

PURPOSE/HYPOTHESIS: Functional recovery on the Knee injury and Osteoarthritis Outcome Score (KOOS) Quality of Life (QoL) subscale has recently been defined as a score of ≥92 for young athletes after anterior cruciate ligament reconstruction (ACLR). However, factors that influence the achievement of QoL functional recovery over time among this population are unknown. The purpose of this work was to test the hypothesis that modifiable factors of knee-related function at the time of return-to-sport (RTS) clearance following ACLR would predict QoL functional recovery 2 years later.

NUMBER OF SUBJECTS: Eighty-two participants (mean ± SD age, 16.7 ± 3.1 years; 54 female) with primary unilateral ACLR from a larger cohort study were included in this analysis. Participants were enrolled within 4 weeks of clearance to return to cutting/pivoting sports.

MATERIALS AND METHODS: At time of RTS clearance, knee-related function was assessed with the International Knee Documentation Committee (IKDC) subjective knee form, isometric quadriceps strength, and 3 single-leg hop tests for distance (single hop [SH], triple hop [TH], and cross-over hop [CH]). A limb symmetry index (LSI; percent) was calculated for all strength and hop tests [(involved limb/uninvolved) × 100%]. At 2 years following RTS clearance, participants completed the KOOS, and were categorized into 2 groups based on the KOOS QoL subscale score: ≥92 (high QoL) and <92 (low QoL). Independent-samples *t* tests were used to determine demographic differences between high QoL and low QoL groups at the time of RTS clearance. Univariable logistic regression models were used to determine if RTS factors predicted 2-year QoL functional recovery status, after controlling for age and sex.

RESULTS: At time of RTS clearance, there were no significant differences in age, height, weight, or time between surgery and RTS between the high QoL and low QoL groups ($P = .47-.77$). At 2 years following RTS clearance, 58.5% of young athletes had achieved QoL functional recovery. Of the 5 RTS predictor variables used in the regression models, only the IKDC score was a significant predictor of QoL at 2 years ($P = .027$). For

every 10-point increase in IKDC score at time of RTS, there was approximately 2 times the odds (OR = 2.05; 95% CI: 1.50, 2.60) of achieving high QoL at 2 years, after adjusting for age and sex.

CONCLUSIONS: IKDC score at the time of RTS predicted QoL functional recovery 2 years following RTS after ACLR. No additional measures of knee-related function at time of RTS were significant predictors of QoL functional recovery status 2 years later.

CLINICAL RELEVANCE: This study indicates that patient-reported measures of knee-related function at the time of RTS after ACLR may be important indicators of subsequent QoL functional recovery. Future work should investigate the impact of additional measures, including biopsychosocial and physical activity factors, which may affect long-term QoL after ACLR.

SP054

ESTABLISHING NORMATIVE STRENGTH AND RANGE-OF-MOTION VALUES IN DIVISION I COLLEGIATE GYMNASTS

Kaysa Marie Heck, Giorgio Zeppieri, Michelle L. Bruner, Stacey Higgins, Michael W. Moser, Kevin W. Farmer

PURPOSE/HYPOTHESIS: Gymnastics is a demanding sport that requires a delicate balance between upper extremity strength and mobility. A gymnast is required to achieve high levels of strength in order to repeatedly land on the hands before exploding off again. However, they must also maintain a certain level of flexibility in order to execute skills correctly. The unique forces experienced during gymnastics place competitive gymnasts at high risk for injury. There is a very fine line between optimal performance and injury risk. Therefore, the purpose of this study was to compare preseason upper extremity range of motion (ROM) and strength between athletes who did or did not sustain a musculoskeletal injury during the subsequent season.

NUMBER OF SUBJECTS: Fifteen Division I collegiate female gymnasts (mean $\pm$ SD age, 20.5 $\pm$ 0.95 years).

MATERIALS AND METHODS: Shoulder, elbow, and wrist ROM and strength were performed during a preseason screening. All ROM and flexibility testing was performed with a 2-tester method. ROM measurements were chosen due to similarity to the overhead positions seen in gymnastics skills. Strength testing was performed using an isokinetic or handheld dynamometer. Subjects were asked to perform maximal muscle contractions. All testing positions were selected based on published standardized testing methods. Athletic training records from the subsequent season identified athletes with any upper extremity injury resulting in loss of training, practice, or competition time. Upper extremity injuries were categorized according to the following body regions: arm/elbow, hand/wrist, or shoulder. Independent-samples *t* tests compared ROM, flexibility, and strength measures between injured versus noninjured groups.

RESULTS: Significant group difference were found in supraspinatus strength ($P = .02$), middle trapezius strength ($P = .04$), elbow extension ROM ($P = .02$), and wrist extension ROM ($P = .02$). Gymnasts who sustained an arm/elbow injury displayed a significant decrease in lower trapezius strength ($P = .05$), shoulder external rotation strength ($P = .01$), shoulder internal rotation strength ($P = .01$), and shoulder flexion ROM ($P = .02$) than gymnasts who did not sustain an arm/elbow injury. There was also a significant difference in elbow extension ROM ($P = .03$) in gymnasts who sustained a hand/wrist injury than those who did not.

CONCLUSIONS: Gymnasts with a time-loss upper extremity injury during the season showed decreased strength of shoulder internal (IR) and external rotators (ER), lower and middle trapezius, and supraspinatus as well as differences in shoulder flexion, elbow extension, and wrist extension ROM at preseason testing. Shoulder ER (90°) and IR (90°) ROM, Biodex IR/ER ratio, and shoulder IR strength did not significantly differ between injured and noninjured groups.

CLINICAL RELEVANCE: This study offers preliminary insight into gymnasts at greater risk for developing upper extremity injury based on the results of routine clinical measures. There are differences in upper extremity

strength and range of motion profiles between collegiate gymnasts who do and those who do not sustain an upper extremity injury. This information suggests that training regimen adjustments and close assessment of routine upper extremity measures demonstrating decreased shoulder strength and range of motion may help decrease injury occurrence.

SP055

PROGRESSIVE LOADING IN THE MANAGEMENT OF PROXIMAL HAMSTRING TENDINOPATHY IN A 72-YEAR-OLD GOLFER

Aaron Hellem, Nathan Schilaty

BACKGROUND AND PURPOSE: Proximal hamstring injuries are uncommon in comparison to musculotendinous junction hamstring injury in athletic populations. However, athletes with proximal hamstring injuries take substantially longer to return to sport and limited evidence exists to guide rehabilitation. Clinicians must therefore draw on available evidence for management of painful tendinopathy. This case study highlights the successful application of a progressive loading program and pain monitoring model in management of proximal hamstring tendinopathy.

CASE DESCRIPTION: A 72-year-old recreational golfer presented to physical therapy (PT) with 9-month history of worsening proximal left buttock pain following an acute lunge injury. Symptoms included pain with sitting, squatting, and walking on uneven ground. There were no signs of proximal avulsion on radiographs. He denied radiating pain or paraesthesias. Examination revealed tenderness of the ischial tuberosity, active straight leg raise to 90°, and hamstring weakness on bilateral comparison during strength testing. There was full and pain free active motion of the lumbar spine, no pain with lumbar facet loading, and no pain with hip scour and FADIR testing. PT was initiated with diagnosis of right proximal hamstring tendinopathy following acute hamstring strain.

OUTCOMES: The patient participated in 8 PT visits over 4 months. PT addressed patient education and progressive loading through tendon healing, load management, and a pain monitoring model. Combinations of isometric/isotonic exercises in positions of decreased hip flexion to minimize insertional compression were initiated to increase tissue capacity. Tolerance to exercise was monitored using a 24-hour "load test." Therapeutic exercise was advanced by manipulating hip flexion angles and movement velocity to gradually increase insertional compression and rate of tendon loading in a progressive nature. Pain levels ≤ 2 -point increase from baseline 24 hours after activity were deemed acceptable based on current tissue tolerance. Strength was measured using a handheld dynamometer and pain was assessed via a 10-point numeric pain-rating scale. Patient-reported outcomes included the Focus on Therapeutic Outcomes Physical Functional Status measure (FOTO score) and the Patient-Specific Functional Scale (PSFS). At time of discharge, the patient demonstrated 43% improvement in seated knee flexion, 3.4% improvement in supine knee flexion strength, and 0/10 pain. He exceeded the predicted FOTO score improvement and reported ≥ 3 points of improvement for all PSFS activities. The patient resumed all golf activities without symptom recurrence.

DISCUSSION: This case study demonstrates successful application of tendon healing and loading principles to the treatment of proximal hamstring tendinopathy in a senior golfer. Despite self-directed conservative measures, persistent buttock pain prompted a referral to PT. Patient education and a progressive loading program aimed at increasing tissue capacity and load tolerance facilitated objective strength gains, patient-reported symptom improvement, and a return to all desired activities.

SP056

VIDEO-BASED MOTION ANALYSIS USE: A SURVEY OF SPORTS PHYSICAL THERAPISTS

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PURPOSE/HYPOTHESIS: Motion analysis is a useful tool for physical therapists (PTs) to assess and optimize movement. Video-based motion-analysis (VBMA) has become increasingly available for smartphones/tablets and requires little to no equipment and cost. Research in this topic is limited. The purpose of this study is to explore the use of VBMA in sports PT practice.

NUMBER OF SUBJECTS: Two hundred sixty-one.

MATERIALS AND METHODS: An 18-question online survey was taken by American Academy of Sports Physical Therapy (AASPT) members. Study sample included licensed PTs practicing at least 4 h/wk treating primarily sports/orthopaedic injuries. Questions included: frequency of VBMA use, reasons for use, potential facilitators/barriers, device/apps used, patients seen, weekly practice hours, one-on-one time with patients, time patients spent with aides/assistants, certifications, and demographics. More than 1 answer was allowed in some responses. After identifying factors associated with VBMA use using Chi-square tests or *t* tests, factors with $P < .2$ were included in a multiple logistic regression model. Final model factors were backward selected using Akaike Information Criteria. Results are reported as odds ratios (ORs) and 95% confidence intervals (CIs).

RESULTS: Two hundred sixty-one respondents met inclusion criteria; 194 (74.3%) use VBMA. Of those, 163 (62.5%) use it for 1% to 25% of their caseload, 112 (57.7%) use their personal device to capture VBMA, 94 (48.5%) use a clinic-issued device, and 60 (30.9%) use a patient device. 90 (46.4%) use a tablet/phone alone to capture VBMA and 96 (49.5%) use a VBMA app. About 90% of respondents reported movement analysis and patient education/feedback as primary reasons for VBMA use. Barriers to VBMA use include time restraint (80, 30.7%), unfamiliarity with device/equipment (50, 19.2%), and lack of device/equipment (48, 18.4%). Younger age, advanced training, and time spent with return patients predicted VBMA use. For every 5 years of age increase, there is a 12% reduced likelihood of VBMA use (OR = 0.88; 95% CI: 0.76, 0.99). PTs with advanced training were twice more likely to use VBMA versus those without (OR = 2.06; 95% CI: 1.02, 4.17). Those spending ≥ 30 minutes with return patients were more likely to use (30-44 versus < 30 minutes: OR = 3.69; 95% CI: 1.85, 7.62; 45-59 versus < 30 minutes: OR = 2.74; 95% CI: 1.27, 6.18). Time spent with patients at initial evaluation, demographics, practice hours and setting, terminal degree, and frequency of delegation to PTAs or PT aides did not predict VBMA use.

CONCLUSIONS: The majority of AASPT respondents use VBMA. Of those using VBMA, most use it in $\leq 25\%$ of their caseload and for movement analysis. Those younger, with any advanced training, or spending 30 minutes or more with return patients were more likely to use VBMA. Future research should explore validity/reliability of VBMA as a movement analysis tool.

CLINICAL RELEVANCE: The majority of AASPT respondents use VBMA and record video by tablet/phone, suggesting that VBMA is accessible and feasible for clinical use. Findings of the present study may inform and motivate clinicians to incorporate VBMA into practice.

SP057

PROLONGED POSTCONCUSSION SYNDROME IN AN ADOLESCENT: A MULTIMODAL APPROACH TOWARD RECOVERY

Robert M. Hofschulte, Purvi Shaan Vora

BACKGROUND AND PURPOSE: A concussion is a brain injury which produces a variety of symptoms based on different subtypes (Vestibular, Ocular, Cervical, Cognitive, Exercise Intolerance, etc). A majority of individuals will spontaneously recover; however, Post Concussion Syndrome (PCS) occurs in about 30% of cases when symptoms persist beyond normal the adolescent recovery of 2 to 4 weeks. The purpose of this case study is to discuss the importance of multimodal approach to concussion rehabilitation.

CASE DESCRIPTION: This case study highlights a 19-year-old man with PCS for the last 2 years. This patient reports that shortly after the injury he completed a course of physical therapy which improved his balance, but denies cervical or vestibular-ocular interventions. The patient completed

his final 2 years in high school and freshman year of college with moderate difficulty due to symptoms burden (headaches, difficulty concentrating, neck pain, and dizziness) and was referred to physical therapy after freshman year. A multimodal assessment and treatment approach was utilized to determine which subtypes of concussion were responsible for continued deficits. Patient has received focused interventions to improve his vestibular-ocular and cervical impairments. Patient is still under care and has completed 8 weeks of treatment.

OUTCOMES: Over the last 8 weeks, self reported outcome measures of Dizziness Handicap Index improved by 18 (MDC, 17), Convergence Insufficiency Symptoms Scale improved from 50 to 34, but is still > 21 so still indicative of convergence insufficiency. He exhibits decreased symptom exacerbation with VOMS assessment. Significant changes with Motion Sensitivity Quotient (MSQ) from 63 to 5.6 (MSQ Scoring: Severe, 31-100; Mild, 0-10). Patient has no symptom exacerbation with Buffalo Concussion Treadmill Test. His Headache Disability Index increased by 10 points (MDC, 29), however, subjectively notes intensity of headaches has significantly decreased. He continues to exhibit 3 line positive Dynamic Visual Acuity testing. Patient had Vestibular Functional Testing performed which was unremarkable.

DISCUSSION: The case study highlights the importance of a multimodal assessment and treatment when rehabilitating individuals from a concussion. The lack of assessment of all concussion subtypes may have played a role in this patient's prolonged recovery. Patient demonstrated significant improvements in physical therapy assessments, overall function, emotional state, and self confidence. Patient still reports difficulty with focus/attention, dual task concentration, memory, and mood swings, which may be influenced by symptom burden and poor sleep quality over the last 2 years. Further research should focus on the most appropriate assessments and algorithms prioritizing treatment for concussion subtypes. Additionally, research focused on the impact prolonged symptoms burden on cognitive and emotional functioning. In conclusion, there is a need to assess all concussion subtypes at initial evaluation allowing earliest implementation of focused intervention for optimal outcomes.

SP058

TRAINING PROTECTIVE FACTORS FOR KNEE PAIN IN HIKING VERSUS NONHIKING OLYMPIC-CLASS SAILORS

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PURPOSE/HYPOTHESIS: Knee pain is a common musculoskeletal condition reported by Olympic class sailors. Hiking in sailing involves high knee torques to control a boat. Our previous studies associated hiking exposure with increased knee pain over the course of competition and that training was protective. Knee pain could impact competitive performance. The purpose of this study was to examine if the training's protective effect differs in hikers versus nonhikers for development of knee pain.

NUMBER OF SUBJECTS: One hundred sixty-three (53 female).

MATERIALS AND METHODS: A convenience sample of sailors having finished competition was collected after the same 5-day Olympic class regatta in 2 different years. A cohort completed a 61-item anonymous questionnaire concerning sailing-related activities, demographic information, and knee pain status. Risk factor exposures were in place at the regatta's inception. The subjects' mean $\pm$ SD age was ($n = 159$) 23.6 ± 4.7 years; range, 18-43 years, body mass index of 23.7 ± 4.6 kg/m²; range, 19.2-32.8 kg/m², competitive sailing experience of 10.8 ± 5.3 years; range, 1-45 years, and current sailing class experience of 4.9 ± 3.4 years; range, 0-16 years. Our previous research describes younger age (< 23 years) and preragatta high unloading (> 2 hours) times increase risk of pain in these athletes. Female gender, obesity, and previous injury history also have links to knee pain in

other populations. Among the sailors surveyed, 78 (48%) were hikers and 85 (52%) were nonhikers. Risk ratios (RR) and 95% confidence intervals (95% CI) were calculated to compare the risk of knee pain between hikers and nonhikers, adjusted RRs were examined using the previously studied exposures for confounding.

RESULTS: One hundred fifty-six (96%) of the 163 subjects reported on training. Training reduced overall risk of knee pain by 84% (RR = 0.16; 95% CI: 0.08, 0.29) in this larger cohort. Training reduced the risk of knee pain in hikers by 80% (RR = 0.2; 95% CI: 0.1, 0.4). Training reduced the risk of knee pain in nonhikers by 78% (RR = 0.22; 95% CI: 0.05, 1.01). Confidence interval overlap indicates no significant difference in training protection between hikers and nonhikers.

CONCLUSIONS: Overall hikers and nonhikers are equally protected by training despite different sailing demands for their knees. More research is required regarding details of their training programs and the specific knee demands of hikers and nonhikers.

CLINICAL RELEVANCE: Specialized training program participation in athletes may protect against new incidence of injury during competition.

SPO59

SINGLE-LEG HOP SYMMETRY MAY PREDICT GAIT SYMMETRY 6 MONTHS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Naoaki Ito, Jacob J. Capin, Thomas S. Buchanan, Lynn Snyder-Mackler

PURPOSE/HYPOTHESIS: Asymmetric gait patterns such as medial tibiofemoral underloading after anterior cruciate ligament (ACL) reconstruction (ACLR) are associated with early onset knee osteoarthritis (OA) development. Group differences in gait exist among those who pass return-to-sport (RTS) criteria (consisting of a previously validated battery of hop tests, quadriceps index, and clinical outcome questionnaires) and those who do not, but both groups continue to present with gait asymmetries at RTS. Meaningful gait asymmetries may persist up to 5 years after ACLR. The single leg hop for distance (SL hop) is one of the criteria for assessing RTS readiness. However, the direct relationship between symmetry in gait and the SL hop has not been investigated. The purpose of this study was to investigate whether symmetry in the SL hop predicts gait symmetry 6 months after ACLR.

NUMBER OF SUBJECTS: Seventy participants (37 men, 33 women; 6 ± 2 months after ACLR).

MATERIALS AND METHODS: This is a secondary analysis of prospectively collected data from a clinical trial. Athletes after primary ACL injury and ACLR were recruited. Inclusion criteria required participants to be in the RTS phase of recovery. Participants completed 2 successful trials per limb for the SL hop. Gait analysis consisting of kinetics, kinematics and joint contact forces during overground walking at self-selected speeds were performed. Joint contact forces were calculated using a previously validated musculoskeletal model. Variables of interest were peak medial compartment contact force (pMCCF), peak knee flexion angle (pKFA), knee flexion (KFE) and extension excursion (KEE), and peak external knee flexion (pKFM) and adduction moment (pKAM). The values for each limb for the SL hop and each biomechanical variable of interest were averaged and used to calculate a limb symmetry index [LSI = (involved/uninvolved) $\times$ 100] in percent. Pearson's correlation and simple linear regression were performed for the SL hop LSI and the LSI for each biomechanical variable of interest.

RESULTS: Statistically significant, moderate positive correlations were observed between LSI in SL hop and pMCCF ($r = 0.323$, $P < .01$), pKFM ($r = 0.323$, $P < .01$), and KFE ($r = 0.303$, $P = .01$). There were no statistically significant findings for pKFA, pKAM, and KEE.

CONCLUSIONS: Poor SL hop symmetry may predict those who present with gait asymmetries including involved limb underloading 6 months after ACLR. Wellsandt et al previously found (in a separate cohort) that athletes who score poorly on the SL hop early after ACLR are more likely to

develop radiographic OA 5 years after ACLR. Hop symmetry may be representative of aberrant gait mechanics associated with OA development.

CLINICAL RELEVANCE: The SL hop may be used as a tool to predict gait asymmetries during the early RTS phase after ACLR in a clinical setting, identifying those who may benefit most from targeted gait interventions to correct aberrant mechanics associated with posttraumatic OA.

SPO60

EFFECTS OF NEUROMUSCULAR TRAINING ON BIOMECHANICAL EFFICIENCY IN HIGH SCHOOL ATHLETES

Joseph Jude Janosky

PURPOSE/HYPOTHESIS: The purpose of this study is to investigate the association between neuromuscular training (NMT) and biomechanical efficiency among high school athletes. We hypothesized that the performance of NMT is associated with improved biomechanical efficiency during the performance of fundamental movements and agility tests when compared to a group of untrained control subjects.

NUMBER OF SUBJECTS: Eight high school soccer and basketball teams (111 athletes; 53.1% male; mean age, 15.6 years) were recruited and assigned to either an intervention or control group for this study.

MATERIALS AND METHODS: The intervention group performed NMT as part of their warm-up prior to each practice and competition throughout their sports seasons (approximately 12 weeks). NMT was administered by experienced sports medicine clinicians who provided exercise instruction, technique cues, and performance feedback during each training session. The control group performed their customary warm-up under the direction of the team's coaches. Biomechanical efficiency was assessed during the performance of static and dynamic tests using an FDA-approved wireless sensor system. Agility was assessed using a timed 3-cone agility test. All tests were administered immediately prior to and following each sports season.

RESULTS: Matched preseason/postseason data were collected from 74 athletes. Significant improvements (point estimate; 95% CI; P value) were observed in the intervention group for left lower extremity (0.25; 95% CI: 0.06, 0.45; $P = .01$) and right lower extremity (0.21; 95% CI: 0.05, 0.37; $P = .01$) loading/landing speed ratios during a single leg hop test, left lower extremity (-136.34; 95% CI: -225.74, -46.95; $P = .003$) and right lower extremity (-110; 95% CI: -211.36, -8.64; $P = .03$) ground reaction force, left lower extremity (-1.03; 95% CI: -.189, -0.18; $P = .02$) and right lower extremity (-0.94; 95% CI: -1.73, -0.14; $P = .02$) initial peak acceleration, and cadence (-12.12; 95% CI: -21.60, -2.65; $P = .01$) during a straight line running test, and time (0.51; 95% CI: 0.24, 0.78; $P = .0003$) during a 3-cone agility test.

CONCLUSIONS: Results demonstrate that season-long, sport-specific, age-appropriate NMT administered by sports medicine clinicians can significantly improve biomechanical efficiency during the performance of fundamental movements and agility tests by high school athletes. To achieve similar results, sports coaches should be trained to provide exercise instruction, technique cues, and performance feedback when administering NMT in real-world settings.

CLINICAL RELEVANCE: Anterior cruciate ligament (ACL) injuries are among the most common and devastating sports-related knee injuries. Neuromuscular training has demonstrated efficacy as a preventive intervention for noncontact ACL injury and has been associated with improvements in several measures of sports performance, but the specific physiologic mechanisms that serve as protective factors and contribute to improved performance have not been well defined.

SPO61

EVALUATION OF FUNCTIONAL MOVEMENT QUALITY IN FEMALE COLLEGIATE DANCERS

Brett Mitchell Kautzmann, James Baird Kase, Cheryl A. Coker, Eydie A. Kendall

PURPOSE/HYPOTHESIS: The Functional Movement Screen (FMS) is a screening tool used to identify body asymmetries, mobility and stabil-

ity within the kinetic chain of whole-body movements and poor-quality movement patterns. These compensatory movement patterns have been associated with increased musculoskeletal injury risk potential. While injury rates can be hard to distinguish, 1 study showed that over 5 years there were 1.09 injuries over 1000 athletic exposures and 0.77 injuries per 1000 hours of dance. To date, however, there are no standardized screening tools to help identify dancers who may be predisposed to injury. This study was designed to investigate movement quality and FMS scores of collegiate dancers, in particular dysfunctional movement patterns.

NUMBER OF SUBJECTS: One hundred eleven female participants in the American College Dance Association, New England Conference, 2019 (mean age, 20.88 years; average dance experience, 14.9 years).

MATERIALS AND METHODS: The FMS examines 7 movements including the deep squat (DS), hurdle step (HS), inline lunge (IL), shoulder mobility (SM), active straight leg raise (ASLR), trunk stability push-up (TS), and rotary stability (RS). Participants were guided through the 7 movements and scored on a scale of 0 to 3 with a total possible score of 21. A composite score of 14 or less, an asymmetry on a given movement or a dysfunctional movement pattern (score of 1) are considered "red flags" and indicative of functional deficiency.

RESULTS: Total FMS scores ranged between 11 and 20 with an average of 16.42. Eleven percent of participants scored a 14 or below. Forty-four percent of the dancers had 1 or more asymmetries and 43% of the dancers had 1 or more scores of 1. The percentage of participants considered proficient in each exercise (scored a 3) were as follows: 17.86% in the DS, 18.75% in the HS, 62.5% in IL, 75.0% in SM, 91.64% in ASLR, 37.5% in TS, and 0% were proficient in RS.

CONCLUSIONS: Poor quality of movement within aspects of functional movement in dance can lead to increased risk of injury. While the overall FMS score is relatively high and a low percentage of dancers scored 14 or less, the percentage of asymmetries and dysfunctional movement patterns are concerning. Also concerning is the low number of participants who demonstrated proficiency in the DS, HS, TS, and RS.

CLINICAL RELEVANCE: This study has provided a step forward toward the understanding of typical functional and dysfunctional movements in collegiate dancers. Poor functional movement was revealed for the deep squat, hurdle step and rotary stability and further research is warranted to understand the nature of these dysfunctions in this population. In addition, the results of this study suggest that corrective exercise interventions be developed that address the functional limitations of dancers in order to decrease the risk of injury in the future.

SP062

IMPROVEMENT IN CLINICIAN UNDERSTANDING AND COMMUNICATION OF PATIENT DEFICITS THROUGH A COMPREHENSIVE RETURN-TO-SPORT ASSESSMENT

Jessica Kellum, Darlene Yao, Tyler Donald Bolley, Corey M. Snyder

PURPOSE/HYPOTHESIS: Understanding a patient's individual deficits is essential to providing targeted rehabilitation with improved outcomes following anterior cruciate ligament reconstruction (ACLR). There are numerous quantitative, qualitative, and patient reported outcome measures and tools to assess these deficits; however, a comprehensive assessment could strengthen clinician understanding and enhance their ability to provide feedback on the many facets of recovery. The purpose of this study is to evaluate the effectiveness of a comprehensive return-to-sport assessment (RTSA) on the metrics of improved clinician understanding of patient deficits and ability to relay areas of deficiencies to their patients.

NUMBER OF SUBJECTS: Sixty-one sports medicine clinicians (physical therapists [PT], PT assistants, athletic trainers, physician assistants, and physicians) across 4 sites in the southeast Michigan area.

MATERIALS AND METHODS: The RTSA was implemented at 4 sites and includes 18 established functional tests in ACLR RTS as well as a measure of knee confidence through the Anterior Cruciate Ligament Return to Sport After Injury (ACL-RSI) Scale. Functional tests are recorded and reported quantitatively for values and symmetry, as well as qualitatively using a 3-point scale on 4 to 6 relevant metrics for each test. All results are summarized in a comprehensive graphical manner. Clinicians completed a survey quantifying their level of understanding of patient deficits (using a 7-point scale) and improvement in ability to relay areas of deficiencies to their patients (using a 5-point scale) before and after clinic-wide implementation of the RTSA.

RESULTS: Results from the survey show that prior to the implementation of the RTSA, clinician's average understanding of patient deficits (out of 7) was 3.84 ± 1.64 (between "Somewhat Specific" and "Moderately Specific"), with 19 clinicians (31%) having a "Thorough" understanding or better. After implementation, the average understanding of patient deficits rose to 5.21 ± 1.47 (between "Thorough" and "Very Thorough") with 46 clinicians (75%) having a "Thorough" understanding or better. Forty-eight clinicians (79%) agreed or strongly agreed that implementation of the RTSA made them able to relay areas of deficiencies to their patients more effectively.

CONCLUSIONS: A comprehensive, multifaceted RTSA improves both clinician understanding and communication of deficiencies. Implementation of the RTSA doubled the number of clinicians with at least a "Thorough" understanding of deficiencies, enabling more targeted rehabilitation.

CLINICAL RELEVANCE: RTSA assists medical providers in determining appropriate treatment to better pinpoint deficits and areas of increased risks. Translating patient recovery performance data into a format that is easily understood equips clinicians with valuable insights that they can turn into actionable milestones for their patients.

SP063

THE EFFECT OF PREFERRED LIMB ON OUTCOMES AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Nina Frances Kelly, Adam Michael Culiver, Matthew Peter Ithurburn, Kevin Michael Ford, Mark Vincent Paterno, Laura C. Schmitt

PURPOSE/HYPOTHESIS: Timing differences during landing have been used to identify a preferred landing leg after anterior cruciate ligament (ACL) reconstruction (ACLR), with only 29% preferring to land on their involved limb. The purpose of this study was to test the hypothesis that those who prefer to land on their INVL would demonstrate higher function, more symmetrical strength and landing mechanics, and sustain a lower proportion of second ACL injuries compared to those who do not.

NUMBER OF SUBJECTS: One hundred fifty-one young athletes (100 female; mean $\pm$ SD age, 16.8 ± 3.0 years) after ACLR at medical clearance to return to sport (RTS).

MATERIALS AND METHODS: Bilateral landing mechanics during a drop vertical jump (DVJ) were assessed using 3-D motion capture and force plate data. The limb contacting the ground first was defined as preferred. The cohort was divided into those who preferred their involved limb (PINV) ($n = 40$; 28 female; mean $\pm$ SD age, 17.6 ± 3.4 years; 8.3 ± 2.1 months post ACLR) and those who did not (NONP) ($n = 111$; 72 female; age, 16.5 ± 2.9 years; 8.4 ± 2.6 months post ACLR). Limb symmetry index (LSI) was calculated to assess performance between limbs for variables of interest. Intergroup differences in single-leg hop testing (single, triple and cross-over hops), isokinetic ($180^\circ/\text{s}$) quadriceps strength, peak vertical ground reaction force (vGRF), knee flexion excursion (KFE), and peak internal knee extension moments (ExtM) were compared using independent-samples t tests ($\alpha = .05$). Second ACL injuries were tracked after RTS, and an association between limb preference and second ACL injury was evaluated using chi-square analyses ($\alpha = .05$).

RESULTS: All hop testing LSIs were higher in PINV than NONP groups (single, 97% versus 93%; $P = .005$; triple, 98% versus 94%; $P = .002$;

crossover, 97% versus 94%; $P = .027$). The PINV group also demonstrated higher isokinetic quadriceps LSI (93% versus 88%, $P = .02$). During DVJ landing, PINV demonstrated greater LSI in vGRF (101% versus 79%, $P < .001$) and KFE (106% versus 93%, $P < .001$), but less in ExtM (94% versus 107%, $P < .001$). A total of 47 (31.1%) second injuries occurred, there were no differences between groups PINV (11/40, 27.5%) and NONP (36/111, 32.4%) ($P = .56$). However, of PINV second injuries, 82% (9/11) were to the contralateral limb, whereas NONP had a more equal distribution of contralateral (47%, 17/36) and ipsilateral (53%, 19/36) second injuries.

CONCLUSIONS: The PINV group demonstrated greater single-leg hop symmetry, quadriceps LSI, and more symmetrical landing strategies compared to NONP. While the occurrence of second ACL injuries did not statistically differ between groups, it appears those in group PINV may have been more likely to sustain a contralateral injury.

CLINICAL RELEVANCE: Consistent with previous reports, only 27% of young athletes after ACLR preferred landing on their involved limb. The higher single-leg hop symmetry, higher quadriceps LSI and more symmetrical landing patterns observed may indicate greater limb confidence and readiness for RTS in those with involved-limb landing preference.

SP064

FASTER WALKING SPEED IS ASSOCIATED WITH GREATER GAIT ASYMMETRY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Rachel Knobel, Naoaki Ito, Jacob J. Capin, Elanna K. Arhos, Thomas S. Buchanan, Lynn Snyder-Mackler

PURPOSE/HYPOTHESIS: Gait asymmetries after anterior cruciate ligament (ACL) injury and reconstruction (ACLR) may lead to early onset radiographic knee joint osteoarthritis (OA). Slower walking speeds have been associated with biomarkers that suggest cartilage breakdown in the knee. The relationship between walking speed and gait symmetry early after ACLR is unknown. The purpose of this study was to determine the relationship between self-selected walking speeds and gait symmetry in athletes after ACLR.

NUMBER OF SUBJECTS: Seventy participants (mean $\pm$ SD age, 21 ± 8 years; 24 ± 8 weeks after ACLR).

MATERIALS AND METHODS: This study is a secondary analysis of prospectively collected data collected from a clinical trial. Athletes (age, 13–55 years) after primary ACLR were recruited. Participants walked overground at self-selected speeds (trials maintained at $\pm 5\%$) as gait kinematics, kinetics, and electromyography were collected. A validated, patient-specific musculoskeletal model was used to calculate tibiofemoral joint contact forces. Gait speed was calculated using pelvic tracking markers during stance. Variables of interest were medial compartment tibiofemoral contact force (pMCCF), external peak knee flexion (pKFM) and adduction moments (pKAM), peak knee flexion angle (pKFA), and knee flexion (KFE) and extension (KEE) excursion. Pearson's correlation and linear regression for the uninvolved limb, involved limb, and interlimb difference (ILD; involved – uninvolved limb) and gait speed were computed for each variable in SPSS ($\alpha = .05$).

RESULTS: On the uninvolved side, there were weak to moderate positive correlations between gait speed and mechanics. At faster speeds, pKFM ($r = 0.505$, $P < .01$), pKFA ($r = 0.449$, $P < .01$), KEE ($r = 0.379$, $P < .01$), pMCCF ($r = 0.377$, $P < .01$), pKAM ($r = 0.346$, $P < .01$), and KFE ($r = 0.301$, $P = .01$) were greater. On the involved side, weak positive correlations were observed for pKFM ($r = 0.280$, $P = .02$) and pKFA ($r = 0.263$, $P = .03$). However, there were no statistically significant correlations between gait speed and pMCCF, pKAM, KFE and KEE for the involved side. Weak negative correlations were found for ILDs in KEE ($r = -0.260$, $P = .03$), pKAM ($r = -0.323$, $P < .01$), and pMCCF ($r = -0.286$, $P = .02$). There were no correlations for ILDs in pKFM, pKFA, and KFE.

CONCLUSIONS: Gait mechanics in the uninvolved knee were more strongly related to gait speed compared to those of the involved knee. Larger

ILD at faster gait speeds may be attributed to the uninvolved limb having stronger correlations with all variables than the involved limb.

CLINICAL RELEVANCE: Increasing gait speed alone as an intervention may accentuate, rather than mitigate, walking asymmetries among individuals after ACLR. Gait-specific training for the ACLR limb may be necessary to address asymmetry in postoperative rehabilitation.

SP065

EFFECTS OF CORE STABILITY AND FATIGUE ON GAIT STABILITY WITH BACKPACKING

John M. Knox, Trae Mingus, David Hudson

PURPOSE/HYPOTHESIS: Approximately 600 000 soldiers sustain a musculoskeletal injury each year. Fifty percent are gradual onset and most are in the lower extremity. We explored how backpacking and core stability might contribute to injuries by comparing spatial-temporal changes in gait under normal and fatigued states of the core muscles and cardiovascular system. Our hypothesis was that fatigue and subjects' core strength would have a significant impact on velocity, step length, and cadence and how they adapted to the load of the backpack.

NUMBER OF SUBJECTS: Twelve.

MATERIALS AND METHODS: Spatial-temporal gait parameters were measured using an instrumented GaitRite mat with and without a backpack with 35% body weight (BW) at baseline, following core muscle fatigue, and cardiovascular fatigue. Core muscle fatigue was achieved after subjects performed a circuit of planks until failure or they broke form more than 3 times. Subjects were grouped into stronger and weaker based on their time to fatigue of core exercise. Cardiovascular fatigue was induced by a step test with a loaded backpack of 35% BW until they reached a 17/20 on the RPE scale then the weight was reduced to 25% BW and they continued the step test until they reached a 19/20 RPE. Twenty minutes of rest was given between core fatigue and cardiovascular fatigue tests.

RESULTS: All subjects walked significantly slower with shorter step length when wearing the backpack compared to no backpack at baseline and following core fatigue ($P < .05$). There was a nonsignificant increase in walking velocity of both groups following the cardiovascular fatigue. Weaker subjects walked significantly slower and with significantly lower cadence compared to the stronger subjects in all conditions ($P < .05$). All subjects showed significantly decreased step length following core fatigue ($P < .05$). Increased velocity following cardiovascular fatigue was achieved by significantly increased cadence in the weaker group ($P < .04$).

CONCLUSIONS: Subjects with greater core stability walked faster in all conditions compared to weaker subjects. This may be a potential risk in marches where weaker people are forced to walk at the same speed and cadence. The weaker group made significant changes in velocity, step length, cadence following fatigue protocols. This is also an indication of potential elevated risk for people with weaker (less endurance) in the core muscle. Cardiovascular fatigue had an interesting effect of making subjects walk faster (nonsignificant). Walking faster by increasing cadence is common adaptation in populations with gait instability.

CLINICAL RELEVANCE: This study showed the importance of core stability when carrying a backpack and that the response following core muscle and cardiovascular fatigue are different. Further work in the area could help planning for basic training in the military and reduce injuries.

SP066

MANAGEMENT OF PROXIMAL HAMSTRING TENDINOPATHY IN A COMPETITIVE POWERLIFTER WITH HEAVY SLOW RESISTANCE TRAINING

Kayla Krueger, Nicholas Benjamin Washmuth

BACKGROUND AND PURPOSE: Heavy slow resistance (HSR) training, which contains both concentric and eccentric phases, increases the loading time experienced by the tendon when performing rehabilitation for tendinopathies. While eccentric exercise has been the widely accepted treatment of choice for the management of tendinopathies, the focus with HSR train-

ing is to perform slow, fatiguing, progressive resistance exercise with both concentric and eccentric components. Heavy slow resistance training has achieved positive clinical results in the management of Achilles and patellar tendinopathy. Due to the unique anatomical features of the proximal hamstring tendon, it is unknown if PHT will respond to HSR training. The purpose of this case report was to describe the clinical outcomes of a competitive powerlifter with proximal hamstring tendinopathy (PHT) who responded favorably to a 12-week, HSR rehabilitation program after previous physical therapy failed to alleviate symptoms.

CASE DESCRIPTION: A 31-year-old male competitive powerlifter was seen in physical therapy for chronic L buttock pain. The patient experienced pain localized at the ischial tuberosity with sitting and weightlifting activities. The clinical examination ruled in a contractile dysfunction involving the proximal hamstring tendon, while ruling out other pathologies. PHT is a chronic, overuse condition that develops as a result of repetitive mechanical loading at the proximal hamstring tendon. Because the patient self-discharged from 2 previous courses of physical therapy, it was decided that treatment would focus on increasing the exercise load intensity with a 12-week home exercise based HSR training program in order to reduce pain and restore function.

OUTCOMES: Numeric pain-rating scale (NPRS) was assessed at baseline, after a 12-week HSR protocol, and 12 months post HSR protocol. An 11-point NPRS (0, no pain; 10, worst imaginable pain) was used to assess the intensity of pain during the patient's primary complaints of weight lifting and prolonged sitting. Within 4 weeks of starting the HSR program, the patient noted significant decreased in pain, which helped provide motivation to remain compliant with the entire 12-week program. The patient experienced clinically important improvements in NPRS immediately after the HSR protocol and these improvements remained 1 year after completing the HSR protocol. The range of NPRS started at 0-8/10 and by the end of the 12-week program decreased to 0-2/10.

DISCUSSION: A meaningful change within 4 weeks of starting the program and continued improvement throughout the remainder of the 12 weeks with outcomes maintained 12 months after completing the program suggests that increasing the loading strategy with a HSR program was helpful. This case supports the notion that load intensity rather than contraction type is the optimal stimulus for the management of PHT.

SP067

PREDICTING RETURN TO SPORT WITH PSYCHOSOCIAL CONSTRUCTS AND SELF-REPORTED KNEE FUNCTIONING

Eric Stephen Kruger, Kelsey A. Edwards, Jimmy Michael Minner, Stephanie L. Baca, Dustin L. Richter, Rebecca A. Dutton, Yuri Yoshida

PURPOSE/HYPOTHESIS: ACL injuries are common injuries in sport often requiring surgical reconstruction. Psychological responses to an ACL injury can affect rehabilitation, eventual return-to-sport and possibly even reinjury. However, little is known about how factors change across time and how they might predict the athlete's return-to-sport. The purpose of this study was to describe the changes across ACL rehabilitation in perceptions of knee functioning, psychosocial factors related to pain (kinesiophobia), and psychological readiness. Additionally, we sought to determine which indicators may best predict return-to-sport.

NUMBER OF SUBJECTS: Seventeen.

MATERIALS AND METHODS: A prospective longitudinal analysis of individuals who underwent a surgical reconstruction for an ACL injury were enrolled in the study. Participants were measured at 3, 6, 9, and 12 months post operatively. Return-to-sport (RTS) was assessed via a single item which had participants rate on a scale of 0 to 100 their current level of activity. The following anchors were used 0 is "Not participating in any sports or rehab activity"; 25 is "Participating in rehab exercises (eg, physical therapy exercises such as quadriceps strengthening and hamstring strengthening)"; 50 is "Participating in sports specific conditioning (eg,

running, box jumps, single leg hops)"; 75 is "Participating in some sports activity (eg, practice but no competition)"; 100 is "Fully participating in sports activity at prior injury level." Psychological readiness was assessed via Anterior Cruciate Ligament Return to Sport After Injury Scale (ACL-RSI), kinesiophobia was assessed via the Tampa Scale of Kinesiophobia (TSK) and knee functioning via 2000 IKDC subjective knee evaluation form (IKDC). Linear mixed effects models were used to develop predictive models using instruments that were assessed at all time points.

RESULTS: Multiple linear effects models were used to individually predict RTS, kinesiophobia approached significance ($R^2 = 0.59$, $P = .09$), psychological readiness and self-reported knee functioning significantly predicted RTS ($R^2 = 0.69$, $P = .01$; $R^2 = 0.71$, $P < .01$, respectively). Additionally, a simultaneous model was used to evaluate all predictors and only self-reported knee functioning significantly predicted RTS in this model accounting for 3.2% unique variance ($P = .03$).

CONCLUSIONS: The results from this study support observations that psychological readiness is an important factor in predicting an athlete's RTS. However, self-reported knee functioning may capture much of the same construct as psychological readiness and therefore it may not be necessary to have athletes complete an additional instrument (eg, the ACL-RSI).

CLINICAL RELEVANCE: Determining return-to-sport after ACL reconstruction depends on numerous factors, all of which are changing over time. Currently, we understand very little about which factors are most important and when to measure them. The results of this study demonstrate that self-reported knee functioning as measured by the IKDC and ACL-RSI are both significant predictors across time and that IKDC may be slightly better at predicting RTS.

SP068

KINETIC FACTORS THAT PREDICT AND CLASSIFY ANTERIOR CRUCIATE LIGAMENT, MEDIAL COLLATERAL LIGAMENT, AND MENISCAL INJURY

Corey Matthew Kunser, Nathan Schilat, Nathaniel Bates, Sydney Kruisselbrink, Timothy Hewett

PURPOSE/HYPOTHESIS: Anterior cruciate ligament (ACL) tears and concomitant medial collateral ligament (MCL) injuries are responsible for bearing loads during athletic movements. MCL injury occurs concomitant with ACL injury 30% to 40% of the time. Biomechanical mechanism for concomitant injury occurrence remains undetermined. The study aim was to determine the kinetic factors that predict and classify ACL, MCL, and meniscal injury outcomes.

NUMBER OF SUBJECTS: Forty cadaveric lower extremities (20 male, 20 female) aged 22 to 52 years.

MATERIALS AND METHODS: The 40 cadaveric specimens were subjected to simulated landings in the mechanical impact simulator. Knee mechanics and forces applied were determined from 3-D motion capture of 44 healthy athletic subjects that performed a drop vertical jump maneuver. Pneumatic cylinders applied designated knee forces (ie. knee abduction moment (KAM), anterior tibial shear (ATS), and internal tibial rotation (ITR)). Two differential variable reluctance transducers (DVRTs) were implanted into the MCL midsubstance and anteromedial bundle of the ACL to measure ligament strain. Six-axis and uniaxial load cells measured forces and torques at the knee and foot, respectively. Stepwise Linear Discriminant Analysis (LDA) was performed to determine 10 prediction factors.

RESULTS: Ten factors determined by stepwise selection are relevant to ACL, MCL, and meniscal injury in this level of contribution: knee abduction torque at IC, peak knee abduction torque, peak knee flexion torque, peak knee compression, lowest value of MCL strain (percent), knee flexion torque at IC, peak knee adduction torque, peak tibial posterior translation, peak ACL strain (percent), peak knee internal rotation torque. All groups predicted correctly, 22.5% misclassified (9/40).

CONCLUSIONS: Ten clinically relevant kinetic factors predict ACL, MCL, and meniscal injury outcomes with a high confidence. Clinically relevant kinetics, as measured on a force plate, can determine the clinical presen-

tation of a singular or concomitant knee injury. Knee abduction moment may be the predominant precursor to ACL and concomitant MCL injury. **CLINICAL RELEVANCE:** This demonstrates that knee injuries to the ACL, MCL, and meniscus are not random, but are determined by biomechanical factors and torques. Primary preventative focus should be on frontal plane knee abduction in landing and cutting tasks.

SP069

DIFFERENCES IN FUNCTIONAL MOVEMENT SCREEN PERFORMANCE AMONG HIGH SCHOOL BASKETBALL PLAYERS BASED ON GRADE LEVEL

Steven J. Lachowski

PURPOSE/HYPOTHESIS: The Functional Movement Screen (FMS) is an assessment tool that has been used as a preparticipation screen to evaluate an individual's overall mobility, motor control, and functional patterning. Until recently, similar outcome criteria have been applied to high school and recreational athletes through the professional level. Recent studies have started to provide normative values for a variety of age ranges and populations including the adolescent athlete. Since the adolescent athlete experiences a number of neuromuscular and musculoskeletal changes during normal growth and development, specific criteria for smaller ages within this population need to be established as these changes may influence performance and injury rates. The hypothesis for this study was that subcategory and composite scores on the FMS among high school basketball players would vary by grade level due to changes relative to normal growth and development.

NUMBER OF SUBJECTS: Twenty-five male and female student athletes participated with grade levels ranging from freshman (grade 9) through senior (grade 12).

MATERIALS AND METHODS: The study was a cross-sectional design that investigated the impact of grade level on FMS performance in high school basketball players. Each participant completed all components of the FMS and was scored according to the established criteria. The mean score and standard deviations for each subcategory of the FMS, along with the mean total scores, were calculated for each grade level. Differences in mean for composite and subcategory scores were assessed for statistical significance ($P < .05$) via 1-way ANOVA.

RESULTS: Composite and individual scores varied by grade level with trends being identified on composite scores and 3 subcategories, although statistical significance was not achieved with the closest subcategory being the Overhead Deep Squat ($P = .076$).

CONCLUSIONS: Differences in average composite scores and 3 subcategories were identified along with trends in performance relative to those averages. Future research should continue to investigate a larger number of athletes incorporating a variety of sports to further determine age-specific normative values for performance and the influence of changes related to growth and development when utilizing functional testing measures.

CLINICAL RELEVANCE: This study is one of the first to examine grade level specific performance on the FMS among adolescent athletes. The results identified differences within the previously published age ranges indicating the need for further research to establish normative values for tests where age-related changes might impact outcomes. This impacts professionals working with this population to consider the influence of associated developmental changes and how findings from movement assessments may result in different intervention strategies for individuals where a program designed for an entire team may not target the appropriate regions or deficits that need to be addressed.

SP070

THE EFFECTS OF FEMORAL TORSION ON FOOT MECHANICS WHILE WALKING

Grace Gibson Laferriere, Michael Patrick Seiser, Kim Hudson, David Hudson

PURPOSE/HYPOTHESIS: This study sought to determine if people with in-

creased femoral torsion have different foot mechanics while walking. Our hypothesis was that subjects with increased femoral torsion would have greater hindfoot and forefoot pronation during late terminal stance.

NUMBER OF SUBJECTS: Sixteen.

MATERIALS AND METHODS: The study was approved by the institutional review board and all subjects provided consent. Femoral torsion was measured using Craig's test with a digital angle finder. Kinematic gait data (hip internal/external rotation [H-IR/H-ER] and pronation/supination of the hindfoot and forefoot) were measured using a 10-camera motion analysis system with a modified Helen-Hayes marker set and the Oxford foot model (Qualisys, Micus, Buffalo Grove, IL). Subjects were ranked based on the Craig's test and then grouped into high and low femoral torsion. Comparisons of kinematic variables were made between the average position during the end of terminal stance (45%-50% of the gait cycle) using Student's t tests.

RESULTS: The high and low femoral torsion groups were significantly different (16.8° versus 5.8° , $P < .001$). During late terminal stance, subjects in the high femoral torsion group had significantly more H-IR (9.5° versus 3.9° , $P < .04$). At the hindfoot (rear foot versus tibia), pronation was not significantly different between groups (-3.5° versus -2.2°); however, the forefoot (forefoot versus tibia) was significantly less supinated in the high group (1.8° versus 6.1° , $P < .01$).

CONCLUSIONS: Subjects with high femoral torsion had increased H-IR and less supination in the forefoot. Hindfoot pronation was not different during terminal stance; however, appeared greater in the high group during pre-swing, which could be due to less supination in the forefoot and the effect that would have on the windlass mechanism. It is arguable that the increase in H-IR dampened the propagation of ER down the limb and interfered with the conversion to supination in the foot indicating a plausible mechanical link between femoral torsion and foot mechanics while walking.

CLINICAL RELEVANCE: Abnormal femoral torsion and pronation have been implicated in several maladies of the hip and lower extremity. People with higher femoral torsion had difficulty transferring external rotation down the limb resulting in a dampening of resupination. These results provide rationale for hip ER strengthening in cases of high femoral torsion to help manage abnormal pronation.

SP071

ACUTE EFFECTS OF WEIGHTED BASEBALLS ON AXILLARY ARTERY BLOOD FLOW IN HIGH SCHOOL BASEBALL PLAYERS

John Lyons LaRue, Heather Shannon Myers, Laura Stanley Pietrosimone

PURPOSE/HYPOTHESIS: Weighted baseballs are a primary mode of performance training to increase velocity, especially at the youth level of participation. The primary purpose of this pilot study was to determine the acute effect of throwing weighted baseballs (WB) compared to standard-weight baseballs (SB) on axillary artery blood flow in high school baseball players. The secondary purpose was to determine the acute effect of each condition on shoulder rotation range of motion (ROM). We hypothesized that throwing WB would acutely decrease axillary artery blood flow compared to SB and would cause a greater increase in external rotation and greater decrease in internal rotation compared to SB.

NUMBER OF SUBJECTS: Five high school male baseball players.

MATERIALS AND METHODS: Each subject completed 2 conditions (WB and SB), separated by 48 hours. The order of conditions were randomized a priori. All throwers completed a standardized warm-up. The SB condition included 30 throws with a 5-oz standard baseball. The WB condition included 30 total throws with a 7-oz baseball (15 throws) and a 14-oz baseball (15 throws). Outcome measures included ultrasound (US) measurement of axillary artery blood flow (peak systolic velocity [cm/s]), axillary arterial diameter (cm), and passive shoulder external and internal rotation ROM (degrees). Paired-samples t tests were utilized to compare change scores (postthrowing value - prethrowing value) for all depen-

dent variables between throwing conditions. Statistical significance was set a priori at $\alpha < .05$.

RESULTS: Five subjects (mean $\pm$ SD age, 16.40 ± 1.67 years; height, 1.82 ± 0.08 m; weight, 75.93 ± 15.33 kg) completed all portions of the study. The mean change in axillary artery blood flow (-6.774 ± 11.617 cm/s) was not statistically significant between conditions ($t_4 = -1.304$, $P = .262$). The mean change in the axillary artery diameter (8.823 ± 19.778 cm) was not statistically significant between conditions ($t_4 = 0.99$, $P = .375$). There were no statistically significant differences in external rotation ROM (mean change, $-0.467^\circ \pm 12.075^\circ$; $t_4 = -0.086$, $P = .935$) or internal rotation ROM (mean change, $-1.733^\circ \pm 7.243^\circ$; $t_4 = -0.535$, $P = .621$) between conditions.

CONCLUSIONS: There were no acute effects of throwing WB compared to SB on axillary artery blood flow, arterial diameter, or shoulder ROM. This pilot study employed a small sample size, which may have limited the identification of an effect. Additionally, 30 throws in each condition may not be adequate to elicit a change in axillary artery blood flow, diameter, or shoulder rotational ROM in this population.

CLINICAL RELEVANCE: This pilot study did not support the hypothesis that throwing WB decreases axillary artery blood flow more than throwing SB. However, with additional subjects, further research may elucidate the potential benefits and consequences of using WB in training. The utility of US to capture acute changes in axillary artery blood flow may be a useful tool for clinical evaluations and investigations in the overhead throwing athlete population.

SP072

COMPREHENSIVE REHABILITATION FOR A FEMALE RUNNER WITH ILIOTIBIAL BAND SYNDROME

Jason Lawrence, Michael Jason Zarro, Kelly Greenway

BACKGROUND AND PURPOSE: Running is one of the most popular forms of exercise in the world. A consequence of running is the risk of sustaining a running related injury (RRI). Novice runners sustain 33 injuries per 1000 hours of participation. Iliotibial band syndrome (ITBS) is the second most common running related injury. It is characterized by pain over the lateral aspect of the knee. It is twice as common in female compared to male runners. Altered running mechanics may be associated with ITBS. Hip drop, rearfoot eversion, tibial internal rotation, hip abductor weakness, and decreased soft tissue extensibility of the vastus lateralis may load the structures on the lateral aspect of the knee. Poor training methods may also be associated with RRIs. Excessive increases in running volume may exceed what the body can tolerate. The purpose of this study was to describe a physical therapy program based on gait retraining, technology assisted running prescription, manual therapy, and exercise for a runner with ITBS.

CASE DESCRIPTION: The patient is a 33-year-old female runner with a diagnosis of left ITBS. She is an avid runner and runs 4 to 6 times per week with an approximate volume of 10 to 25 total miles. Her goal is to run half and full marathons without pain. Rehabilitation principles were based on functional manual therapy per the Institute of Physical Art (IPA), therapeutic exercise, neuromuscular re-education, gait training, and progressive running mileage increases guided by a Global Positioning System (GPS) monitor.

OUTCOMES: Weekly running mileage, average weekly mile time, mileage per run and average mile time per run were calculated using a GPS monitor. Self-reported symptoms during each run were collected at each visit and the Lower Extremity Functional Scale (LEFS) was collected on initial and final visit.

DISCUSSION: The patient demonstrated significant progress over the course of 9 weeks. Her average mile time per run decreased (20 to 9 minutes), average weekly mile time decreased (18.2 to 10.7 minutes), mileage per run increased (3.50 to 4.59 miles), weekly mileage increased (7.03 to 15.70 miles), and LEFS score improved (65 to 75 points). After completing physical therapy, she was able to resume independent training and

complete the London Marathon without symptoms. This case report indicates that using a physical therapy program consisting gait retraining, technology assisted running prescription, manual therapy, and exercise improves function and running performance. Further research is needed to evaluate the most appropriate application of these principles.

SP073

HYPERMOBILITY AND RUNNING PATTERNS IN YOUTH FEMALE RUNNERS

Anne Lennon, Micah C. Garcia, Kevin R. Ford, Jason Long, Jeffery Allen Taylor-Haas

PURPOSE/HYPOTHESIS: The Beighton Hypermobility Scale (BHS) is a tool used by clinicians to assess for hypermobility, which has been previously linked to musculoskeletal pain. The purpose of the study was to explore the effect of hypermobility on running kinematics in youth female runners. Our hypothesis was that females presenting with hypermobility would demonstrate different kinematics than those with normal joint mobility.

NUMBER OF SUBJECTS: Seventy-four (mean $\pm$ SD age, 13.4 ± 3.1 years).

MATERIALS AND METHODS: The BHS was used to classify participants as hypermobile (score $\geq 4/9$) or nonhypermobility (score < 4). Participants underwent standard 3-D motion analysis while running on a treadmill at a self-selected speed.5 Temporal-spatial parameters (TSPs) and lower extremity kinematics were measured during stance phase of the gait cycle. Nonpaired t tests ($P < .05$) were calculated between the hypermobile and nonhypermobility group.

RESULTS: No significant differences were found in running patterns between hypermobile ($n = 16$) and nonhypermobility ($n = 58$) females. A post hoc stratification was also assessed, isolating mobility of the lower quadrant. Lower quadrant hypermobility, a composite assessment of the BHS that assesses spinal mobility and hamstring flexibility, was determined by a positive during: "active forward flexion of the trunk with the knees fully extended so that the palms of the hands rest flat on the floor." Running velocity (3.1 ± 0.6 versus 2.6 ± 0.5 m/s, $P < .01$) and stride length (2.1 ± 0.4 versus 1.8 ± 0.4 m, $P = .01$) were found to be significantly greater in those with lower quadrant hypermobility ($n = 13$). These subjects also demonstrated a more extended knee position at toe off ($-10.4^\circ \pm 5.2^\circ$ versus $-14.6^\circ \pm 6.1^\circ$, $P = .03$), greater heel to center of mass (COM) distance at initial contact (16.4 ± 5.8 versus 12.3 ± 6.8 cm, $P = .02$), and increased tibia inclination angle at initial contact ($13.9^\circ \pm 3.4^\circ$ versus $9.8^\circ \pm 4.4^\circ$, $P < .01$).

CONCLUSIONS: The BHS is an upper extremity-dominant tool, which may be less beneficial in exploring the effect of hypermobility on running patterns. When stratified by lower quadrant mobility, individuals with hypermobility demonstrated increased running velocity and greater stride length. In addition, these subjects demonstrated greater heel to COM distances and tibia inclination angles at initial contact, findings previously reported in runners demonstrating an overstriding running pattern. Overstriding is associated with increased peak knee extensor moment, patellofemoral and tibiofemoral joint forces, and potential increased risk of stress fracture. Further studies are warranted to determine a relationship between lower quadrant mobility and injuries associated with overstriding.

CLINICAL RELEVANCE: The BHS may not be an appropriate tool for assessing joint mobility in youth female runners. Rather, assessing for lower quadrant mobility using a component of the BHS may be more discriminative when determining implications on running kinematics.

SP074

COMPARISON OF A NOVEL UNILATERAL HAMSTRING ENDURANCE TASK WITH THE NORDIC HAMSTRING EXERCISE

Zachary Lentini, Daniel Garrett Cobian, Mikel Renee Stiffler-Joachim, Grant Thomas, Benjamin Davis, Bryan C. Heidereich

PURPOSE/HYPOTHESIS: Hamstring strain injuries (HSI) are common in sprinting sports, resulting in substantial time loss and frequent recurrence. Many screening and postinjury hamstring assessments focus on peak strength, but the relationships between strength, injury risk, and performance are unclear. More robust assessments of hamstring function must be developed to effectively mitigate HSI risk factors and optimize rehabilitation. Hamstring endurance may be an important aspect of HSI management, but endurance is rarely assessed in clinical settings. The purpose of this study was to assess the reliability of and relationships between performance of a novel unilateral hamstring endurance test (END), and the Nordic hamstring exercise (NHE), which is commonly used in both testing and training.

NUMBER OF SUBJECTS: Twenty-five healthy, active volunteers (mean $\pm$ SD age, 23.0 ± 3.7 years; BMI, 24.3 ± 2.9 kg/m²; 13 female).

MATERIALS AND METHODS: On 2 distinct occasions, subjects completed the NHE, then the END test with each limb using a NordBord device (Vald Performance, Queensland, AU). Mean NHE peak force (NHEPF, N/kg) was computed from the average of 3 trials. For the END test, subjects were positioned in 60° of knee flexion with shoulders flexed and hands grasping stationary handles. Subjects performed sustained maximal isometric knee flexion while maintaining this position. Peak isometric force (ENDPF) and time to reach a 25% decrement in force production (ENDTIME) were recorded. Between-limb variability of NHE and END performance was assessed. Spearman's rank correlations were used to assess the relationships between NHE and END performance, and test-retest reliability was evaluated with intraclass correlation coefficients (ICC) and root-mean-square error (RMSE) calculations.

RESULTS: NHEPF demonstrated excellent reliability (ICC_{3,1} = 0.93; RMSE, 9.3%-13.6%) while ENDPF had good reliability (ICC_{3,1} = 0.78-0.86; RMSE, 13.2%-16.9%). ENDTIME results were mixed, with good ICC reliability (ICC_{3,1} = 0.70-0.78) but a large RMSE (50.4%-60.3%). NHEPF was strongly correlated with ENDPF (ρ = 0.695-0.800, $P < .001$), but subjects with greater NHEPF showed a tendency to record lower ENDTIME. The relationship was statistically significant on the first data collection (ρ = -0.397 to -0.634, P = .001-.049), but not the second. Between-limb variability of ENDPF (7.0%-11.7%) was greater than NHEPF (5.1%-6.1%).

CONCLUSIONS: Both the bilateral NHE and a novel unilateral isometric hamstring endurance test are reliable assessments of hamstring strength, but the bilateral NHE assessment may underrepresent between-limb asymmetry. Increased hamstring strength may be associated with reduced fatigue resistance to a sustained maximal isometric contraction.

CLINICAL RELEVANCE: Individuals with greater hamstring strength may be less fatigue resistant to maximal effort contractions, which may be an important aspect of hamstring muscle function related to the causes and effects of HSI. In addition, bilateral assessments of hamstring strength may mask between-limb asymmetries.

SP075

DOES APPLICATION OF BLOOD FLOW RESTRICTION IMPROVE REPORTED FUNCTIONAL OUTCOMES FOR THE LOWER EXTREMITY? A SYSTEMATIC REVIEW

Steven Lesh, Neil DeCleene, Brandon Lee Neds, Brad Tippin, Josh Tonozzi

PURPOSE/HYPOTHESIS: The purpose of this systematic review was to determine if the therapeutic application of blood flow restriction (BFR) improves lower extremity functional outcomes. Blood flow restriction is being used in varying rehabilitation settings with differing protocols and dosing. Up to this point, there has been emerging evidence suggesting positive effects when using blood flow restriction during the rehabilitation process regarding strength gains, but little published evidence exists reporting the actual impact related to functional outcomes for patients who have received blood flow restriction training postinjury or

postsurgery. Evidence has indicated that strength training alone does not directly transfer over to functional improvements. In a need to better improve patient outcome reporting using blood flow restriction, functional improvements should be associated with this intervention.

NUMBER OF SUBJECTS: Seven studies were included.

MATERIALS AND METHODS: A systematic review of recent literature was completed to identify evidence related to the clinical question. The search was completed by utilizing EBSCOhost. A PRISMA strategy utilizing key words identified 12 534 articles with 13 articles identified through other sources. After applying screening criteria 7 articles were included for data extraction and analysis. Two reviewers assessed quality of evidence using the PEDro scale. A neutral third reviewer was utilized to resolve discrepancies leading to a consensus quality rating of poor/fair/high.

RESULTS: All 7 included articles scored a 7 or better on the PEDro scale demonstrating that only high quality randomized controlled reports were included for analysis. BFR training produced significantly ($P < .05$) improved results in the following functional outcome measures: timed up and go (TUG), 30-second sit-to-stand (30STS), 100-m sprint time, 6-minute walk test (6MWT), modified queens college step test (QCST), multistage locomotion test (MSLT), Y-Balance Test, and timed stair ascent (TSA). Other functional outcome measures that showed nonstatistically significant but greater improved outcomes with BFR training versus control groups included the self-selected walking velocity (SSWV), sit-to-stand 5 times (STS5), 4-square step test (FSST), and Knee Osteoarthritis Outcome Score (KOOS). Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores were improved in every category in the blood flow restriction training group whereas other intervention groups only improved in some of the categories.

CONCLUSIONS: Evaluation of analyzed evidence strongly suggests a significant interaction between BFR training and functional gains through reported outcomes tools. There was an overwhelming consensus in all analyzed high quality studies that blood flow restriction training improved reported functional outcome scores. Future studies should be done to evaluate the consistency of BFR protocols and dosing.

CLINICAL RELEVANCE: Observed and statistically significant improvements in lower extremity functional outcomes should be an indication to further implement BFR training within the rehabilitation setting. There is strong consensus across included studies to support this position. Based on the results of this systematic review, implementation of blood flow restriction into clinical practice is strongly recommended for improving patient outcomes for lower extremity performance.

SP076

DETERMINATION OF FOOT-STRIKE ANGLE AMONG NOVICE RUNNERS

Alexandre Dias Lopes, Bethany Labossier, Shelagh Brice

PURPOSE/HYPOTHESIS: Although the possible effects of running patterns on injury risk is highlighted in the available literature, an important first step for clinicians and researchers who deal with running injuries is to acknowledge the effects of foot-strike angle (FSA) on recreational runners. Therefore, the aim of this study was to determine the FSAs of novice runners.

NUMBER OF SUBJECTS: Eight hundred twenty novice runners.

MATERIALS AND METHODS: Video recordings of the FSAs of healthy persons between the ages of 18 and 65 years were gathered at Aarhus University in Denmark. All the participants were equipped with the same neutral and conventional running shoe (Adidas Supernova Glide 3) and instructed to run at a self-selected, comfortable pace. Next, the participants were instructed to run 27.5 m along a laboratory runway, to turn around, and to run back to the start. A digital camera (Casio Exilim EXF1) was placed perpendicular to the runway—at 14 m from the starting point and with the middle of the lens 15 cm above the floor—and set to record at 300 frames per second. The runners' FSAs were recorded before and after the turning point, resulting in video of the lateral and medial sides of each

foot. A photocell timing module (ALGE Timing) was used to measure the participants' running paces. Two observers independently evaluated each video. Each participant's FSA was then evaluated 4 times—2 times for each foot—with the FSA defined as the angle of the foot when it touches the ground. The videos were then evaluated using ImageJ. Data Analysis: descriptive data for the demographic characteristics and FSAs are presented as means and standard deviations. The Supernova Glide 3 has a heel-to-toe-drop angle of 2.7° for US men's size 10 shoes (corresponding to a 271-mm foot length). The Bland-Altman method was employed to measure the absolute value of the bias between the observers.

RESULTS: The data for the 820 runners (412 male and 408 female) who were recorded are as follows: mean $\pm$ SD age, 37.1 ± 10.2 years; BMI, 26.2 ± 4.4 kg/m²; and running pace, 11.8 ± 1.8 km/h. In terms of FSA, the left ankle was $20.9^\circ \pm 5.1^\circ$, and the right ankle was $21.7^\circ \pm 4.8^\circ$; after the heel-to-toe-drop angle was deducted, the FSA was $18.2^\circ \pm 5.1^\circ$ for the left ankle and $19.0^\circ \pm 4.8^\circ$ for the right ankle. The absolute value of the bias between observers was $0.40^\circ \pm 2.45^\circ$.

CONCLUSIONS: This is the first study in which a high-speed camera was used to measure the FSAs of novice runners who were wearing the same type and model of shoe while running at a self-selected, comfortable pace on a runway. We conclude that this method of evaluating FSA is feasible and could be used in future studies. The FSA identified in this study was approximately 21° .

CLINICAL RELEVANCE: FSA knowledge could be important for clinicians, who should be aware of the ankle's biomechanical characteristics and of those characteristics' implications for running practice. The possible relationship between FSA and novice runners' injuries should be elucidated in future studies.

SP077

DYNAMIC STABILITY ASYMMETRIES FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Kathryn Lucas, Phillip Gribble, Brian Noehren

PURPOSE/HYPOTHESIS: The risk of tearing the uninjured anterior cruciate ligament (ACL) is heightened following a primary ACL reconstruction despite patients achieving excellent forward hop symmetry. One challenge with the forward hop test is that it allows patients to compensate with heightened use of visual input, which may mask poor dynamic stability. A lack of dynamic stability is relatively unexplored following an ACL reconstruction. Dynamic stability can be measured by calculating the time to stabilization (TTS) upon landing from a hop. Besides a forward hop, a backward hop may provide additional insight as it restricts visual guidance upon landing. Therefore, the purpose of this study was to evaluate TTS during a single-leg forward and backward hop between limbs in an ACL reconstructed cohort and compare them to a control group.

NUMBER OF SUBJECTS: Eighteen subjects, 13 subjects 6 months post-ACL reconstruction (5 female; mean $\pm$ SD age, 17.0 ± 3.2 years; BMI, 22.5 ± 3.7 kg/m²) and 5 healthy control subjects (2 female; age, 18.0 ± 1.2 years; BMI, 21.0 ± 2.0 kg/m²).

MATERIALS AND METHODS: Subjects performed forward and backward single-leg hops for distance onto a force plate, holding each landing for 10 seconds. TTS of the center of pressure upon landing was calculated in the anterior-posterior (AP) and medial-lateral (ML) directions. A paired *t* test was used to run within-subject analyses and independent *t* tests for between-subject comparisons.

RESULTS: ACL subjects had 94% limb symmetry in backward hops and 99% in forward hops. Subjects after ACL reconstruction displayed higher uninjured AP (involved, 2.1 ± 0.8 seconds; uninvolved, 2.8 ± 1.3 seconds; $P = .03$) and ML (involved, 1.4 ± 0.9 seconds; uninvolved, 2.2 ± 1.3 seconds; $P = .02$) TTS during a backward hop. No TTS difference between limbs was found in forward hopping ($P > .05$). Subjects' uninjured limb had significantly higher TTS than healthy subjects in the AP (ACL, 2.8 ± 1.3 seconds; healthy, 1.5 ± 0.3 seconds; $P < .01$) and ML (ACL, 2.2 ± 1.3 sec-

onds; healthy, 1.2 ± 0.6 seconds; $P = .04$) directions, but the injured limb was not significantly different ($P > .05$).

CONCLUSIONS: Despite excellent hop distance limb symmetry, the ACL cohort displayed significant TTS impairments of the uninvolved limb compared to the injured limb as well when compared to the control group. Backward hopping was able to identify asymmetries between limbs that could not be detected with forward hops. Backward TTS may aid in testing for dynamic control after ACL reconstruction, and backward hops may help with training dynamic stability.

CLINICAL RELEVANCE: Despite the ACL cohort achieving near perfect hop symmetry, challenges with underlying stability persist. The differences in dynamic stability between limbs during backward hopping tasks suggest that rehabilitation protocols may need additional tasks to challenge balance with less reliance on visual input. Rehabilitation protocols are focused on the involved limb, but dynamic stability of the uninvolved limb is needed as well. Evaluating and treating quality of movement during a backward hop may provide clinicians a task that utilizes decreased visual input.

SP078

COMPARING SHORT-TERM OUTCOMES FOR ACUTE AND CHRONIC SHOULDER INSTABILITY WITH CONSERVATIVE TREATMENT

Caitlin Ludington, Adam Daniel Lutz, Logan John Gudde, Carlos Gonzalez, Ellen Shanley

PURPOSE/HYPOTHESIS: Effective nonoperative management of shoulder instability typically incorporates specific exercise programs targeting scapular and glenohumeral stabilization, and neuromuscular control into a comprehensive treatment plan. No prior studies have examined differences in treatment characteristics or patient reported outcomes between patients treated conservatively for acute and chronic shoulder instability. The purpose of this study was to compare treatment characteristics and short-term Penn Shoulder Scores (PENN) between patients treated conservatively for acute and chronic shoulder instability.

NUMBER OF SUBJECTS: Thirty-four patients diagnosed with acute ($n = 18$) or chronic instability ($n = 16$).

MATERIALS AND METHODS: Patients that completed a course of physical therapy at ATI Physical Therapy in Washington State with a primary diagnosis of shoulder instability, confirmed by chart review, were considered for inclusion. Postoperative patients and those with concomitant fracture were excluded. Baseline patient information and episodic treatment characteristics were extracted from the ATI Patient Outcomes Registry. Separate univariate ANOVAs were used to compare differences in treatment metrics, visits, and short-term PENN between patients with acute and chronic instability. Significance was set a priori at $P < .05$.

RESULTS: There were no significant differences between patients with acute and chronic shoulder instability for age, BMI, number of visits or units per visit completed; females were more likely to have chronic shoulder instability ($P = .04$) and those with a history of dislocation were equally likely to have acute or chronic instability ($P = .2$). Those being treated for acute instability had higher final PENN scores (91.5 ± 9.2 versus 78.6 ± 20.0 , $P = .02$) and greater change in PENN scores (35.6 ± 17.5 versus 11.9 ± 19.0 , $P < .001$). While not significant, initial PENN scores trended towards being higher in those with chronic instability.

CONCLUSIONS: This study demonstrates significantly better short-term outcomes for patients presenting with acute versus chronic shoulder instability. In patients with chronic shoulder instability, conservative treatment seems to improve function in the short term, but the improvement remains below the MDC, and just above the MCID for the PENN. These findings suggest that efforts to restore short-term function and preventing should focus on identifying patients suffering acute shoulder instability to maximize function.

CLINICAL RELEVANCE: This study demonstrates good utility of conservative treatment for acute shoulder instability in the short term. Further

research comparing long-term outcomes, as well as other treatment options for chronic instability may be warranted.

SP079

FACTORS ASSOCIATED WITH SELF-SELECTED STEP RATE IN COLLEGIATE CROSS-COUNTRY RUNNERS: A COMPARATIVE STUDY

Lace Elly Luedke, Mitchell John Rauh

PURPOSE/HYPOTHESIS: Cross-country is a popular high school and collegiate sport, but has a high rate of running-related injuries (RRI) among participants. In high school runners, higher step rates have been associated with greater running experience and decreased height, and low step rates have been prospectively associated with increased risk of shin RRI. Presently, these associations have not been reported in collegiate cross-country runners. The purpose of this study was to compare step rates between collegiate and high school distance runners. We hypothesized collegiate runners would run at higher step rates. Secondary objectives included determining if step rates in collegiate runners are related to experience and anthropometric variables and whether their self-selected step rates were prospectively related to lower extremity RRI.

NUMBER OF SUBJECTS: Twenty-nine NCAA Division III collegiate cross-country runners (13 female; mean $\pm$ SD age, 19.7 ± 1.3 years).

MATERIALS AND METHODS: Runners completed a survey on demographics. Step rates were assessed at self-selected speed during overground running on an outdoor track the first day of the season. Runners were followed during the season for occurrence of time-loss lower extremity RRI. A cohort of 68 high school runners (47 females) was used for comparison of step rates. For collegiate runners, bivariate correlations were used to examine relationships between step rate and years of running experience, height and body mass. Odds ratios (OR) and 95% confidence intervals (CIs) were used to assess injury risk.

RESULTS: While collegiate runners' self-selected step rates (177.1 ± 7.2 steps/min [spm]) were higher than high school runners' (171.3 ± 8.3 spm; $P = .01$), the difference was nonsignificant when adjusted for higher self-selected speeds (collegiate, 4.6 ± 0.5 m/s; high school, 3.8 ± 0.5 m/s; $P = .48$). A significantly lower percentage (6.9%) of collegiate runners ran at ≤ 166 spm than high school runners (30.9%; $P = .01$). The percentage of collegiate runners with step rates ≥ 178 spm (48.3%) was not significantly higher than for high school runners (30.9%; $P = .10$). In the collegiate runners, years of running experience ($P = .81$) and height ($P = .11$) were not significantly correlated to self-selected step rate. Body mass was negatively correlated with step rate ($r = -0.43$, $P = .02$). During the season, 41.3% of collegiate runners experienced RRI. While collegiate runners with step rates of ≤ 166 spm were more likely to experience RRI than runners with step rates of ≥ 178 spm, the association was nonsignificant (OR = 2.5; 95% CI: 0.12, 50.4; $P = .54$).

CONCLUSIONS: A smaller proportion of collegiate runners displayed step rates ≤ 166 spm than high school runners, which may partially explain the nonsignificant relationship between low step rate and RRI in this pilot study; that is, it lowered the study's power to detect a statistically significant risk relationship.

CLINICAL RELEVANCE: While higher step rates were found in collegiate than high school runners, the difference was largely explained by increased speeds. A larger sample of collegiate runners' step rates is needed to better evaluate step rate as a risk factor for RRI.

SP080

INTERLIMB ASYMMETRIES OF CONCENTRIC MEAN FORCE DURING THE COUNTERMOVEMENT JUMP: SEX DIFFERENCES IN COLLEGIATE TENNIS PLAYERS

Marco Aurelio Machado, Courtney Heberlie, Benjamin Ericksen, Brad Warren Willis, Aaron Daniel Gray, Trent Guess, David William Echelmeyer, Seth L. Sherman, Bryan Mann

PURPOSE/HYPOTHESIS: While receiving less attention as compared to similar high-risk sports in terms of noncontact musculoskeletal injuries, tennis requires considerable jumping, cutting and running. Furthermore, female athletes are at a 3- to 5-fold increased risk of suffering a noncontact lower extremity (LE) injury than males, with interlimb asymmetries during dynamic jumping and landing tasks considered primary risk factors. Dynamic movement assessments of lower-limb strength and power, such as the countermovement jump (CMJ), are frequently used to evaluate interlimb asymmetries linked to performance, rehabilitative progress and even risk of injury. Unfortunately, there is limited evidence examining key indicators of lower extremity strength among collegiate tennis players, including the production of concentric mean force (ConMF), and the degree of interlimb asymmetry observed between sexes. This study aimed to determine if sex differences exist in the percentage of interlimb ConMF asymmetry during the CMJ in collegiate tennis players. We hypothesized that collegiate female tennis players would demonstrate a greater percentage of interlimb ConMF asymmetry than males during the CMJ.

NUMBER OF SUBJECTS: Twenty-two.

MATERIALS AND METHODS: A total of 22 healthy NAIA tennis players (9 female, 13 male) participated in preseason testing. Participants performed 2 CMJ in series following routine warm-up. To perform the CMJ, subjects were instructed to jump "as high and as fast as possible," with hands placed on their hips. Jumps were recorded by two 1-dimensional force-plates to obtain ConMF (Newtons) per limb during the initial take-off phase. Interlimb asymmetry was calculated as the difference in ConMF between LE, divided by the sum of ConMF from both legs. This value was then multiplied by 100 and reported as a percentage. Results were averaged between the 2 trials. An independent-samples t test was used to compare percentage of interlimb ConMF asymmetry between females and males, with statistical significance accepted at $P < .05$.

RESULTS: All data are presented as mean $\pm$ SD. Female tennis players demonstrated a statistically significant greater percentage of interlimb ConMF asymmetry as compared to males during the CMJ (female, $6.67\% \pm 4.72\%$; male, $2.89\% \pm 3.52\%$; $P < .01$).

CONCLUSIONS: Collegiate female tennis players displayed over twice as much interlimb asymmetry in ConMF as compared to males during the CMJ, reinforcing the value of portable and efficient tools to monitor key indicators of strength in high risk populations.

CLINICAL RELEVANCE: Though relative-risk thresholds regarding dynamic strength assessments of interlimb asymmetries among collegiate tennis players are lacking, this study underscores the utility of portable force-plate technology in future efforts to longitudinally monitor and potentially reduce sex disparities in jumping mechanics through targeted identification and intervention.

SP081

EFFECTS OF TASK AND PREVIOUS ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION ON LIMB SYMMETRY INDEX IN FEMALE COLLEGIATE LACROSSE PLAYERS

Mary Foresman Mahon, Emma Alfred, Jeffrey B. Taylor, Anh-Dung Nguyen, Audrey E. Westbrook, Kevin R. Ford

PURPOSE/HYPOTHESIS: Over the past 3 decades participation in women's lacrosse has exploded across the national collegiate sports scene demonstrated by an increase of teams by 300%. While the popularity of the sport has grown, there is also an increase in injuries, particularly anterior cruciate ligament (ACL) tears. Following ACL reconstruction (ACLR) and rehabilitation, a large percentage of athletes return to sport. However, nearly 30% of these young female athletes will sustain a second ACL injury within 2 years. Hip/ knee compensations and limb asymmetries during dynamic tasks have been reported following ACLR. The purpose of this study was to identify limb asymmetries and joint compensatory strategies during single-leg landing and unanticipated cutting trials in female lacrosse players.

NUMBER OF SUBJECTS: Twenty-six female Division I lacrosse players volunteered to participate in this study. Five players with previous ACLR (2.1 ± 0.5 years).

MATERIALS AND METHODS: Participants with history of ACLR ($n = 5$, 2.1 ± 0.5 years) were compared to those without ACLR (CTRL, $n = 21$) while performing a controlled single-leg landing (SLL) and an unanticipated jump-stop cut (JSC). For the SLL, the participants stood on a single leg and hopped forward a distance 40% of their height over a 10.7-cm barrier and landed on the same leg, balancing for 2 seconds. The JSC consisted of a jump stop and subsequent 45° cut in the direction of a randomly displayed arrow. Three trials were performed on each leg for each movement on a synthetic turf surface with an embedded force platform. Limb symmetry indices (LSI) were calculated for sagittal and frontal plane hip and knee moments and angular range of motion. A 3-way repeated-measures ANOVA ($P < .05$) with task, joint, group factors was performed for kinematic and kinetic variables.

RESULTS: A significant group times joint interaction ($P = .003$) was found for sagittal plane moment variables. Specifically, the LSI in players with previous ACLR had greater reliance on hip extensors (124.4%; 95% CI: 105.65%, 143.2%) and lower reliance on knee extensors 85.1% (95% CI: 76.5%, 93.7%) compared to no differences in the CTRL (hip, 94.4%; 95% CI: 86.3%, 102.4%; knee, 98.8%; 95% CI: 92.9%, 104.8%). Frontal plane moments, and frontal/sagittal plane range of motion did not exhibit significant main effects or interactions ($P > .05$).

CONCLUSIONS: The utilization of greater hip extensor and less knee extensor moment during both tasks was present in highly active Division I lacrosse players that had previous ACLR. This compensatory movement pattern consistent with quadriceps torque deficits could increase the risk of sustaining a second ACL injury.

CLINICAL RELEVANCE: Understanding compensatory movement patterns of the hip and knee is imperative when designing a targeted, effective rehabilitation protocol for athletes who have undergone an ACLR. Being able to identify these aberrant patterns before returning to sport may decrease the likelihood of reinjury.

SP082

DOES GRIP AND SHOULDER STRENGTH RELATE TO SHOULDER ROTATOR CUFF TEAR?

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PURPOSE/HYPOTHESIS: Determining a means to better preoperatively define extent of rotator cuff (RTC) dysfunction is desired. A surrogate to replace invasive arthroscopy or expensive diagnostic. Testing would be valuable. The purpose of this research study was to prospectively examine the relationships between the percent loss (affected compared to unaffected) of hand grip and shoulder strength, and RTC tear dysfunction in those with proven tears.

NUMBER OF SUBJECTS: Twenty-five.

MATERIALS AND METHODS: Subjects were chosen from a single orthopaedic surgeon specializing in shoulder surgery who were deemed through examination to have a RTC tear and elected to undergo repair. Prior to surgery each subject was assessed bilaterally for hand grip strength, shoulder external rotation (ER) and abduction (ABD) strength using dynamometry, and subjective patient-reported outcome measures. Additionally, actual surgically reported RTC tear size via arthroscopy was gathered following repair. Descriptive statistics and Pearson correlation coefficients were used to analyze data.

RESULTS: A Pearson correlation coefficient of -0.440 was calculated between ASES Function score and ABD strength, suggesting a moderate correlation; -0.466 between ASES Function score and ER strength, suggesting a moderate correlation; -0.511 between ASES Function score and number of tendons torn, suggesting a strong correlation; and

-0.418 between ASES Index score and ER strength, suggesting a moderate correlation. Data suggests weak and nonsignificant correlations between grip strength and RTC dysfunction. The P value was set to less than .05.

CONCLUSIONS: An inverse relationship was found between ASES Function scores, and shoulder strength and number of RTC tendons torn. This suggests that ASES Function score decreases as the percent difference between affected and unaffected shoulder ABD and ER strength and number of tendons torn increases. Also, an inverse relationship was found between ASES Index scores and ER strength, suggesting that ASES Index score decreases as the percent difference between affected and unaffected shoulder ER strength increases.

CLINICAL RELEVANCE: The results suggest lower ASES Function and Index scores implicate an increased percent of ABD and ER strength loss and an increased number of torn tendons when compared bilaterally. Weak relationships were found between grip strength and RTC dysfunction.

SP083

RELIABILITY OF MEASURING GLENOHUMERAL ABDUCTION RANGE OF MOTION WITH A GONIOMETER AND A DIGITAL INCLINOMETER

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PURPOSE/HYPOTHESIS: Mobility impairments are common among adults with shoulder pain. The reliability of measuring total shoulder abduction has been well documented, but the reliability of measuring glenohumeral abduction is lacking evidence. Therefore, the purpose of this study was to investigate interrater and intrarater reliability of measuring glenohumeral abduction with a digital inclinometer and goniometer. Secondary purposes of the study were to determine concurrent validity for the measurement tools and for patient position during measurements of glenohumeral abduction.

NUMBER OF SUBJECTS: Thirty.

MATERIALS AND METHODS: Thirty asymptomatic participants, 18 female and 12 male, had passive right glenohumeral abduction measurements performed in standing and in supine. Standing measurements were completed with both an inclinometer and goniometer. Supine measurements were completed with a goniometer. Raters consisted of 2 groups of second year Doctor of Physical Therapy program students.

RESULTS: The intraclass correlation coefficients (ICCs) for intrarater reliability were 0.85 for goniometry in standing, 0.86 for the digital inclinometer in standing, 0.81 for the goniometer in supine. The intrarater reliability analysis showed that the standard error of measurement was 3.4 for goniometry in standing, was 3.1 for the digital inclinometer in standing, and 3.0 for goniometer in supine. The intrarater reliability analysis showed the minimal detectable change was 9.42 for goniometry in standing, 8.59 for the digital inclinometer in standing, and 8.32 for the goniometer in supine. The intraclass correlation coefficients (ICCs) for interrater reliability were 0.40 for goniometry in standing, 0.62 for the digital inclinometer in standing, 0.30 for the goniometer in supine. The interrater reliability analysis showed that the standard error of measurement was 6.1 for goniometry in standing, was 4.6 for the digital inclinometer in standing, and 7.8 for goniometer in supine. The interrater reliability analysis showed the minimal detectable change was 16.91 for goniometry in standing, 12.75 for the digital inclinometer in standing, and 21.62 for the goniometer in supine. The ICCs for concurrent validity between goniometry in standing were 0.92 for group 1 raters and 0.23 for group 2 raters. The ICCs for concurrent validity between the goniometer and digital inclinometer during measurements performed with the patient standing were 0.98 for group 1 raters and 0.91 for group 2 raters.

CONCLUSIONS: Good interrater reliability was found for measuring glenohumeral abduction in standing with either a goniometer or digital inclinometer, as well as in supine with a goniometer. Intrarater reliability was

poor to fair for measurements of glenohumeral abduction. The results support the interchangeable use of a goniometer and digital inclinometer for measuring glenohumeral abduction in the standing position. When measurements are completed by the same rater the results support the interchangeable use of the standing or supine position for measurements completed with a goniometer.

CLINICAL RELEVANCE: Clinicians may use either a goniometer or inclinometer to measure passive GHJ abduction ROM with the patient standing. If more than 1 clinician is taking measurements of passive GHJ abduction, then both clinicians should take measurements in standing with a digital inclinometer. Accuracy of GHJ abduction ROM measurements are better between sessions as compared to between examiners. Performing shoulder PROM with scapular stabilization appears to be a valid method for assessing GHJ mobility.

SP084

MUSCULOSKELETAL CHARACTERISTICS OF ADOLESCENT SOFTBALL ATHLETES WITH AND WITHOUT AN UPPER EXTREMITY INJURY

Chelsea Leonard Martin, Kaylee Pobocik, Mary C. Hannah, Mallory S. Faherty, Shefali Mathur Christopher, Srikanth Vallabhajosula

PURPOSE/HYPOTHESIS: Upper extremity (UE) injury risk is a concern among adolescent softball players. Understanding contributing musculoskeletal factors (MS) is important to clinicians for mitigating injury risk. Currently, data on MS characteristics and injury risk among softball athletes are limited. The purpose of this study was to identify MS differences among softball athletes based on UE dominance and injury status.

NUMBER OF SUBJECTS: Sixty-seven adolescent softball athletes participated (mean $\pm$ SD age, 15.8 ± 3.3 years) and classified into injured ($n = 18$) and uninjured ($n = 49$) groups based on self-reported dominant UE noncontact injury in the past year that occurred during softball participation.

MATERIALS AND METHODS: The dominant side (D) throwing UE and ipsilateral hip were established. ROM assessments included internal (IR), external rotation (ER), and total range of motion (TROM) of glenohumeral and hip joints. Strength included IR and ER of glenohumeral and hip joint, and hip abduction. Flexibility assessments included pectoralis minor length (PML), and posterior shoulder tightness (PST). Postural measurements included forward head posture and forward shoulder posture (FSP). A 2-way ANOVA compared D and nondominant (ND) sides of both groups.

RESULTS: Significant main effect for dominance showed increased PST (D, $112^\circ \pm 6.3^\circ$; ND, $115^\circ \pm 6.8^\circ$; $P = .015$) and shoulder IR strength (D, 7.6 ± 1.7 kg; ND, 7 ± 1.5 kg; $P = .014$), and decreased PML (D, 12.7 ± 1.1 cm; ND, 13.2 ± 0.9 cm; $P = .015$), FSP (D, $60^\circ \pm 10.6^\circ$; ND, $56^\circ \pm 10.5^\circ$; $P = .011$), IR ROM (D, $60^\circ \pm 10.3^\circ$; ND, $69^\circ \pm 9.5^\circ$; $P < .001$), and TROM (D, $174^\circ \pm 17.8^\circ$; ND, $179^\circ \pm 19.9^\circ$; $P = .019$) on the dominant side. Significant main effect for injury showed that those who were injured had increased hip IR (Injured: D, 8.5 ± 1.3 kg; ND, 8.4 ± 1.3 kg; Uninjured: D, 7.6 ± 1.6 kg; ND, 7.8 ± 1.6 kg; $P = .03$) and ER (Injured: D, 9.0 ± 1.4 kg; ND, 9 ± 1.6 kg; Uninjured: D, 8.3 ± 1.6 kg; ND, 8.3 ± 1.6 kg; $P = .029$) strength. No other significant differences were found.

CONCLUSIONS: On the dominant side, adolescent softball athletes demonstrated increased PST and shoulder IR strength and decreased PML, FSP, IR ROM, and TROM, potentially due to the unilateral demands of the sport on the UE. Those who were injured demonstrated increased hip IR and ER strength.

CLINICAL RELEVANCE: This study demonstrated similar findings to previous overhead throwing athlete studies regarding dominant shoulder flexibility and ROM; however, this study found differences in strength when compared to injury status which differs from previous overhead athlete studies. Hip strength differences in those who have an UE injury warrants further investigation to explore long-term MS adaptations and injury risk in adolescent softball players to improve injury mitigation programs.

SP085

UTILITY OF THE KERLAN-JOBE ORTHOPEDIC CLINIC OUTCOME MEASURE AND ITS RELATIONSHIP TO MUSCULOSKELETAL CHARACTERISTICS IN SOFTBALL ATHLETES

Chelsea Leonard Martin, Kaylee Pobocik, Mary C. Hannah, Mallory S. Faherty, Srikanth Vallabhajosula

PURPOSE/HYPOTHESIS: Upper extremity (UE) health is essential for adolescent softball players. Adequate UE and lower extremity (LE) strength, range of motion (ROM), and flexibility are essential to decrease UE dysfunction in overhead athletes. Previous research has shown that the Kerlan-Jobe Orthopedic Clinic Shoulder and Elbow questionnaire (KJOC) is sensitive to detect UE dysfunction, but data is limited among softball adolescent athletes. Additionally, the relationship between KJOC score and musculoskeletal (MS) characteristics in overhead athletes are unknown. The purpose of this study is to investigate the sensitivity and specificity of KJOC score in detecting UE dysfunction in adolescent softball athletes; secondly, to identify relationships between KJOC score and MS characteristics among this population.

NUMBER OF SUBJECTS: Sixty-seven adolescent softball athletes participated (mean $\pm$ SD age, 15.8 ± 3.3 years) who reported playing without pain ($n = 51$), and playing with pain ($n = 11$). Five subjects did not report arm status.

MATERIALS AND METHODS: Subjects filled out the KJOC outcome measure and completed an injury questionnaire. Dominance was assigned to the throwing UE and ipsilateral LE. ROM assessments included internal (IR) and external rotation (ER) of the glenohumeral (GH) and hip joints. Strength assessments included IR and ER of the GH and hip joint, and hip abduction. Flexibility assessments included pectoralis minor length, and posterior shoulder tightness. Postural measurements included forward head posture and forward shoulder posture. An ROC curve was used to determine sensitivity and specificity of the KJOC to arm function. Correlations between KJOC score and all MS data were assessed using a Pearson correlation.

RESULTS: The results of the ROC curve demonstrated high sensitivity (0.982) and specificity (0.867) of the KJOC with a cutoff score of 8.43 and an excellent area under curve of 0.977. Pearson correlation demonstrated significant but weak relationship between KJOC score and dominant GH IR ROM ($r = 0.242$, $P = .05$), as well as dominant hip ER strength ($r = -0.262$, $P = .033$). No other significant correlations were found.

CONCLUSIONS: The high specificity and good sensitivity means that the KJOC can be used as an effective tool in adolescent softball athletes. Second, the negative correlation between GH IR ROM and hip ER strength provides 1 point of evaluative information for clinicians.

CLINICAL RELEVANCE: The KJOC is a reliable tool to screen UE dysfunction in adolescent softball athletes. This study agrees with previous research that increased GH IR may be beneficial in maintaining arm health for adolescent softball players. Future research is needed to validate the findings of this study. Furthermore, research is needed to track longitudinal changes in KJOC score and MS characteristics to help clinicians better screen for athletes at risk for UE injury throughout the season, and provide treatment approaches specific to the adolescent softball population.

SP086

IMPROVED PSYCHOLOGICAL DISTRESS IS ASSOCIATED WITH IMPROVED RUNNING ABILITY IN INJURED RUNNERS

Benjamin Robert Maschke, Evan Othmer Nelson, Allison M. Palmsten, Bryan C. Heiderscheit, Michael Obermeier, Hayley Russell, Terese Lynn Chmielewski

PURPOSE/HYPOTHESIS: Psychological distress can negatively influence rehabilitation outcomes in injured athletes. Few studies have focused on injured runners. The purpose of this study was to examine psychological distress and self-reported running ability over 12 weeks in injured runners. The hypotheses were: (1) running ability and psychological distress would improve over 12 weeks, (2) high baseline psychological distress would be associated with poorer running ability at 12 weeks, and

(3) across 12 weeks, decreased psychological distress would be associated with improved running ability.

NUMBER OF SUBJECTS: Thirty-two runners attending physical therapy for a running-related injury (10 male; mean $\pm$ SD age, 36.7 ± 11.9 years).

MATERIALS AND METHODS: Questionnaires completed at physical therapy consult (baseline) and 12 weeks later were University of Wisconsin Running Injury and Recovery Index (UWRI), Athletic Fear Avoidance Questionnaire (AFAQ), and Optimal Screening for Prediction of Referral and Outcome–Yellow Flag Screening Tool (OSPRO-YF). UWRI includes 9 items (0–36 points), and higher scores mean better running ability. AFAQ includes ten items (10–50 points), and higher scores mean greater fear-avoidance beliefs in athletics. OSPRO-YF includes 17 items that estimate scores on 11 psychological questionnaires. Item scores in the top or bottom quartile for negative or positive psychological questionnaires, respectively, are assigned a yellow flag (0–11 total), and items scores are also summed (6–89 points); more yellow flags or higher score means higher psychological distress. Change scores (12 weeks – baseline) were computed for all measures. Paired *t* tests (UWRI, AFAQ and OSPRO-YF sum) or Wilcoxon test (OSPRO-YF) compared baseline and 12-week scores. Intervariable associations were examined with Pearson or Spearman Rank correlation, as appropriate, for baseline AFAQ, OSPRO-YF and OSPRO-YF sum scores with 12-week UWRI score and among change scores.

RESULTS: All questionnaire scores significantly improved from baseline to 12 weeks (UWRI, 15.8 ± 5.5 versus 25.7 ± 7.9 ; AFAQ, 21.0 ± 8.2 versus 18.7 ± 7.1 ; OSPRO-YF sum, 31.2 ± 9.8 versus 27.2 ± 9.6 ; all, $P < .05$). Median yellow flags on OSPRO-YF improved from 2 to 1 ($P = .02$). Baseline AFAQ, OSPRO-YF and OSPRO-YF sum were not correlated with 12 week UWRI. Change in AFAQ and OSPRO-YF sum score were negatively correlated with change in the UWRI ($r = -0.55$ and $r = -0.41$, $P < .05$, respectively).

CONCLUSIONS: Psychological distress and running ability improved over 12 weeks. Psychological distress at baseline was not associated with running ability 12 weeks. Conversely, improved psychological distress over 12 weeks was associated with improved running ability. Change in OSPRO-YF sum score, not yellow flags, was correlated with change in running ability.

CLINICAL RELEVANCE: Psychological distress is present in injured runners and improves as running ability improves; thus, recurrent screening of psychological distress and running ability may be necessary. AFAQ and OSPRO-YF sum score may give meaningful insight into psychological distress in injured runners.

SP087

EFFECT OF AUDITORY CUES ON RUNNING BIOMECHANICS IN INDIVIDUALS WITH PATELLOFEMORAL PAIN SYNDROME: A PILOT STUDY

Danny McAndrew, Brooke E. Farmer, Jennifer Joy Bagwell, Dimitrios Katsavelis, Terry Lee Grindstaff

PURPOSE/HYPOTHESIS: Altering running cadence has been shown to reduced knee joint forces and pain in individuals with patellofemoral pain syndrome (PFPS). A metronome is often used as an auditory stimulus to alter cadence, but music, which also has a set beat frequency, may offer a more pleasing alternative. Preliminary data indicates within-session increases in cadence and decreases in peak knee flexion angle when listening to music. The purpose of this study was to determine the effect of listening to music at a specific beat frequency on running biomechanics and knee pain in individuals with PFPS after a 2-week intervention.

NUMBER OF SUBJECTS: Five participants (4 male, 1 female; mean $\pm$ SD age, 24.6 ± 4.5 years; height, 178.4 ± 9.1 cm; mass, 75.9 ± 8.3 kg; Tegner, 6.4 ± 1.3) with PFPS were recruited.

MATERIALS AND METHODS: During baseline testing participants performed a 5-minute jogging warm-up at a self-selected pace, immediately followed by a 2-minutes-of-running data collection with cadence determined during the first 30 seconds. Next, participants were given a playlist of music at a beat frequency 5% to 15% faster than baseline cadence. Participants were instructed to match their cadence to the beat frequency of each song

and to listen to the playlist during each run over the next 2 weeks. Follow-up testing occurred after 2 weeks, using similar methods. The primary outcome measures were cadence, peak knee flexion angle (degrees), peak external knee flexion moment (Nm/kg) and lower extremity functional scale (LEFS) scores. Paired *t* tests were conducted to determine differences in outcome variables and effect sizes were calculated to determine the magnitude of the effect.

RESULTS: There was a significant decrease in peak knee flexion angle ($P = .05$; Pre, $41.2^\circ \pm 6.2^\circ$; Post, $38.2^\circ \pm 4.7^\circ$; $d = -0.55$). There was not a significant change in cadence ($P = .10$; Pre, 165.6 ± 9.2 steps/min; Post, 168.8 ± 10.4 steps/min; $d = 0.34$), peak external knee flexion moment ($P = .72$; Pre, 3.1 ± 0.9 Nm/kg; Post, 3.3 ± 1.1 Nm/kg; $d = 0.19$), or LEFS scores ($P = .35$; Pre, 74 ± 7.1 ; Post, 77.3 ± 3.2 ; $d = 0.60$).

CONCLUSIONS: Listening to music at a specific beat frequency was effective to cause a decrease in peak knee flexion angle after a 2-week intervention. Individuals did not retain other within-session biomechanical changes and did not demonstrate clinically meaningful changes in function. Further research is required to better understand optimal stimulus parameters (metronome versus music) and potential treatment responders.

CLINICAL RELEVANCE: Although the use of an auditory stimulus, such as a metronome or music, has strong potential to alter running biomechanics and improve clinical outcomes for individuals with PFPS the results of this preliminary investigation suggest changes may be relatively small or not clinically meaningful.

SP088

EFFECT OF VOLITIONAL PREEMPTIVE ABDOMINAL CONTRACTION OF MULTIFIDUS THICKNESS DURING BARBELL FRONT AND BACK SQUATS

Joseph B. McCormick, Timothy Wayne Stark, Joseph Eunice, Kyle Aaron Barnett, Aaron William Walling

PURPOSE/HYPOTHESIS: To determine the effects of volitional preemptive abdominal contraction (VPAC), body position and squat bar position on lumbar multifidus muscle (LMM) thickness during a maximal barbell squat. We hypothesized that both the front squat position and the use of VPAC would result in increased lumbar multifidus thickness when compared to the back squat position and no VPAC conditions.

NUMBER OF SUBJECTS: Twenty-three.

MATERIALS AND METHODS: A total of 23 subjects were included in the study, aged 18 to 28 years with a mean $\pm$ SD age of 22.4 ± 2.6 years. BMI ranged from 21.6 to 36.7 kg/m² (mean $\pm$ SD, 27.6 ± 3.97 kg/m²). No subjects were excluded. Diagnostic ultrasound (DUS) of LMM was used to measure changes in thickness at L4–L5 in 10 different body positions with and without VPAC. For the VPAC conditions, subjects gently inhaled, exhaled, then stiffened their trunk as if they were about to be hit in the belly. Positions included prone with and without VPAC, standing back squat with an unweighted dowel rod, with and without VPAC, and standing front squat with an unweighted dowel rod, with and without VPAC. The 4 maximum isometric squats included, front squat with and without VPAC and back squat with and without VPAC. All squats were performed at 60° of knee flexion. A 2-way repeated-measures ANOVA with Bonferroni correction compared each position to one another.

RESULTS: Statistical significance (95% CI) was found when comparing maximal squats. Significant values are the mean change from baseline (relaxed prone) to maximal squat and included: front squat without VPAC greater than back squat without VPAC ($P = .03$); front squat with VPAC greater than back squat without VPAC ($P = .012$); and front squat with VPAC greater than back squat with VPAC ($P = .001$).

CONCLUSIONS: The maximal isometric front squats produced greater LMM thickness than the back squat. VPAC produced greater LMM thickness during a maximal isometric front squat, than in a maximal isometric back squat.

CLINICAL RELEVANCE: To maximize activation of the lumbar multifidus, physical therapists should recommend front squats as opposed to back squats

in weightlifting programs as well as the inclusion of VPAC. LMM thickness has been correlated with increased stabilization of the lumbar spine. Utilization of the front squat position with VPAC may be important in the reduction mechanical stress on the lumbar spine, especially in individuals with prior history of low back pain.

SP089

STATIC FOOT STRUCTURE IS NOT A SUFFICIENT SURROGATE FOR FOOT ARCH MOBILITY IN YOUTH RUNNERS

Claire McKeone, Jeffery Allen Taylor-Haas, Micah C. Garcia, Jason Long, Kevin R. Ford

PURPOSE/HYPOTHESIS: The Arch Height Index (AHI) is a valid and reliable tool for quantification of foot arch structure and deformation in adults and children. In adult runners, feet classified as planus tend to have greater arch mobility. However, little is known about foot arch height classification and foot arch mobility in healthy youth runners. The purposes of this study were to identify: (1) the distribution of foot structure and arch deformation within youth runners and (2) the distribution of arch mobility in feet classified as planus or cavus.

NUMBER OF SUBJECTS: One hundred twenty-two (44 male, 78 female; mean $\pm$ SD age, 13.5 $\pm$ 2.7 years).

MATERIALS AND METHODS: The measures of the AHI include dorsum arch height (DAH), total foot length, and truncated foot length (TFL) in both a seated and standing position. DAH was measured at 50% of the total foot length by a vertical caliper. TFL was measured as the distance from the heel to the center of the first metaphalangeal joint. AHI was then calculated as the DAH divided by TFL. To assess foot mobility, arch deformation (AD) was calculated as the difference in seated and standing AHI. Seated AHI was used to stratify foot structure as planus, rectus, or cavus and AD was used to stratify foot flexibility as rigid, normal, or flexible. Stratification bins were set based on the minimum cohort value plus a percentage of the range of cohort values of the AHI and AD values, respectively (planus and rigid, 0%-40%; rectus and normal, 40%-60%; cavus and flexible, 60%-100%).

RESULTS: The mean seated AHI value for all subjects was 0.36 $\pm$ 0.03. AHI stratification revealed 56 planus, 119 rectus, and 68 cavus feet. (One foot measure was excluded due to an error in AHI measurement.) The mean AD for all subjects was 0.02 $\pm$ 0.01. AD stratification revealed 46 rigid, 154 normal, and 43 flexible feet. Further analysis revealed 31% (n = 76) of the feet presented with rectus/normal classifications while 19% (n = 46) presented as nonrectus/nonnormal. In the latter cohort, there were 16 planus/rigid, 4 planus/flexible, 4 cavus/rigid, and 22 cavus/flexible feet.

CONCLUSIONS: These findings support the previously defined AHI normative values (0.36 $\pm$ 0.02) in children. In the 19% of feet that were not rectus/normal, planus feet were more likely to be rigid while cavus feet were more likely to be flexible. These findings contradict previous adult literature that reported planus feet were more likely to have increased arch mobility (flexible) while cavus feet were more likely to have decreased arch mobility (rigid).

CLINICAL RELEVANCE: This cohort of healthy youth runners demonstrated a high number of planus/rigid and cavus/flexible feet (n = 38, 16%). These findings suggest that using a static foot structure measurement (as determined by seated AHI) as a surrogate measure for dynamic arch motion (as determined by AD) may not be a valid approach for clinicians. Further research is warranted to determine the implications of foot structure and mobility on running mechanics, performance, and injury potential in youth runners.

SP090

EFFECTS OF DYNAMIC AND STATIC STRETCHING ON BALANCE IN COLLEGE-AGED WOMEN

Kelly Marie Meiners, Janice K. Loudon

PURPOSE/HYPOTHESIS: The purpose of this study was to examine the effect of static stretching, dynamic stretching, or no warm up on static and dy-

namic balance as measured by the Star Excursion Balance Test (SEBT), Balance Error Scoring System (BESS) and postural sway as measured by the Technobody Prokin.

NUMBER OF SUBJECTS: Fourteen active women between the ages of 18 and 25 years participated in the study. Subjects were excluded if they had sustained a lower extremity injury or head injury in the last 12 months, scored a level 1 (low) on the IPAQ, history of ankle surgery or instability, current or past neurological deficits, and non-English speaking.

MATERIALS AND METHODS: The subjects were randomized into either a static stretching, dynamic stretching, or no warm-up protocol for each visit. Once the preliminary task was performed, it was removed from randomization on the next visit. Following the warm-up or no warm-up, the subjects performed randomly: Postural sway as measured by the Tecnobody Prokin, SEBT, and BESS. All balance tests were performed each session. The study was completed over 3 consecutive days. Completion of the study resulted in the following outcome measures: Summed BESS scores; Summed SEBT reach scores all normalized with lower extremity length on the SEBT; Unilateral measures of postural sway in medial lateral and forward backward deviation as well as speed of movement as measured by the Tecnobody Prokin. To determine the effect of warm-up on balance, a 1-way repeated-measures ANOVA was conducted to compare each of the 9 scores between the 3 stretching protocols.

RESULTS: No significant difference was found in any of the conditions, on any measure with the exception of postural sway measures between the no warm-up and dynamic stretching protocol ($t = 0.815$, $P < .05$). The dynamic stretching subjects demonstrated increased sway in medial-lateral directions. Wilks' lambda scores were all insignificant with Standard Deviation of movement Forward/Backward approaching significance with Wilks' $\lambda = 0.698$ ($F_{2,122}$, $P = .115$; multivariate $\eta_p^2 = 0.302$).

CONCLUSIONS: No significant difference was found between any of the conditions, with the exception of a significant difference between the dynamic stretch protocol and the no stretching protocol on the postural sway measures. The dynamic stretching subjects demonstrated increased postural sway in medial-lateral directions.

CLINICAL RELEVANCE: Based on the results of this study, a 5-minute warm-up is not beneficial in static or dynamic balance outcomes in young active females. Perhaps a warm-up that included balance challenges would be more effective in improving balance activity. Since age affects balance, future studies investigating warm-up in an older population may reveal a different outcome.

SP091

IMPLEMENTING STANDARDIZED RETURN-TO-SPORT TESTING FOR ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION PATIENTS IN AN OUTPATIENT ORTHOPAEDIC CENTER

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PURPOSE: Describe a quality improvement (QI) process aimed at standardizing return to sport (RTS) testing and documentation for anterior cruciate ligament (ACL) reconstruction patients in an outpatient orthopaedic physical therapy (PT) clinic.

DESCRIPTION: Individuals who undergo ACL reconstruction hope to return to previous activity levels. To determine when patients are ready to return to these activities and minimize risk of reinjury, a battery of objective tests is recommended. Despite this evidence, use of objective RTS testing remains limited. A systematic review found only 13% of studies report use of objective criteria for RTS. Additionally, a large number of studies cite time based criteria despite knowledge that recovery from ACL surgery is complicated by various factors. Therefore, a large outpatient orthopaedic clinic managing approximately 300 ACL surgeries a year sought to standardize RTS testing criteria for a QI project. This project had 2 aims: (1) standardize the use of RTS testing and (2) standardize the documenta-

tion of these tests in discrete data format within the electronic medical record (EMR). Simultaneous changes were made to address the aims: (1) a team of clinicians (physical therapists and PT assistants) performed a literature review and selected the RTS tests based on the best available evidence and (2) discrete data fields were added into EMR documentation to record results of the selected tests. The EMR changes were devised to minimize documentation time (ie, automatic calculation for limb symmetry indices, tests organized by postoperative month, normative values included). Several staff meetings were dedicated to review testing protocols and to teach clinicians how to document the results of the tests in the new discrete fields. To measure success of these changes, preimplementation and postimplementation descriptive statistics were used. In the preimplementation phase 85 of 312 eligible patients (27%) had at least 1 test documented. In the postimplementation phase 136 out of 283 eligible patients (48%) had at least 1 documented test.

SUMMARY OF USE: This project highlights a multifaceted QI project in a busy outpatient orthopaedic clinic with a high volume of ACL patients. By standardizing documentation into discrete fields, clinicians can efficiently examine the testing results of ACL reconstruction patients and track longitudinal progress throughout rehabilitation. Objective RTS testing standardizes clinical decisions for when a patient may safely return to sport or progress to higher-level activities. Implementing evidence-based testing improves patient care and standardizing documentation improves communication among providers.

IMPORTANCE TO MEMBERS: Standardizing care can be a challenge in large PT clinics. Organizing a team of clinicians with expertise in this patient population played a key role in the success of this project. Changes to the EMR were made with clinician input to avoid interruption of documentation efficiency. Staff meetings included presenting discrete data results to maintain engagement from therapy providers.

SP092

INJURY PREVENTION STRATEGIES FOR COLLEGIATE SOCCER ATHLETES: WHAT LOAD MONITORING METRICS SHOULD CLINICIANS FOCUS ON?

Layla Moran, Kevin R. Ford, Jeffrey B. Taylor

PURPOSE/HYPOTHESIS: Monitoring training load is crucial to preventing both under and overtraining while simultaneously optimizing performance. With the advent of wearable technology, collecting data from athletes has become more feasible. By understanding the variables that may influence injury most, both coaches and clinicians can improve their injury prevention strategies and return to sport decisions. The purpose of this study was to determine differences in internal and external load variables between injured and noninjured female collegiate soccer players.

NUMBER OF SUBJECTS: Twenty-three Division I collegiate women's soccer players. Goalkeepers were not included in these analyses.

MATERIALS AND METHODS: Players were instrumented with a wearable global positioning system (GPS) and heart rate monitor during every scheduled practice and match over a 13-week season to measure objective external load (total distance) and internal load (average heart rate) measures. Objective measures were then categorized by practice or game data. Subjectively rated measures of internal load (stress, sleep quality, sleep duration, and soreness) were collected with a daily electronic questionnaire. Injuries were documented daily by the sports medicine staff and players were dichotomized into injured (INJ) (missed >5 sessions throughout the season) and uninjured (NON-INJ) groups for analysis. Independent *t* tests examined group differences in internal and external load variables ($\alpha = .05$).

RESULTS: Injured players travelled significantly higher average distances in games (INJ, 9577 ± 1728 m; NON-INJ, 6545 ± 2441 m; $P = .003$) and exhibited lower average heart rates during practice (INJ, 118.1 ± 9.4 ; NON-INJ, 127.1 ± 9.4 ; $P = .04$) than uninjured players. There were no significant differences in average distance values in practice, average heart rate in games, stress, sleep quality, sleep duration, or soreness between groups.

CONCLUSIONS: Over the course of a collegiate soccer season, female athletes that missed at least 5 sessions throughout the season averaged higher external workloads during games and had lower internal workloads (average heart rates) during practice than those who were not injured.

CLINICAL RELEVANCE: With the increasing use of load monitoring and metrics to guide injury prevention and return to sport decisions, it is important to consider which metrics are clinically relevant and significant to monitor. These results suggest that clinical decision making should emphasize external load metrics. Though subjective measures of internal load metrics did not reveal any differences between groups in this study, further research is needed to identify appropriate methods of internal load data collection and the relationship of these variables to injury.

SP093

PREVALENCE OF INJURY-RELATED RISK FACTORS IN ADOLESCENT BASEBALL PITCHERS

Ivan Joseph Mulligan, Mark Andrew Boland, Elizabeth Stiffler, Daniel C. Zambanini, Sean Donegan, Sydney Raine Lee, Angela N. Tyke, Joseph Steven Breisinger, Kaitlyn Reese

PURPOSE/HYPOTHESIS: As pitching related injuries rise in adolescent baseball, it is crucial to identify the prevalence of known reported and measurable risk factors in adolescent baseball pitchers. The current study hypothesizes that adolescent baseball pitchers will have a high prevalence of both measurable and reported risk factors.

NUMBER OF SUBJECTS: Twenty-four.

MATERIALS AND METHODS: Twenty-four male pitchers (aged 9-16 years; mean $\pm$ SD age, 12.75 ± 2.02 years), recruited from a rural area in central Pennsylvania, participated in the study. Subjects completed a questionnaire comprised of reported risk factors identified by the literature. Kinematic data were analyzed using marker-based VICON motion analysis. In addition, data were collected on the subject's anthropometric measurements, range of motion measurements, and isokinetic strength using Biodex dynamometer.

RESULTS: Of the 24 participating pitchers, 63% (15/24) reported elbow and/or shoulder pain during or after pitching. Of the pitchers who reported pain, 93% (14/15) had a stride length less than 90% of their height. Overall, 54% (13/24) of subjects reported pitching through fatigue, 42% (10/24) exhibited an ER/IR strength ratio on the dominant arm of less than 72%.

CONCLUSIONS: The current study identified a high prevalence of pitching related risk factors for injury in youth male baseball pitchers, established from previous studies.

CLINICAL RELEVANCE: Injury in youth pitchers is becoming more widespread. This study has confirmed a high prevalence of injury related risk factors in adolescent baseball pitchers that can be measured clinically and addressed before pain/injury ensues.

SP094

EXAMINING THE RELATIONSHIP BETWEEN ARM SLOT, STRIDE LENGTH, AND ARM PAIN IN ADOLESCENT BASEBALL PITCHERS

Ivan Joseph Mulligan, Mark Andrew Boland, Sean Donegan, Angela N. Tyke, Joseph Steven Breisinger, Daniel C. Zambanini, Kaitlyn Reese, Elizabeth Stiffler, Sydney Raine Lee

PURPOSE/HYPOTHESIS: With the rise in pitching related injuries and the popularity of adolescent baseball, it is crucial to identify clinically measurable risk factors that relate to the incidence of arm pain in adolescent baseball pitchers. Subjects who report arm pain will display an increase in biomechanical risk factors during the pitching motion.

NUMBER OF SUBJECTS: Twenty-four.

MATERIALS AND METHODS: Twenty-four male pitchers (aged 9-16 years; mean $\pm$ SD age, 12.75 ± 2.02 years), recruited from a rural area in central

Pennsylvania, participated in the study. Subjects completed a questionnaire comprised of reported risk factors identified by the literature. Kinematic data were analyzed using marker-based VICON motion analysis.

RESULTS: Of the 24 participants, 63% (15/24) reported arm pain. A positive predictive value of 0.93 (14/15) was found between arm pain and poor stride length. Poor arm slot in relation to arm pain had a positive predictive value of 0.73 (11/15). The relationship of poor arm slot and/or poor stride length to arm pain yielded a positive predictive value of 0.93 (14/15). Poor arm slot and poor stride length had a positive predictive value of 1.0 (15/15).

CONCLUSIONS: The current study identified a relationship between poor stride length and arm pain, in addition to poor arm slot and poor stride length. Future studies should be performed in order to determine the exact relationship between these 3 variables.

CLINICAL RELEVANCE: The study suggests that stride length may be a more notable predictor of arm pain than arm slot. However, pitchers who report arm pain should be evaluated for a variety of biomechanical factors as a potential contributing cause to that pain.

SP095

NATURAL HISTORY OF HIP IMPINGEMENT: A PRELIMINARY ANALYSIS OF A POPULATION-BASED COHORT

Allison Marie Mumbleau, Rena Hale, Nathan Schilatay

PURPOSE/HYPOTHESIS: The number of hip arthroscopies (HA) performed in the United States increased nearly 6-fold from 2004 to 2009. HA addresses a constellation of pathologies, including femoroacetabular impingement syndrome (FAI). Recent advancements in clinical examination skills and diagnostic imaging have yielded a tremendous increase in the recognition of nonarthritic, intra-articular hip pathologies. Previous studies have studied epidemiologic and demographic data in patients with FAI presenting to tertiary care providers. Despite this, the current body is limited to few studies, none of which describe data in FAI patients presenting to all primary care providers. The purpose of this retrospective study was to summarize descriptive characteristics, including surgical treatments rates, rate of sports participants who undergo HA and the incidence of bilateral HA, in Olmsted County residents diagnosed with FAI (January 1, 2000 through December 31, 2016) who presented to primary care providers. To our knowledge, this study is the first to evaluate this information in FAI patients presenting to all primary care providers, rather than exclusively tertiary care providers. Identification of these values may allow for a clearer understanding of rates and characteristics of those who undergo HA.

NUMBER OF SUBJECTS: One thousand one hundred eighty-eight patients, aged 14 to 40 years, presenting to a primary care provider at Mayo Clinic with hip pain (January 1, 2000 through December 31, 2016).

MATERIALS AND METHODS: Using the resources of the Rochester Epidemiology Project, retrospective electronic medical record (EMR) review identified patients diagnosed with hip pain. These patients were then individually evaluated on radiograph to determine FAI diagnosis. Demographic, operative status, basic medical information, and treatment modalities were also collected. Descriptive statistics were performed on all patients diagnosed FAI.

RESULTS: In the cohort of patients diagnosed with FAI, 21% underwent HA. There was not a statistically significant ($P = .3332$) difference in surgical rate in those who did or did not complete physical therapy preoperatively. Of those who underwent HA, 60% defined themselves as sport participants, versus 51% of those who did not undergo HA. Eight percent of patients underwent staged, bilateral HAs.

CONCLUSIONS: Preliminary results suggest that 1 in 5 patients diagnosed with FAI who present to a primary care provider will convert to a HA. The presence or absence of preoperative physical therapy does not seem to significantly change the surgical rate in this cohort. Consistent with

previous literature, patients in this cohort who underwent HA were more likely to be active, in comparison to those who did not undergo HA. The number of patients requiring bilateral HA in this cohort was lower than previously reported when compared to patients presenting to a tertiary care provider.

CLINICAL RELEVANCE: At this time, specific epidemiologic and demographic information in patients presenting to a primary care provider with FAI is undefined in the literature. This knowledge may aid physical therapists in educating and counseling patients, setting expectations, and establishing efficient treatment and referral plans.

SP096

REASONS FOR NOT RETURNING TO PREINJURY LEVEL OF ACTIVITY AND SPORTS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: The rate of return to preinjury level of activity and sport (PLAS) after anterior cruciate ligament reconstruction (ACLR) is less than optimal. Reasons that explain the low rate of return to PLAS are not well determined. Mostly clinical measures related to functional-performance and patient-reported outcomes are used to determine patients' readiness and predict returning to PLAS. However, reasons for not returning to PLAS reported by patients and what factors predict the most common reasons reported by patients for not returning to PLAS after ACLR are not well studied. The purpose of this study was to determine the rate of return to PLAS, identify the most commonly reported reasons for not returning to PLAS, and determine predictors for the most commonly reported reasons for not returning to PLAS.

NUMBER OF SUBJECTS: One hundred twenty-seven patients 1 to 5 years after ACLR.

MATERIALS AND METHODS: Patients indicated their PLAS, knee injury profile (mechanism of injury, concomitant knee injuries), surgical factors (time from injury to surgery, harvested grafts), and knee giving way and second injuries after ACLR. Patients answered whether they have returned to the same frequency, duration, and intensity of PLAS. Patients also indicated the reasons for not returning to the PLAS, this includes problems in the reconstructed knee, lack of confidence or worried about sustaining reinjury, little time to participate in sport, and work or family obligations. Patients' characteristics, preinjury level of activity, injury profile, time from injury to surgery, surgical factors, duration of rehabilitation, and knee giving-way and second injuries after ACLR were evaluated by the univariate logistic regression to determine predictors of common reasons for not return to PLAS.

RESULTS: The rate of return to PLAS was 10% ($n = 13$) after ACLR. Seventy-three (68%) reported lack of confidence or worried about sustaining reinjury and 53 (49.5%) reported having problems in the reconstructed knee as reasons for not returning to PLAS, of which 48 (44.9%) and 35 (32.7%) indicated as primary or only reason respectively. Additionally, 30 (28%) patients reported little time to participate in sport and 26 (24.3%) reported work or family obligations as a reason for not return, of which 6 (5.6%) and 5 (4.7%) of them indicated as primary or only reason respectively. Knee giving way after ACLR was the only predictor of problems in the reconstructed knee (26/39, 66.7%; OR = 3.04; 95% CI: 1.32, 7.01; $P = .009$).

CONCLUSIONS: Lack of confidence or worried about sustaining reinjury and problems in the reconstructed were the most commonly reported reasons accounted for not returning to PLAS, followed by less time to devote for playing sport and work or family responsibilities. Experiencing dynamic knee instability has an association with concurrent impairments in the reconstructed knee.

CLINICAL RELEVANCE: Postsurgical rehabilitation intervention may address patients' psychological aspects and ensure resolving knee impairments and functional deficits to improve the rate of return to PLAS.

SP097

INCORPORATING A DUAL-TASK ASSESSMENT
PROTOCOL WITH FUNCTIONAL HOP TESTING

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PURPOSE/HYPOTHESIS: Hop tests assess several constructs important for return to sport after anterior cruciate ligament (ACL) injury, yet athletes still experience a high rate of reinjury. Simultaneous performance of a secondary task requiring cognitive processing may test the athlete under more realistic contexts. The purpose of this study was to examine a clinically feasible, dual-task assessment paradigm applied during functional hop tests in healthy individuals.

NUMBER OF SUBJECTS: Thirty-four healthy, physically active participants with past participation in organized cutting/jumping sports at the high school or college level(s) completed testing procedures.

MATERIALS AND METHODS: Participants performed the crossover triple hop for distance (XHOP) and medial triple hop for distance test (MHOP) under 3 separate conditions: standard procedures and 2 dual-task protocols including the backward digit span memory task and a visuospatial recognition task. The visuospatial task involved displaying an image consisting of 18 randomly placed red and blue circles on a screen, where the participant was asked to identify the number of red circles in each image. The backward digit span task was applied by introducing a sequence of random numbers to the participants, who were required to repeat the sequence in reverse order. Each motor and cognitive task was performed independently and simultaneously, in accordance with the dual-task paradigm.

RESULTS: No differences in hop distance were observed with the simultaneous application of a cognitive task, with the exception of the backward digit span memory task resulting in decreased hop distance ($P = .04$, $d = 0.14$). There were no differences in cognitive accuracy according to hop test type, although the effect size was greater for the XHOP ($P = .08$, $d = 0.49$) compared to the MHOP ($P = 1.0$, $d = 0.07$). The dual-task protocol revealed good-excellent within- ($ICC_{3,1} = 0.85-0.99$) and between-session ($ICC_{3,k} = 0.94-0.99$) intrarater reliability for hop distance across all dual-task conditions. The addition of a cognitive task to the XHOP and MHOP resulted in improved standard error of measurement and minimal detectable change, as compared to standard testing procedures.

CONCLUSIONS: The simultaneous application of a cognitive task did not alter hop distance, with the exception of the backward digit span memory task resulting in decreased hop distance with a trivial effect size. There were no differences in cognitive accuracy according to task type (sitting, XHOP, MHOP). All combinations of dual-task assessment demonstrated good-excellent within- and between-session intrarater reliability among healthy individuals, but measurement precision was deficient.

CLINICAL RELEVANCE: During single-leg hop testing among healthy individuals, hop distance was decreased with the addition of cognitive loading in one instance. Cognitive accuracy was generally maintained across 3 different dual-task conditions. Although this dual-task protocol demonstrated acceptable reliability, further exploration is warranted relative to its clinical utility.

SP098

CUBITAL TUNNEL SYNDROME IN A COLLEGIATE BASEBALL
ATHLETE AFTER ULNAR COLLATERAL LIGAMENT
RECONSTRUCTION AND ULNAR NERVE TRANSPOSITION

Luke James Novosel, Corbin Hedi

BACKGROUND AND PURPOSE: Cubital Tunnel Syndrome (CTS) is a compression-based neuropathy that can lead to sensory and motor deficits of the affected upper extremity. Aside from Carpal Tunnel Syndrome, CTS is the second most common neuropathy of the upper extremity and the most common neuropathy of the throwers' elbow. In mild-to-moderate case, conservative management is indicated, including: anti-inflammatories,

bracing/splinting, soft tissue/neural mobilization, and activity modifications. Transient paresthesia's may persist without severe compression or axonal loss.

CASE DESCRIPTION: A 20-year-old right hand-dominant male collegiate baseball pitcher with complaint of posterior elbow pain while throwing. Initial diagnosis/management provided by team trainers: 4 to 6 weeks of rest and physical therapy followed by a throwing program. Pain persisted when initiating throwing, except more medially—worse with higher velocities and during follow-through. Further examination eventually indicated large, grade III ulnar collateral ligament (UCL) tear, flexor-pronator strain, and exostosis of the sublime tubercle. The athlete underwent right UCL reconstruction, exostectomy, and ulnar nerve decompression. He attended physical therapy over 3 months with a multimodal approach including soft tissue mobilization, multiregional strengthening, mobility training, functional dry needling, and electrical stimulation. While strength and motion improved, the athlete continued to report numbness in his fourth and fifth finger and demonstrated reduced motor function. Continued complications lead to eventual ulnar nerve transposition and decompression. Physical therapy resumed following and successful outcomes were achieved.

OUTCOMES: Subjective improvement of 95% reported 23 weeks following ulnar nerve transposition. Interval testing of upper extremity strength and peripheral nerve function performed at 8, 12, and 22 weeks postop. Largest improvements in myotome/dermatome testing of C8 was shown from weeks 12 to 22, from 70% to 95%. Gross upper extremity strength was at 5/5 by week 22. Successful initiation of return to throwing at week 24. Full return planned for spring 2020.

DISCUSSION: This case presents a unique clinical situation that exemplifies the importance of interdisciplinary collaboration and communication regarding patient progress and complications. Current literature examining return to sport (RTS) following ulnar nerve decompression/transposition indicate that 62% are able to RTS but only 52% return to similar levels—likely due to residual complications. Furthermore, pitchers who undergo ulnar nerve modification experience more walks per 9 innings pitched versus individuals who only receive UCLr, alone. With this subject, many conservative treatment options were provided initially with relatively little to no improvement in function or symptoms. However, multidisciplinary communication lead to an appropriate diagnosis and intervention selection, which has provided the athlete with an eventual, positive outcome and successful preliminary RTS.

SP099

THE IMPORTANCE OF TRANSVERSE PLANE
FLEXIBILITY FOR PROFICIENCY IN GOLF

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Malachy P. McHugh, Stephen J. Nicholas*

PURPOSE/HYPOTHESIS: The purpose of this study was to assess musculoskeletal flexibility in the upper and lower extremities and spine in golfers. Since the golf swing is primarily a transverse plane motion, it was hypothesized that more proficient golfers would have greater flexibility in transverse plane motions compared to less proficient golfers.

NUMBER OF SUBJECTS: Twenty male amateur golfers were categorized as proficient (golf index = <6, $n = 8$) or average (golf index = 10-24, $n = 12$).

MATERIALS AND METHODS: Flexibility was assessed with 4 upper extremity range of motion (ROM) tests (shoulder flexion, internal rotation, external rotation, posterior shoulder), 3 spine ROM tests (toe touch, trunk lateral flexion, seated trunk rotation), and 6 lower extremity ROM tests (straight leg raise, Thomas test, Ober test, hip abduction, hip internal and external rotation). These 13 tests constituted 4 sagittal plane tests (shoulder flexion, toe touch, straight leg raise, Thomas test), 4 frontal plane tests (posterior shoulder, trunk lateral flexion, Ober test, hip abduction) and 5 transverse plane tests (shoulder internal and external rotation, seated trunk rotation, hip internal and external rotation). The effect of golf pro-

iciency on flexibility was assessed using independent-samples t tests for individual flexibility tests.

RESULTS: Proficient golfers were younger (27 ± 6 years versus 48 ± 16 years, $P = .001$) but did not differ in height ($P = .13$) or weight ($P = .43$). Of the 4 sagittal plane tests only shoulder flexion differed between groups, with proficient golfers having 11° greater motion. None of the 4 frontal plane tests differed between groups. All but 1 of the 5 transverse plane tests differed between groups ($P < .01$), with the proficient golfers having greater motion in hip external rotation (19°), hip internal rotation (14°), seated trunk rotation (24°), and shoulder internal rotation (16°). All between-group differences were apparent bilaterally.

CONCLUSIONS: Good transverse plane flexibility, particularly in the spine and hips appears to be a distinguishing characteristic of proficient golfers. Flexibility in the frontal and sagittal plane was unrelated to golf proficiency.

CLINICAL RELEVANCE: Standard assessments of functional movement in golfers typically do not emphasize transverse plane movements. This data highlights the importance of transverse plane flexibility for proficiency in golf.

SP0100

FACTORS ASSOCIATED WITH LEG-REACH ASYMMETRY DURING THE STAR EXCURSION BALANCE TEST IN DIVISION I ATHLETES

Santiago Ortega, Sergio Ibarra, Rebecca Pierce, Susan S. Levy, Sara Pauline Gombatto

PURPOSE/HYPOTHESIS: Asymmetry of leg reach distance ≥ 4 cm during select directions of the Star Excursion Balance Test (SEBT) has been associated with lower extremity injury risk in athletes. While past studies have evaluated differences in balance, movement, and reach distance during the SEBT in people with and without lower extremity injuries, the purpose of the current study was to determine whether balance, joint angles, and/or moments contribute most to reach distance asymmetry. Because the SEBT tests balance, we hypothesized that balance measures would significantly predict leg reach asymmetry in each direction, followed by movement factors.

NUMBER OF SUBJECTS: Thirty-six Division I athletes, aged 18 to 22 years (20 men's basketball, 16 women's volleyball).

MATERIALS AND METHODS: A motion capture system recorded lower extremity (hip, knee, and ankle) joint angles and moments, center of pressure (COP) measures, and reach distance during 3 directions of the SEBT (Anterior, Posterior-Medial [PM], and Posterior-Lateral [PL]). Reach distance asymmetry ≥ 4 cm was determined for each athlete (asymmetric, symmetric), in each direction. Bivariate correlations identified what measures were most related to reach distance ($r > 0.45$). Then, logistic regression analysis was conducted to determine what categories of measures (COP, joint angles, joint moments) predicted reach distance asymmetry in each direction of the SEBT.

RESULTS: For the anterior direction, COP measures approached significance in predicting asymmetry ($P < .08$), improving overall correct classification to 75%, from a null model's 58%. Specifically, 60% of asymmetric cases and 86% of symmetric cases were correctly classified using COP measures for the anterior direction. For the PL direction, joint angle measures approached significance in predicting asymmetry ($P < .06$), improving overall classification from 61% with the null model to 69%. Including joint angle measures, 50% of asymmetric cases and 82% of symmetric cases were correctly classified for the PL direction. For the PM direction, joint moment measures were significant predictors of asymmetry ($P < .03$), improving overall classification from 53% with the null model to 75%. Including joint moment measures, 79% of asymmetric cases and 71% of symmetric cases were correctly classified for the PM direction.

CONCLUSIONS: Balance, based on COP measures, appears to an important factor related to leg reach asymmetry in the anterior direction of the

SEBT, while joint angle and moment measures were most important for explaining reach asymmetry in the PL and PM directions of the SEBT, respectively. Future research on predictors of reach asymmetry during the SEBT, with a larger sample size, would allow for individual balance and movement measures to be explored further.

CLINICAL RELEVANCE: Findings suggest that different intervention strategies may be useful to improve leg reach asymmetry, depending on direction of the SEBT. Improving balance may be more important for the anterior direction, while controlling limb movements may be more important for the PM and PL directions.

SP0101

UTILIZING THE KINECTV2 TO IDENTIFY SEX DIFFERENCES IN JUMP-LANDING STRATEGIES AMONG ADOLESCENT BASKETBALL PLAYERS

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PURPOSE/HYPOTHESIS: As the incidence and prevalence of noncontact lower extremity injuries among adolescent female athletes rise, examining methods to enhance screening techniques informing targeted prevention programs is warranted. Unfortunately, traditional lab-based motion analysis systems identifying movements associated with elevated risk of injury, including increased dynamic knee valgus, are unable to perform large scale assessments due to high cost, limited efficiency, and lack of portability. As a result, interest in reliable, valid, and portable markerless motion-analysis systems such as the KinectV2 have grown, though studies using KinectV2 to monitor dynamic jump-landing strategies of individuals engaged in high-risk sports are limited. Therefore, the purpose of this study was to determine if KinectV2 can identify sex differences in the knee-ankle separation ratio (KASR) at initial contact (IC) and peak flexion (PF) during a drop-vertical jump (DVJ) among adolescent basketball players. We hypothesize KinectV2 will identify sex differences in KASR at IC and PF among adolescent basketball players.

NUMBER OF SUBJECTS: Forty-two.

MATERIALS AND METHODS: A total of 42 healthy individuals participated. Groups included female ($n = 25$; mean $\pm$ SD age, 16 ± 1.2 years; height, 66.8 ± 3.4 inches; weight, 137.4 ± 20.4 lb) and male ($n = 17$; age, 15.8 ± 1.7 years; height, 70.8 ± 3.8 inches; weight, 161.5 ± 28.7 lb) basketball players from 4 local high schools. Prior to recording, verbal instructions and demonstration of the DVJ were provided, using a 31-cm-high jump platform. Clients performed the DVJ by dropping to the ground, followed by an immediate maximal vertical jump as if catching a rebound. Following practice trials, 3 trials were recorded by a single KinectV2 utilizing custom software to determine the KASR at IC and PF of the DVJ. The KinectV2 was located 3 m in front of the client and 1 m off the floor. Knee to ankle separation ratio at IC and PF is interpreted as <1 indicating knee valgus and >1 signifying knee varus. A KASR of 1.0 represents the knee joint centers being directly above the ankle joint centers. To determine if sex differences existed between groups in the KASR at IC and PF, an independent-samples t test with Bonferroni correction was used with significance accepted at $P < .025$.

RESULTS: Adolescent female basketball players displayed a lower KASR at IC (female, 0.98 ± 0.16 ; male, 1.13 ± 0.18 ; $P < .01$) and PF (female, 1.02 ± 0.19 ; male, 1.25 ± 0.28 ; $P < .01$) during the DVJ compared to males.

CONCLUSIONS: KinectV2 is capable of identifying sex differences in jump-landing strategies among high-risk adolescent basketball players, with females demonstrating increased knee valgus as compared to males. Future investigations examining KASR's relative risk ratio within high-risk groups is warranted.

CLINICAL RELEVANCE: KinectV2 offers a portable, valid, affordable and efficient method to assess altered dynamic jump-landing strategies associated with increased risk of noncontact lower extremity injury.

SP0102

EVIDENCE-BASED CLASSIFICATION FOR POWER WHEELCHAIR SOCCER

Casey Pherson, Justin Currin, Mackenzie Marie Maison, Blake Logan Bohanan, Brittany Saetre, Anna Szpalik, J.P. Barfield

PURPOSE/HYPOTHESIS: The International Paralympic Committee (IPC) requires that adaptive sports wishing to participate in the Paralympic Games have an objective, evidence-based system of athlete classification. Currently, power wheelchair soccer is not included in the Paralympic games as the sport lacks this objective, evidence-based classification system for its athletes. To this end, the purposes of this study were to: (1) identify determinants of sport performance in power wheelchair soccer, and (2) examine tests of impairment and performance for their ability to distinguish functional ability in power wheelchair soccer athletes.

NUMBER OF SUBJECTS: Forty-four coaches, classifiers, and athletes participated to determine factors significant to sport performance. An additional 50 power soccer athletes completed tests of impairment and/or sport performance. Participants who completed physical assessments averaged 26 ± 13 years of age, reported 9 ± 6 years of playing experience, and included persons with a variety of impairments including cerebral palsy ($n = 10$), muscular dystrophy ($n = 7$), spina bifida ($n = 4$), spinal cord injury ($n = 5$), spinal muscular atrophy ($n = 17$), traumatic brain injury ($n = 2$), and other physical impairments ($n = 5$).

MATERIALS AND METHODS: To address purpose 1, coaches, classifiers, and athletes were recruited through online recruitment. These individuals were given 3 weeks to complete a survey developed to meet IPC recommendations for identifying sport determinants. Specifically, the survey enabled sport stakeholders to qualitatively and quantitatively indicate the most important factors to power wheelchair soccer participation. Based on survey results, researchers selected tests of impairment and performance that best reflected constructs identified in the survey. The research team then traveled to 2 tournament sites and assessed power soccer athletes on ten tests of physical impairment and 4 tests of sport performance. Tests of impairment included active cervical range of motion (left and right), passive cervical range of motion (left and right), active trunk range of motion (left and right), Functional Dexterity Test, gross grip strength (bilateral), and pinch-grip strength (bilateral), and the Short Blessed Test (cognitive function). Tests of sport performance included forward slalom, backward slalom, reverse spin kick from the left, and reverse spin-kick from the right. To analyze tests' abilities to distinguish among players, data histograms were analyzed to determine natural cut points between higher functioning and lower functioning players.

RESULTS: The results of the survey revealed that cervical rotation, trunk rotation, cognition sufficient to effectively communicate, comfort with navigating the chair, visual tracking, and the ability to spin kick were considered to be most important in order to actively participate in powerchair soccer. Four tests of impairment demonstrated the clearest breaks in data and included the functional dexterity test (total pegs), the time it took to complete the functional dexterity test, active trunk rotation to the right, and passive cervical rotation to the left. The 2 performance tests with the clearest breaks in data were the time it took to perform the backward slalom and the distance from the goal point after performing a reverse spin-kick from the right side.

CONCLUSIONS: Data demonstrated that clear distinctions in athlete abilities can be made using certain tests of both impairment and performance. Validating these objective measures are the first step to developing IPC-mandated evidence-based classification for power wheelchair soccer and are consistent with current initiatives underway in other sports to meet IPC requirements.

CLINICAL RELEVANCE: Currently, the governing body for power wheelchair sport primarily uses subjective measures for manual muscle testing which are not recommended by IPC. The current study completes year 1 of a 4-year project to develop and validate an evidence-based sport classifica-

tion model for power wheelchair soccer, a current Paralympic sport but one yet to be included in the Paralympic Games.

SP0103

ENERGY TRANSFER IN MECHANICALLY LINKED TRAMPOLINE SYSTEMS: INJURY POTENTIAL

Peter Eric Pidcoe, Edward Nyman

PURPOSE: The purpose of this project was to highlight the risk associated with the use of interconnected trampoline systems (ie, trampoline parks) secondary to mechanical energy transfer, stiffness variations, and the associated proprioceptive changes.

DESCRIPTION: Inertial Measurement Units (IMUs) were used to systematically measure trampoline performance and energy transfer characteristics differences between trampoline park (PARK) and gymnastics (GYM) trampolines. A rotating impact hammer with a smooth convex surface approximating the surface area of an average sized jumper's feet was used to provide consistent impulse loads to the trampoline surface. After release, the head was allowed to oscillate until extinction. These impulse loads were delivered to the trampoline surface at centrally located and off-center locations. The coefficient of restitution (COR) of the collision was calculated from angular velocity data. Damping was evaluated by fitting an exponential function to the peaks of the acceleration magnitude as the trampoline bed returned to baseline. Independent t tests were utilized to evaluate the differences between trampoline types with equal sample variances assumed ($P \leq .05$). In addition to mechanical characteristics, the effect of a "double-bouncing" technique and energy transfer from adjacent trampolines was assessed.

SUMMARY OF USE: Energy return: with respect to impact location, PARK center and off-center impacts yielded statistically different CORs. No difference between locations was delineated for GYM data. PARK and GYM energy return values were also statistically different from each other. Damping: with respect to impact location, PARK center and off-center impacts were not statistically different. There was also no difference in the GYM data. However, PARK and GYM damping were statistically different from each other, with the PARK system damping more quickly. Double-bouncing effect: modeled data suggest that a slight temporal delay between 2 jumpers making contact with the trampoline bed can result in energy transfers from the first jumper to make trampoline contact to the other jumper with magnitudes near 500 lb-f and at rates in excess of 2000 lb-f/s. These loads are sufficient to fracture bone. Between-trampoline energy transfer: in the PARK configuration, a trampoline bed can be impacted by jumping activity on adjacent trampolines. This energy transfer is greatest in configurations with the largest common perimeter and can reach a magnitude as high as 37%. This can result in bed displacements that adversely impact proprioceptive cues to the adjacent surface jumper.

IMPORTANCE TO MEMBERS: Trampoline parks are commonly advertised as safe and effective tools for exercise, weight loss, and recreation. This report highlights the inherent risk of trampoline PARK designs secondary to interaction between the multiple linked trampolines. This design results in unpredictable bed performance such that a jumper cannot rely on the consistency of sequential bounces to predict future actions. Any planned aerial activity (from simple jumps to higher energy rotational skills) would be subject to performance degradation secondary to a change in the position or energy return characteristics of the bed. The said effect increases the risk of injury to all jumpers participating upon this system and is compounded as the number of participants on the trampolines increases.

SP0104

VALIDITY OF LOWER EXTREMITY POSTURAL SWAY FOR BASELINE CONCUSSION TESTING

Marisa Luisa Pontillo, Shawn Hines, Brian Sennett

PURPOSE/HYPOTHESIS: Clinical tests such as the Balance Error Scoring System (BESS) and King-Devick (KD) are utilized frequently in the athletic population for baseline testing, and additionally as return to play criteria. However, the sensitivity of the BESS has been questioned, as the distribution of scores for an uninjured population demonstrates a floor effect, and substantial interrater variability exists. Biomechanical testing is able to detect smaller magnitudes of change, but has not been validated against these clinical tests. The purpose of this study was to determine the distribution of lower extremity postural sway variables in the athletic population, and to determine the relationship between clinical and biomechanical baseline concussion testing.

NUMBER OF SUBJECTS: Ninety-six healthy Division I collegiate athletes (41 female).

MATERIALS AND METHODS: Biomechanical testing consisted of single-leg stance, performed blindfolded, for two 20-second trials each lower extremity, on a force plate system connected to a dedicated computer with commercially available software (SpartaTrac). Center of pressure data were quantified by velocity and frequency of motion (lower extremity (LE) sway) and converted to T score, with a higher T score indicating better stability (decreased sway). Data were averaged across the 2 trials by side (left, right). Baseline concussion testing (BESS and KD) were obtained from the athletes' files. The BESS involves 3 stances (double-legged, single-legged, and tandem) and 2 surfaces (firm and foam); the score is the number of operationally defined errors, with a lower score indicating better balance. The KD test is an assessment of rapid number naming which requires the athletes to quickly read a series of numbers on 3 test cards, with a higher score indicating better performance (faster speed). Two trials were performed, and the average of the trials was used for statistical analysis. Statistical Analysis: descriptive statistics assessed if the data were normally distributed. *t* tests were used to determine if differences existed between sides for biomechanical testing (left versus right). Spearman's rho correlations were used to determine the relationship between clinical and biomechanical test variables. Significance was set to $P = .05$.

RESULTS: LE sway and KD was normally distributed; BESS showed a floor effect. No difference was seen between left and right lower extremities for biomechanical testing ($P > .05$). LE sway was significantly correlated to BESS test subsections (single-leg stance, foam: $\rho = -0.30$; 95% CI: $-0.47, -0.11$ and foam total score: $\rho = -0.30$; 95% CI: $-0.47, -0.11$), BESS total score ($\rho = -0.31$; 95% CI: $-0.48, -0.12$), and KD average ($\rho = -0.38$; 95% CI: $-0.54, -0.19$). All correlations were medium in magnitude.

CONCLUSIONS: The lower extremity sway scores demonstrate validity when compared to clinical concussion tests.

CLINICAL RELEVANCE: The distribution of sway scores in the athletic population indicates that this test may be better suited to detecting subtle differences in changes, and overcomes the limitations of the conventional clinical evaluations.

SP0105

SPINAL BIOMECHANICS AND BACK PAIN AMONG FEMALE GYMNASTS DURING EXTENSION-BASED SKILLS: A FEASIBILITY STUDY

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PURPOSE/HYPOTHESIS: Back pain is a common complaint among female adolescent gymnasts. The etiology in gymnasts is considered to be multifactorial, with rapid growth spurts, maturation, and training volume contributing to pain. Due to the high volume and extreme spinal motions required by gymnastics, quantification of movements patterns may help to better understand back pain development. Our purpose was to compare the spinal movement patterns during basic extension skills among gymnasts with and without a history of back pain. We sought to evaluate these movements in the native gym environment using wearable sensors. We hypothesized that female youth gymnasts with a recent back pain would

have larger spinal range of motion (ROM) during a back walkover (BWO) and back handspring (BHS) compared to gymnasts without back pain.

NUMBER OF SUBJECTS: Seventeen.

MATERIALS AND METHODS: Female gymnasts between 8 and 18 years old from local clubs were recruited. We divided gymnasts into 2 groups: those having back pain within the past 12 months and those without history of back pain. Gymnasts performed 3 repetitions of BWO and BHS on floor and balance beam while wearing a set of wearable sensors (Opal V2, APDM Inc). A BWO requires a controlled bridge with a kickover, while a BHS requires the athlete to jump backwards to their hands and then do a kickover. Both are considered to be foundational skills. Spine kinematics were then processed via Moveo Explorer. Valid spine sagittal plane maximums, minimums, and ROM of each skill repetition were compared between groups via Kruskal-Wallis analysis of variance.

RESULTS: Seventeen participants (6 with back pain) completed BWOs and BHSs with acceptable sensor data. There were no demographic differences between the 2 groups for age (back pain, 13.9 ± 2.6 years; no back pain, 13.3 ± 1.7 years), height (149.3 ± 18.9 cm; 147.1 ± 4.7 cm), weight (37.1 ± 9.5 kg; 37.2 ± 3.6 kg), or years of experience (10.5 ± 3.4 years; 9.3 ± 2.6 years). During BWO skills, gymnasts in the back pain group had greater peak extension ($45.0^\circ \pm 15.4^\circ$; $34.6^\circ \pm 7.1^\circ$; $P = .011$) and greater ROM in the sagittal plane of the spine ($94.6^\circ \pm 18.9^\circ$; $80.9^\circ \pm 19.6^\circ$; $P = .032$). There were no differences between groups in peak extension, peak flexion, or ROM during BHS skills ($P \geq .054$).

CONCLUSIONS: The findings of our study indicate that adolescent female gymnasts with a 12-month history of back pain have significantly higher spinal ROM and peak extension during BWO compared to gymnasts without pain. While still preliminary, our findings illustrate the feasibility of collecting sensory data using wearable sensors in a native gymnastics environment. More research is needed to further delineate the relationship between joint hypermobility and back pain, as well as ground reaction forces during these skills.

CLINICAL RELEVANCE: This study highlights the relationship between increased ROM and back pain among gymnasts. When treating this athlete population, clinicians should be aware of the potentially abnormal movement patterns during extension-based skills, especially among those returning to sport after back pain or injury.

SP0106

CORRELATION OF MAXIMAL DORSIFLEXION AND WEIGHT DISTRIBUTION WITH DEEP-SQUAT ABILITIES IN COLLEGE DANCERS

Alisa Raniuk, Nathan Stover, Brittney Logan Herrick, Eric Daniel Bevers, Mackenzie Rhodes, Cheryl A. Coker, Eydie A. Kendall

PURPOSE/HYPOTHESIS: Dancers spend a great deal of time in the plié position. Extreme ankle dorsiflexion is necessary for this position and serves as the foundation for efficient production of force for jumping and absorbing impact for landing. Maintaining heel contact with the ground can be difficult when limited dorsiflexion movement causes the center of mass to move outside of the base of support, unless other compensatory movements occur. The Deep Squat (DS) of the Function Movement Screen (FMS) mimics a plié. The purpose of this study was to examine the relationship between maximal ankle dorsiflexion angle along with typical weight distribution of dancers and compare these with FMS DS scores.

NUMBER OF SUBJECTS: One hundred eleven female participants in the American College Dance Association, New England Conference, 2019 (mean age, 20.88 years; average dance experience, 14.9 years).

MATERIALS AND METHODS: One hundred eleven female collegiate dancers (mean $\pm$ SD age, 20.88 ± 2.51 years; time dancing, 14.9 ± 5.19 years), performed the FMS via rotating stations. Markers were placed on the base of the fifth metatarsal, lateral malleolus, and fibular head of each dancer. Ankle and knee joint angles were captured using an iPad to video the movement. The frame with the maximum angle was identified and the

angle was measured using Dartfish software. A Fit3D Proscanner was used to determine weight distribution in standing, and recorded as percentage of weight within 4 quadrants (right/left, back/front). Correlations were determined using Spearman's rank-order correlation.

RESULTS: The mean DS score was 2.05. The mean maximum dorsiflexion value was 10.8, the minimum 0.00, and the maximum 29.6; 17.86% of participants scored a 3 (were functionally proficient) in the DS. There was a significant positive relationship between maximal dorsiflexion angle and the FMS DS score. Participants who scored less than a 3 on the DS favored 1 leg during normal stance more than those who scored a 3. Preferred weight distribution on the right inversely correlated with DS scores.

CONCLUSIONS: Limited dorsiflexion range of motion and unequal weight distribution negatively impact DS FMS score, and a dancer's ability to perform a plié. Given the limited number of dancers who scored a 3, there is a high incidence of dysfunction in this item and compensatory movements are necessary to perform the task, putting dancers at risk for injury. The relationship between these variables suggest that dancers could benefit from work on improving ankle range of motion and correcting asymmetries during stance.

CLINICAL RELEVANCE: Rehabilitation of ankle injuries is common in physical therapy practice and ankle injuries are one of the most common types of injuries seen in the dance population. Understanding the relationship between screen items such as the deep squat and body structure and function limitations such as range of motion deficits and asymmetries, can better inform preventative and restorative strategies used with dancers.

SP0107

REHABILITATION OF A FLEXOR HALLUCIS LONGUS REPAIR IN A DIVISION I FEMALE VOLLEYBALL PLAYER

Julia Laura Rapicavoli, Simona Latino, Jeffrey Thomas Ruiz, Jessica Nichole Hiestand, Vincent Scavo, Luis Alejandro Feigenbaum

BACKGROUND AND PURPOSE: Posterior Ankle Impingement Syndrome (PAIS) is caused by pathology of the soft tissue and/or osseous structures of the hindfoot. PAIS can be a debilitating injury for any athlete, especially those who must perform repetitive and/or forceful plantarflexion in order to meet the demands of their sport. To date, there have been no published studies documenting the rehabilitation of surgical intervention for PAIS. The purpose of this study is to describe the rehabilitation of a Division I volleyball athlete who underwent surgical intervention for PAIS, specifically an open flexor hallucis longus (FHL) repair and os trigonum removal.

CASE DESCRIPTION: A 19-year-old female volleyball player underwent surgical intervention for PAIS following years of posterior ankle pain that was exacerbated by running or jumping. During arthroscopic investigation, it was noted that her FHL tendon was significantly torn and frayed and subsequent open repair of the tendon was indicated. Postoperative restrictions included no resistive toe flexion or combined weight bearing dorsiflexion and toe extension for 8 weeks. Standard clinical measures, as well as self-reported outcomes using the FADI, were assessed immediately postoperatively and every 3 weeks thereafter until normal values were achieved. The frequency of physical therapy sessions was 5 times a week. Her rehabilitation consisted of neuromuscular re-education, proprioceptive training, general core and lower extremity strengthening, and blood flow restriction therapy (BFR).

OUTCOMES: The athlete had a successful return to sport. Beginning at week 3 postoperatively, she completed BFR training 3 times/wk targeting inversion, plantarflexion, and great toe flexion strength. At postop week 20, we conducted limb symmetry indices including the Square Hop Test, Figure-of-eight Hop Test, and Side Hop Test, which demonstrated less than or equal to 10% deficit of the involved limb. At this point, she was cleared to return to volleyball practice with restrictions on total ground contacts. The athlete was then cleared for full sport participation at 22

weeks postoperatively. She continued to rehabilitate 2 to 3 times a week at this point to work on power of the involved extremity. At 26 weeks postoperatively, the athlete achieved full symmetry with hop testing and was formally discharged from physical therapy.

DISCUSSION: This case was particularly unique considering the lack of literature regarding this surgical procedure and its postoperative protocol. The use of blood flow restriction therapy during early phases of rehab allowed for hypertrophy of lower-leg muscles without using heavy resistance. Additionally, alternate ways of gastrocnemius/soleus strengthening were implemented to avoid combined motions of dorsiflexion and toe extension in weight bearing. Emphasis was placed on motor control and endurance of the foot intrinsic to allow for neutral foot posture during dynamic sport activities.

SP0108

EFFECT OF CONCUSSION ON REACTION TIME AND NEUROCOGNITIVE FACTORS: IMPLICATIONS FOR SUBSEQUENT LOWER EXTREMITY INJURY

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PURPOSE/HYPOTHESIS: Recent evidence has demonstrated that athletes are at greater risk for a lower extremity injury following a return to sport (RTS) after concussion. The reason for this is not completely clear, but it has been hypothesized that persistent deficits in neurocognitive factors may be a contributing factor. These potential deficits may result in slower reaction time, processing speed, and verbal and visual memory. Ultimately, these changes may predispose an athlete to a musculoskeletal injury upon RTS. This study assessed simple reaction time, processing speed, and verbal and visual memory in a group of athletes, postconcussion upon clearance for RTS. We hypothesized that the concussion group would demonstrate worse scores on both assessments compared to a sex-, age-, and sport-matched cohort.

NUMBER OF SUBJECTS: Twelve subjects (mean $\pm$ SD age, 16.1 ± 1.4 years; height, 172.3 ± 11.3 cm; weight, 65.7 ± 15.3 kg) who had suffered a sports-related concussion and 8 healthy individuals (age, 16.5 ± 2.1 years; height, 172.2 ± 10.9 cm; weight, 67.9 ± 15.4 kg) who were matched to the concussed group by age, sex, and sport.

MATERIALS AND METHODS: Concussion subjects were recruited through the university's concussion clinic and had been cleared for RTS (60.58 ± 53.95 days following concussion) by a licensed healthcare provider. Subjects played a range of sports including soccer and football. Each subject underwent neurocognitive tests that included a simple reaction time test (SRT) and King-Devick test (K-D). The K-D is a rapid number naming assessment that assesses saccadic eye movements, attention, and language. The test involved the subject reading aloud single digit numbers from left to right, like reading a book, on 3 progressively more difficult test cards as quickly as possible with minimal error. This test was repeated a second time and an average of the 2 trials was calculated. The SRT used a rubber disc with a wooden rod attached. The disc was dropped and the subject was instructed to catch the rod as quickly as possible. The reaction time was scored as the distance between the disc and lowest part of the hand on the rod. A total of 8 trials were collected and scores averaged. Independent *t* tests were performed to compare the groups with significance set a priori at $P < .05$.

RESULTS: There was a significant difference ($P = .024$) between groups for SRT with the concussed group (14.6 ± 4.2 cm) demonstrating a better SRT than the control group (18.7 ± 2.5 cm). There were no significant differences ($P = .670$) between the groups for the K-D (concussed, 46.7 ± 18.2 seconds; healthy, 43.8 ± 6.6 seconds).

CONCLUSIONS: With no significant differences between groups in the K-D assessment and, surprisingly, the concussed group having a better SRT compared to the healthy group, our hypothesis was not support-

ed. Moreover, these specific measures do not reveal potential persistent deficits in neurocognitive characteristics that may place an individual at greater risk for MSK injury following RTS.

CLINICAL RELEVANCE: The unexpected better SRT scores in the concussed group may be due to biased sampling in the small cohorts. And the lack of differences between the 2 groups in K-D scores may be attributable to the extensive time between concussion and RTS. Accordingly, it is premature for clinicians to assume no greater risk for MSK injury following a concussion.

SP0109

THE EFFECT OF AGE AND CONCOMITANT SURGERY ON STRENGTH IN ADOLESCENT ATHLETES POST QUADRICEPS TENDON ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Knee extensor strength deficits occur after ACL reconstruction (ACLR). Studies have reported that patients >18 years old have a decreased extensor deficit compared to those <18 years old. However, deficits in relation to age have not been assessed among adolescents. Additionally, knee extensor strength may not be associated with meniscal pathology post-ACLR. Isokinetic dynamometric strength testing is frequently used to assess strength postoperatively in order to identify these deficits. Our first purpose was to examine the effect of age on isokinetic extensor and flexor deficits among adolescents post-ACLR. We hypothesized age would be inversely related to extensor strength deficits. Our second purpose was to compare the effect of concomitant meniscal surgery on extensor or flexor strength deficits in adolescents post-ACLR. We hypothesized concomitant meniscus surgery would be associated with greater deficits in flexor and extensor strength.

NUMBER OF SUBJECTS: Forty-four participants aged 14 to 18 years at time of surgery who underwent isokinetic testing within 5 to 10 months of primary quadriceps tendon ACLR before returning to sport.

MATERIALS AND METHODS: Peak torque was assessed at 60°/s, 180°/s, and 300°/s, through a limited range of knee extension and flexion. Our primary outcome variables were peak torque percent deficit of involved leg compared to uninjured leg for flexion and extension. We constructed a series of multivariable regression models, where age was the independent variable, peak torque flexor/extensor deficits at each testing speed was the dependent variable, and sex and weight were covariates. We compared peak torque extensor and flexor deficits between those with and without concomitant meniscus surgery using independent-samples *t* tests.

RESULTS: There were no significant demographic differences between those with and without concomitant meniscus surgery. The relationship between age at time of surgery and peak torque extensor deficits at 300°/s demonstrated a linear but nonsignificant association ($\beta = 2.98$; 95% CI: $-0.21, -6.16$; $P = .06$). For every year increase in age, the expected deficit at 300°/s increased by approximately 3% ($r = 0.24$). Patients who underwent isolated ACLR demonstrated significantly greater flexor deficits than those who underwent ACLR with concomitant meniscus surgery when tested at 180°/s (-3.7 ± 14.1 versus 5.2 ± 9.9 , $P = .02$) and 300°/s (-6.4 ± 15.1 versus 6.8 ± 17.5 , $P = .01$).

CONCLUSIONS: Contrary to our first hypothesis, we observed a steady increase in strength deficit at 300°/s associated with increasing age. Contrary to our second hypothesis, no significant differences were found in extensor strength between those with and without meniscus surgery. Additionally, those with concomitant meniscus surgery demonstrated significantly less flexor deficit than those without meniscus surgery.

CLINICAL RELEVANCE: Age and concomitant meniscal surgery may influence strength in adolescents post-ACLR. These findings can be considered when developing strength-based rehabilitation programs for patients recovering from ACLR.

SP0110

RELATIONSHIPS BETWEEN WRIST AND HAND ANTHROPOMETRIC MEASURES AND INJURY RISK AMONG RECREATIONAL ROCK CLIMBERS

Oliver Cereno Rivera, Elizabeth Gray, Adam Wielechowski, Prakash Jayabalan, Erin E. Reagan

PURPOSE/HYPOTHESIS: The sport of rock climbing has gained recent popularity and has shown a high incidence of wrist and hand injury. Recent studies have shown the incidence and risk of injuries in the upper extremity, as well as tissue adaptations that can occur. Currently, there is limited research regarding injury predictors related to wrist and hand anthropometric measures. The purpose of the study is to determine if there is a relationship between wrist and hand anthropometric measures and injury risk among rock climbers. We hypothesize that ape index (wing span/height), wrist flexion to extension strength ratio, and finger length to width ratio will demonstrate a relationship to wrist and hand injury in rock climbers.

NUMBER OF SUBJECTS: Ninety-eight.

MATERIALS AND METHODS: Ninety-eight subjects were recruited between 2 local climbing gyms. Subjects were surveyed on demographics (gender, age, height, weight, hand dominance), climbing experience (years), climbing frequency (sessions per week), ability (beginner, novice, intermediate, expert), climbing type (boulder, top rope, sport) and history of rock climbing related wrist and hand injury occurrence. Subjects then underwent dynamometry assessment for grip strength, isometric wrist flexion and wrist extension strength. Measurements were taken utilizing a tape measure for wing-span and finger length and width. All objective measures were performed by 1 physical therapist utilizing the same procedure for all subjects.

RESULTS: Data analysis was performed comparing the injured and non-injured subjects utilizing a Wilcoxon rank-sum test for ape index, and a mixed effects model with a random intercept for both wrist flexion to extension strength ratio and finger length to width ratio. Ape index ($P = .54$), wrist flexion-to-extension strength ratio ($P = .85$), and finger length to width ratio ($P = .38$) did not have a significant relationship ($P < .05$) with wrist and hand injury in the rock climbing population sampled. Covariates including weight, hand dominance, laterality of injury, gender, and age were considered within each analysis, however none demonstrated a significant relationship ($P < .05$) with wrist and hand injury in the rock climbing population sampled.

CONCLUSIONS: The findings of this study demonstrated no differences between the anthropometric measures taken between the injured and non-injured subjects. Specifically, ape index, wrist flexion to extension strength ratio, and finger length to width ratio demonstrated no relationship with wrist and hand injury among a sample of rock climbers.

CLINICAL RELEVANCE: This study demonstrates the nonimpact of certain anthropometric and objective measures on wrist and hand injuries in a rock climbing population. Future efforts should examine the effects of guided rock climbing training progressions on incidence of wrist and hand injury.

SP0111

EFFECTS OF OPEN-KINETIC-CHAIN VERSUS CLOSED-KINETIC-CHAIN ACCESSORY LIFTS ON LOWER EXTREMITY STRENGTH

Benjamin Matthew Rogozinski, Trisha M. Kesar, Kyle Buckham, Ryan Gehr, Sam Fitzalan Geisslinger, Elizabeth Sloan Scovil

PURPOSE/HYPOTHESIS: The purpose of the present study was to determine if the type of lower extremity (LE) accessory exercise performed in a resistance training program elicited significantly different improvements in LE strength and power. We hypothesized that both the closed kinetic chain (CKC) group and open kinetic chain (OKC) group would display significant improvements in LE strength and power; the CKC group would show significantly greater improvements in the squat, deadlift, broad jump, and unilateral triple hop test; there would be no difference in improvement between groups in isometric LE strength.

NUMBER OF SUBJECTS: Twenty-seven.

MATERIALS AND METHODS: Twenty-seven recreationally trained participants were randomly assigned to 2 training groups (OKC, $n = 13$ and CKC, $n = 14$). Each participant underwent testing to determine their squat 1RM, deadlift 1RM, bench press 1RM, unilateral triple hop distance, broad jump distance, and isometric strength of the knee. The 7-week program consisted of a 3-day-a-week upper- and lower-body split design where both groups performed core lifts consisting of the barbell squat, deadlift, and bench press. For accessory exercises, the CKC group performed only CKC LE accessory exercises and the OKC group performed only OKC LE accessory exercises.

RESULTS: Significant improvements ($P < .05$) were seen in the squat, deadlift, bench press, unilateral triple hop test, and broad jump for all participants. Significant improvements in isometric strength were only seen in the OKC group. When compared to the CKC group, the OKC group demonstrated significantly greater improvements in the squat, broad jump, and isometric knee flexion strength.

CONCLUSIONS: The results indicate that both OKC and CKC LE accessory exercises are effective methods to build strength and power in recreationally trained individuals when combined with concurrent training of core lifts. OKC LE accessory exercises may be superior to CKC exercises for building strength and power during a short-term resistance training protocol.

CLINICAL RELEVANCE: Despite the current paradigm shift in favor of CKC exercises, fitness professionals should consider incorporating LE OKC exercises into resistance training programs, especially at the beginning of a new program. Additionally, rehab professionals should consider the incorporation of high intensity LE OKC resistance training to build strength in areas of isolated muscle weakness.

SP0112

COMPARISON OF SPORTS-RELATED CONCUSSION EPISODES BEFORE AND AFTER LEGISLATIVE CHANGES

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PURPOSE/HYPOTHESIS: Sport-related concussion has had a strong focus of attention for at least the past 10 years. Reports of athletes at all levels of sport dealing with significant residual neurological symptoms following 1 or more concussion events has led to legislation in virtually every state to address this diagnosis for better prevention and care. In May 2009 Washington State become the first state to require removal and clearance for return to play in youth athletes. Over the next 6 years all states and the District of Columbia would adopt some form of youth sports concussion legislation. North Dakota passed its concussion legislation in April 2011. Legislative efforts have focused on education among coaches, athletes, and parents, and more required involvement by healthcare professionals in the care of sport-related concussion after injury. This study compares the concussion rates among youth involved in sports and recreation activities reporting to a regional emergency department in North Dakota during the 4-year span 2001-2004 to a similar time span 10 years later, 2011-2014. Our hypothesis is that there would be an increase in the incidence of concussion among youth in the later time frame following the passage of the sport concussion law as heightened awareness became more evident among healthcare professionals and the general public with the advent of legislation and media coverage of sport-related concussion.

NUMBER OF SUBJECTS: Two hundred forty-two.

MATERIALS AND METHODS: Electronic medical records at a regional health care facility were accessed to identify those youth (aged 0-19 years) who were diagnosed in the emergency department with a concussion following a sports or recreational activity during the years 2001-2004 and 2011-2014. Other demographic data, such as gender, age, sport, and year of injury were also examined. An unpaired t test was applied to the concussion diagnoses made each year of each time period. An alpha level of .05 was used to determine statistical significance.

RESULTS: A 60% increase ($P = .003$) in diagnosed concussions was seen comparing the 2001-2004 time span (93 concussions) to 2011-2014 (149 concussions). Gender splits were male (82) and female (11) in 2001-2004 and male (111) and female (38) in 2011-2014, with ratios of 13.4 female: male in 2001-2004 and 34.2 in 2011-2014, respectively. The top 4 activities generating concussion in decreasing order in 2001-2004 were bicycle, football, hockey, and playground activities. For 2011-2014 injury prevalence order was miscellaneous sports, hockey, football, and baseball/softball.

CONCLUSIONS: As anticipated, incidence of sport-related concussion at the emergency department of 1 regional hospital in North Dakota increased significantly during the 4-year period 2011-2014 as compared to a similar period 10 years earlier. This would coincide with the increased media coverage and state legislature addressing the issue of safety in the context of sport-related concussion. We also saw a higher percentage of female to male concussions reported during the latter 4-year span but aren't able to account for that increase beyond speculation.

CLINICAL RELEVANCE: We were not surprised that the incidence of concussion rose in the later 4-year period examined. However, we also know that not all athletes with sport-related concussions would be represented in the emergency department records, with some athletes being managed by other health care providers. It is also known that stricter return to play criteria with new legislation and newer research has led to underreporting by athletes who want to continue play despite the risk. These results indicate that education and government influence can make a difference in safety measures applied to sports and recreation activities.

SP0113

DIAGNOSTIC ULTRASOUND OF TRANSVERSE ABDOMINIS WITH THE DOUBLE-LIMB LOWERING TEST

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PURPOSE/HYPOTHESIS: Core musculature is responsible for lumbopelvic stabilization during static posture and dynamic activity, however variations in the literature exist regarding the best way to assess core strength. The Double-Limb Lowering Test (DLLT) is used to quantify core strength by assessing the ability to maintain the correct position of pelvis during leg lowering. The purpose was to compare the (1) thickness of the transverse abdominus (TrA) through diagnostic ultrasound (DUS) during DLLT, (2) activity level to TrA strength via DLLT, and (3) TrA strength and DLLT to gender/BMI.

NUMBER OF SUBJECTS: Sixty-seven subjects local university students (convenience sample).

MATERIALS AND METHODS: Prior to testing, subjects completed an informed consent form, a health/activity history form and blood pressure assessment. The maximal volitional isometric contraction (MVIC) was assessed with hips/knees flexed to 90° resisting against 2 MicroFet dynamometers stabilized against a parallel bar. DUS measured TrA thickness during the first of 3 MVIC trials with a 30-second rest between trials. Then, a blood pressure cuff (40 mmHg) was used to assess failure point of abdominal muscles strength during the DLLT, while DUS images were recorded every 15° and at failure point (less than 40 mmHg). The angle was recorded using an inclinometer attached to the ankle and an angle board. Descriptive statistics were used to determine means. Pearson correlations were used to determine the relationship between the normalized DLLT data for MVIC recorded and the thickness of the TrA, gender, activity level and normalized TrA thickness during the DLLT.

RESULTS: Forty-three females and 24 males participated, with a mean $\pm$ SD age of 22.4 ± 2.3 years, mean BMI of 24.5 ± 3.1 kg/m², DLLT mean angle of failure of $31.0^\circ \pm 20.70^\circ$. No significant correlation existed between TrA thickness during DLLT and activity level of subject ($r = -0.084$, $P < .05$). No significant correlation existed between TrA thickness during DLLT

and activity level of subject ($r = -0.084$, $P < .05$). However, a significant moderate correlation between the angle of failure on the DLLT and MVIC measured ($r = -0.594$, $P < .01$) and ($r = -0.495$, $P < .01$) in males, females respectively was noted. Also, a significant moderate correlation between MVIC and angle failure on the DLLT ($r = -0.536$, $P < .01$) existed. A significant moderate correlation between MVIC and TrA thickness at failure of the DLLT ($r = 0.496$, $P < .01$) was present. No significant correlation existed between DLLT, gender and activity level. Data analysis was performed using SPSS Version 25 ($P < .05$).

CONCLUSIONS: A significant inverse relationship between the failure angle and MVIC in males and females was present, indicating that subjects who have a thicker TrA fail at a lower angle during the DLLT. Additionally, a significant positive correlation between MVIC and TrA thickness at failure of the DLLT indicated that subjects who have thicker TrA may have stronger isometric contractions.

CLINICAL RELEVANCE: The DLLT is reliable in testing the TrA strength and therefore may be beneficial in assessing core strength in athletes and clients.

SP0114

OXYGENATION CHANGES IN THE QUADRICEPS DURING EXERCISE BETWEEN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION INVOLVED AND UNINVOLVED LIMBS

Susan A. Saliba, Abbas Haider Jaffri

PURPOSE/HYPOTHESIS: Patients with ACLR have persistent weakness and quadriceps dysfunction. We aimed to study perfusion characteristics of the muscle to determine the potential for a physiological mechanism associated with ACLR. We investigated quadricep muscle oxygenation changes during knee extension between ACLR involved and uninvolved limbs.

NUMBER OF SUBJECTS: Twenty participants, 10 patients with primary, unilateral ACLR (7 male, 3 female; mean $\pm$ SD age, 22.9 ± 3.5 years; height, 170.81 ± 7.93 cm; weight, 73.7 ± 15.1 kg) and 10 matched controls (7 male, 3 female; age, 22.9 ± 3.5 years; height, 170.4 ± 10.7 cm; weight, 68.86 ± 9.51 kg) participated.

MATERIALS AND METHODS: Each participant completed a single data collection session consisting of 5-second isometric contractions at 25%, 50%, and 75% of the volitional maximum followed by a 30-second maximal isometric knee extension contraction. Oxygenated hemoglobin (O₂Hb) measures were continuously recorded on the reconstructed thigh (versus the uninvolved contralateral limb as well as nondominant thigh of healthy controls) using 3 wearable, wireless near-infrared spectroscopy units placed superficial to the vastus medialis, lateralis and rectus femoris muscles. Relative changes in perfusion were ensemble averaged and plotted for each contraction intensity with associated 90% confidence intervals. Statistical significance was defined as portions of the exercise trials where confidence intervals of the O₂Hb graph did not overlap. Effect sizes (d ; 90% confidence interval [CI]) were taken for statistical significance.

RESULTS: We observed significantly lower relative change of O₂Hb was also observed in ACLR involved versus uninvolved for vastus medialis at 100% ($d = 2.62$; 90% CI: 2.54, 2.70) of the volitional control. We didn't observe any other significant difference for any other contraction intensity.

CONCLUSIONS: Differences exist in quadriceps muscle oxygenation between patients with ACLR during the same exercises between involved and uninvolved limbs. However not all portions of the quadriceps are affected uniformly across contraction intensities.

CLINICAL RELEVANCE: After ACL reconstruction (ACL-R), the average strength of the quadriceps is only 75% of the uninvolved limb. This decrease in muscle function is potentially caused by arthrogenic muscle inhibition (AMI), but the causes of AMI are not well understood. One of the reasons of AMI can be changes in perfusion as blood perfusion correlates with muscle activity, however no study has looked at blood per-

fusion changes in Quadricep after ACL-R. This is the first study that showed a general trend of smaller change in the magnitude of oxygen by the Quadriceps in the ACL-R limb. This inability to use oxygen in the ACL-R involved limb may contribute to the persistent weakness seen after ACL-R.

SP0115

THE EFFECTS OF FATIGUE ON LANDING ERROR SCORING SYSTEM PERFORMANCE: A PILOT STUDY

Adam Douglas Saloom, Nicholas Keith Purcell, Nicole Melfi, Katy Eileen Mitchell

PURPOSE/HYPOTHESIS: The Landing Error Scoring System (LESS) is a clinically feasible injury screening tool, with excellent reliability and validity, used to quantitatively assess landing mechanics at the trunk and lower extremities during a drop-jump task. Results from the LESS help guide healthcare professionals in designing specific programs to address an athlete's functional deficits leading to abnormal mechanics. However, there is limited literature related to landing mechanics measured by the LESS following an established fatigue protocol. The purpose of this pilot study was to examine the effects of fatigue on jump landing mechanics as measured by the LESS.

NUMBER OF SUBJECTS: Eight.

MATERIALS AND METHODS: Eight participants (5 female, 3 male) with the average $\pm$ SD age of 29.25 ± 3.41 years were recruited as part of a sample of convenience. The LESS is a 17-item outcome measure which assesses landing mechanics primarily in athletes (max score, 19). The fatigue protocol was based on the work of Webster et al. which consisted of 5 rounds of 10 squats, 2 vertical jumps, and 10 single-leg drop landings (5 on each leg). An additional 10 squats were added each round (Round 1, 10 squats; Round 2, 20 squats; Round 3, 30 squats, etc) Each participant was rated 3 times prior to the fatigue protocol and 3 times after the fatigue protocol. Participants were rated by the same PT for all tests. Following the fatigue protocol, participants completed the LESS again. Scores between pre-fatigue LESS and postfatigue LESS were compared via t tests and 1-way ANOVAs at an alpha set at .05.

RESULTS: No significant difference was found between pre-fatigue (mean, 4.42) and postfatigue (mean, 5.29) LESS scores ($P = .213$). There was a significant difference found in vertical jump height when comparing rounds 1 to 5 ($F_{4,28} = 4.782$, $P = .005$ for jump 1 and $F_{4,28} = 6.206$, $P = .027$ for jump 2). A significant difference was found in modified Borg rating when comparing rounds 1 to 5 ($F_{4,28} = 16.520$, $P < .0005$).

CONCLUSIONS: The fatigue protocol used in the pilot study did not affect jump landing mechanics as assessed by the LESS. However, completion of the fatigue protocol resulted in decreased vertical jump height and increased rating of fatigue on the modified Borg scale which indicates the fatigue protocol was effective in eliciting fatigue.

CLINICAL RELEVANCE: The results suggest that fatigue may not alter jump landing mechanics as significantly as other studies have shown and therefore may not increase risk of ACL injury. While fatigue did increase throughout the protocol, the intensity and type may not be representative of the fatigue experienced during a practice or game. Future studies may benefit from revising the fatigue protocol in order to regulate testing and recovery periods, as well as simulate a more game-like fatigue. In this study, fatigue was shown to have a significant effect on performance during vertical jump testing but not alter landing mechanics, which may guide clinicians and future researchers in return to sport testing protocols and injury prevention programs.

SP0116

SEX DIFFERENCES IN PAIN, PSYCHOLOGICAL READINESS FOR RETURN TO SPORT, AND KINESIOPHOBIA FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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Nnamdi Amilo, Mallory S. Faherty, Carolyn Killelea, Daniel Le, Lee Diehl, Alison Toth, Annunziato Amendola, Dean Taylor, Jocelyn Wittstein, Jonathan Riboh, Timothy Sell

PURPOSE/HYPOTHESIS: Secondary anterior cruciate ligament (ACL) injury to the ipsilateral ACL graft or contralateral ACL following return to sport (RTS) is common after ACL reconstruction (ACLR), with some evidence indicating that young males are at greater risk than young females. The reasons for these sex differences are unclear. One potential factor may be kinesiophobia as it has been identified as a predictor for reinjury following RTS. Studies investigating kinesiophobia in other patient populations have identified sex differences, although whether this holds true in ACLR patients remains unknown. The purpose of this study was to examine whether ACLR patients also exhibit sex differences in kinesiophobia. A secondary purpose of the study was to determine if there are sex differences in readiness to RTS and self-reported pain after clearance for RTS. We hypothesized that there would be sex differences found with evaluation of these parameters.

NUMBER OF SUBJECTS: A total of 20 participants voluntarily participated in the study. All subjects had undergone ACLR. There were 11 males (mean $\pm$ SD age, 23.1 ± 8.4 years; height, 178.9 ± 7.6 cm; weight, 76.8 ± 10.4 kg) and 9 females (age, 19.6 ± 5.3 years; height, 165.1 ± 4.1 cm; weight, 73.2 ± 25.0 kg).

MATERIALS AND METHODS: Surveys were administered at the time of clearance for RTS (average $\pm$ SD, 10.5 ± 2.3 months post ACLR). They included the Tampa Scale of Kinesiophobia (TSK-11), the Anterior Cruciate Ligament Return to Sport After Injury (ACL-RSI) scale, and a self-reported pain using a visual analog scale (VAS). The TSK-11 is a shortened version of the Tampa Scale of Kinesiophobia questionnaire, contains questions on a scale from 1 to 4, and is widely used to measure pain-related fear. The pain VAS asked patients to indicate their pain level between 0 and 100. The ACL-RSI is a 12-item questionnaire measuring readiness to return to sport where patients rate their responses from 0 to 100 for each item. Mean and standard deviations were calculated for TSK-11 scores, overall ACL-RSI scores and the pain VAS. Wilcoxon rank-sum tests were run to examine potential differences between sexes for each of the surveys. Statistical significance was set a priori at $P < .05$.

RESULTS: There was no significant difference ($P = .23$) between sexes for the VAS of pain (males, 4.6 ± 6.5 ; females, 1.2 ± 3.3). No significant differences ($P = .73$) were observed between sexes (males, 18.7 ± 3.2 ; females, 19.7 ± 4.6) for TSK-11 scores. Significant differences ($P = .03$) between sexes were observed for the ACL-RSI with males reporting a significantly higher score of 92.8 ± 16.2 compared to females (77.0 ± 15.5). A higher score represents a greater psychological readiness to return to sport.

CONCLUSIONS: The results of this study did not demonstrate significant differences between sexes for kinesiophobia or pain level, contrary to our hypothesis. However, consistent with our hypothesis, males had significantly higher ACL-RSI scores, suggesting males possibly have higher psychological readiness following clearance for RTS.

CLINICAL RELEVANCE: The significant differences between sexes in ACL-RSI at the time of RTS may provide some insight into risk of secondary injury following ACLR. Although this result is contrary to some of the early research examining sex differences in secondary injury rates, it suggests that sex-specific care following ACLR may require consideration.

SP0117

FUNCTION AND RECOVERY TIMELINES FOR ADOLESCENTS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION WITH QUADRICEPS TENDON-PATELLAR BONE AUTOGRAFT

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PURPOSE/HYPOTHESIS: Anterior cruciate ligament (ACL) rupture is an increasingly common injury in young athletes. Surgical intervention is recommended for adolescents for return to prior activities and to reduce

risk of subsequent injury. The use of quadriceps tendon-patellar bone autograft (QPA) for primary anterior cruciate ligament reconstruction (ACLR) is a suitable graft choice for patients who have not reached skeletal maturity. Timelines for achieving functional milestones and return to sport testing have not been reported following this procedure. The purpose of this study was to identify average timelines for return to ballistics and return to sport testing, as well as to investigate performance on common functional tests in adolescents who underwent ACLR with QPA with or without concomitant meniscus repair.

NUMBER OF SUBJECTS: Sixty-two.

MATERIALS AND METHODS: Individuals aged 12 to 18 years at the time of surgery who underwent ACLR with QPA and completed return to sport testing were included. We collected data from subjects with isolated ACLR and ACLR with concomitant meniscus repair who underwent surgery between January 1, 2015 to July 31, 2017. Subjects with other concomitant injury requiring surgical intervention, previous or contralateral ACLR, and those who did not complete return to sport testing were excluded. Data were collected retrospectively and outcomes between subjects undergoing isolated ACLR were compared to those with ACLR and concomitant meniscus repair at return to ballistics and return-to-sport testing time points using independent-samples t tests for normally distributed continuous variables, Mann-Whitney U for nonnormally distributed variables, and chi-square analyses for categorical variables.

RESULTS: Subjects who underwent meniscus repair and ACLR were significantly older than those who underwent isolated ACLR (mean $\pm$ SD age, 16.1 ± 1.2 versus 15.0 ± 1.5 years; $P = .001$). On average, patients returned to ballistics approximately 4 months following surgery (median, 118 days; IQR, 96-132 days) and completed return to sport testing at approximately 9 months after surgery (median, 278 days; IQR, 248-344 days). Although there was a difference in single-leg squat involved/uninvolved percentages between individuals with ACLR and meniscus repair and those with isolated ACLR, this difference was not statistically significant ($90.0\% \pm 11.1\%$ versus $86.1\% \pm 9.1\%$ difference, $P = .11$). There were no statistically significant differences between groups on any of the functional outcome measures performed during the return to sport test including single-leg squat for time, Y-Balance, and hop testing.

CONCLUSIONS: A mean of greater than 95% symmetry was achieved on all functional tests at return to sport testing by those subjects that completed all tests. This is consistent with return to sport clearance criteria at this institution. This study is limited by the small number of subjects that completed all functional tests.

CLINICAL RELEVANCE: Timelines for recovery from ACLR with QPA in this study can support clinicians in decision making and planning for adolescents requiring ACLR.

SP0118

A PILOT STUDY ASSESSING AN IMMEDIATE FUNCTIONAL PROGRESSION PROGRAM IN ATHLETES WITH A SPONDYLOLYSIS

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PURPOSE/HYPOTHESIS: Half of all adolescents report low back pain (LBP), with an even higher rate among athletes. Spondylolysis, a stress fracture in the lumbar spine, is the most common identifiable cause of LBP in adolescent athletes. Experts recommend resting for as long as 3 months before beginning rehabilitation after this injury. However, resting for long periods has negative consequences including muscle atrophy, weight gain, anxiety, and depression. The purpose of this pilot study was to assess the viability of using an immediate functional progression program to treat adolescent athletes with an active spondylolytic injury.

NUMBER OF SUBJECTS: Thirteen patients (mean $\pm$ SD age, 14.1 ± 2 years; 31% female) with active spondylolytic injuries.

MATERIALS AND METHODS: Adolescent athletes were referred to physical therapy (PT) immediately after diagnosis of the active spondylolysis. The

PT program progressed patients based upon function ability and athletes returned to sport when they passed predetermined criteria. Clinical outcomes were compared to a previous sample of adolescents with a spondylolysis ($n = 196$) treated with 2 to 3 months of rest. Ninety-two percent of historical controls were able to return to sport within 6 months with a median time of 4.7 months. Adverse reactions were noted in 8% of historical controls. The immediate functional progression program would be considered viable if patients were able to return to sport significantly sooner than historical control, with similar clinical outcomes. Pain and function (Micheli Functional Scale) were assessed at baseline, 1 month, 3 months, and 6 months. Data Analysis: descriptive statistics were calculated to assess viability of the program.

RESULTS: Twelve patients completed the immediate functional progression program. Eleven patients (92%) were able to return to sport in a median time of 2.5 months. One patient (8%) had an adverse reaction during care with a significant recurrence of LBP and was unable to return sport by 6 months. All patients demonstrated significant improvements in pain and function.

CONCLUSIONS: The immediate functional progression program returned athletes to sport 2 months sooner with similar clinical outcomes when compared to historical controls. Beginning PT immediately and progressing the patient based on functional ability appears to be a viable method for treating this population and warrants future research.

CLINICAL RELEVANCE: Adolescent athletes with an active spondylolytic injury were able to return to sport markedly sooner using an immediate functional progression program. Further research through a randomized controlled design is needed to substantiate these findings.

SP0119

BETWEEN-SET RECOVERY DURING BLOOD FLOW RESTRICTION TRAINING: TO OCCLUDE OR NOT TO OCCLUDE?

Faisal Dee Shaikh, Kevin R. Ford, Coty Rajek, Clint Marsh Coursey, Austin Midgette, James Smoliga, David R. Sinacore

PURPOSE/HYPOTHESIS: Blood flow restriction training (BFRT) at low loads has been reported to induce similar strength gains as higher load training. The purpose of our study was to assess adaptability and strength gains in a short-term lower extremity BFRT protocol in healthy adults with continuous cuff pressure (CCP) and released cuff pressure (RCP) during recovery periods to inform future clinical protocols. We hypothesize that CCP will have greater adaptations and strength gains.

NUMBER OF SUBJECTS: Nine healthy adults (mean $\pm$ SD age, 21.8 ± 3.2 years; height, 174.6 ± 5.3 cm; mass, 71.2 ± 7.5 kg).

MATERIALS AND METHODS: Participants completed prescreening survey and provided informed consent prior to testing. They were randomly allocated into (RCP) or (CCP) during the recovery period. At baseline, a 5-repetition maximum (RM) testing was performed for double-leg press (DLP) and single-leg extensions (SLE). Five trials of DLP and SLE were allotted to reach. The estimated 1RM was calculated for session weight of 30% of 1RM. Each session, a cuff (SMARTcuff) was placed at proximal thigh and inflated to 80% arterial occlusion measured via dorsal pedal pulse with doppler ultrasound. Participants completed 6 sessions of 4 sets of DLP and SLE with 60-second recovery periods. They were instructed to perform reps to fatigue for each set. CCP remained 80% during recovery periods and reduced to 0% when switching exercises. RCP allotted full reperfusion during recovery periods. Rating of perceived exertion (RPE) and pain visual analog scale (VAS) were assessed immediately after completed sets. The 5RM was reassessed 48 hours after last session. A repeated-measures ANOVA was used to determine the effects of DLP and SLE training and group on the following variables: reps per set, 5RM, VAS, and RPE.

RESULTS: RCP completed more average reps per set for DLP (RCP, 17.7; 95% CI: 15.78, 19.7; CCP, 13.1; 95% CI: 11.3, 14.8; $P = .004$) and SLE (RCP, 10.2; 95% CI: 7.9, 12.5; CCP, 6.6; 95% CI: 4.5, 8.6; $P = .027$) during

each session over 4 weeks than CCP. Both groups improved significantly in 5RM (DLP: pre, 216.4 kg; 95% CI: 156.3, 276.4 kg; post, 236.8 kg; 95% CI: 174.2, 299.4 kg; $P = .002$; SLE, 44.5 kg; 95% CI: 33.617, 55.5 kg to 54.7 kg; 95% CI: 40.0, 69.4 kg; $P = .004$). There was a significant interaction between group and training regarding pain ($P = .027$) and RPE ($P = .023$) trending towards higher early session pain in DLP with CCP. SLE RPE also had a significant group-by-training interaction ($P = .041$). No significant interaction was found with the pain scores ($P = .169$) for SLE.

CONCLUSIONS: RCP performed more reps per set across training sessions but both groups significantly improved 5RM DLP and SLE, indicating CCP may allow greater training adaptations than RCP. Although, RCP had significantly less pain, especially in early sessions. In later sessions, pain scores for CCP trended down and were similar to RCP, indicating possible adaptation.

CLINICAL RELEVANCE: While CCP may be more painful initially, it could result in greater training adaptations than RCP during recovery and may be an option for patients unable to tolerate high volume training.

SP0120

EXPLORATION OF FACTORS THAT AFFECT FUNCTIONAL MOVEMENT SCREEN HURDLE-STEP PERFORMANCE IN DANCERS

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PURPOSE/HYPOTHESIS: Dancers spend a considerable amount of time in single leg stance, requiring greater stability from the stance limb, while the moving limb performs intricate and variable motions. The hurdle-step (HS) item in the Functional Movement Screen (FMS) imitates this stance limb/moving limb relationship as a measureable, consistent, and reproducible assessment item. The FMS describes deficits that may contribute to poor scores on the HS: such as limited bilateral asymmetric hip mobility stability or dynamic stability. The purpose of this study was to explore the relationship between FMS HS scores and body morphology, maximum knee and ankle range of motion angles, and preference for weight distribution in standing, in the college dancer population.

NUMBER OF SUBJECTS: One hundred eleven female dancers for FMS, 47 for Fit3D.

MATERIALS AND METHODS: Subjects were taken through the FMS with a DPT student assessor. The calf and thigh diameters of the right legs were measured using a meter stick. Stickers were applied to bony prominences in order to better determine angles of the knee and ankle. The HS was video recorded on iPads. The videos were uploaded into Dartfish and each dancers' third trial was used to measure knee and ankle angle. Fit3D was used to determine weight distribution during normal stance and body morphological estimates, such as weight-to-height ratio. One-way analysis of variance, via SPSS Version 25, was used to investigate the difference in ankle angle, knee angle, forward/backward stance preference, leg diameters, etc dependent on the FMS HS score.

RESULTS: Only 16.5% of the participants scored 3/3, demonstrating proficiency in the HS; 64.6% scored a 2, 16.5% scored a 1, and 0.8% scored a 0. There was no significant differences in any of the variables studied, with respect to the different HS score. Maximum knee flexion varied from 86.9° to 137.8° . Many of the dancers (even some scoring a 3) chose to perform the item while in extreme plantarflexion, so the ankle dorsiflexion angles recorded were not a representation of their maximum dorsiflexion. Leg morphology measures (calf and thigh diameter and height-to-weight ratio) were also not significantly different for the HS score groups. There was also no significant difference in forward/backward stance preference relative to HS scores.

CONCLUSIONS: None of the explored variables appear to have an impact on a college dancer's ability to perform the HS of the FMS.

CLINICAL RELEVANCE: The data showed that angles of knee flexion and dorsiflexion and thigh and calf diameters could not be used as a predictive measure for HS score in this population. The mean FMS scores showed

that the HS might be an area of focus for improved functional mobility and decreased injury risk in dancers, but it is important to look into the mechanism behind the poor performance of the individual and address specific issues rather than use a more superficial approach to diagnosing movement problems.

SP0121

TEST-RETEST RELIABILITY OF THE DYNAMIC EXERTION TEST AMONG HEALTHY ATHLETES

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PURPOSE/HYPOTHESIS: Sport-related concussions (SRC) require a comprehensive evaluation of neurocognitive, vestibular, ocular, and autonomic nervous systems to determine return to play (RTP) readiness following injury. To date, provocative aerobic exertion assessments have fulfilled an objective evaluation of the autonomic nervous system, but concussion affects vestibular and oculomotor systems, which may be perturbed during dynamic, but not static aerobic exertion. We recently developed the Dynamic Exertion Test (EXiT) to screen combined autonomic, dynamic, and functional readiness following concussion. An important component of any exertion test for SRC is its performance and stability in healthy athletes. Thus, the purpose of this investigation was to examine the reliability of heart rate (HR) response and performance on the EXiT components in healthy athletes.

NUMBER OF SUBJECTS: Forty-five healthy males and females aged 14 to 35 years that fulfilled ACSM's guidelines for regular aerobic activity were enrolled. Exclusion criteria included: (a) experienced a concussion within 6 months, (b) reported 2 or more prior concussions, (c) prior diagnosis of a neurological, vestibular, or ocular motor disorder, (d) incapable of treadmill running up to 8.5 mph and 7.0 mph for males and females respectively, or (e) meeting any exclusion criteria from the ACSM's Physical Activity Readiness Questionnaire.

MATERIALS AND METHODS: Subjects completed 2 consecutive bouts of each agility task from EXiT: the box drills, zig-zag drill, pro agility run, and arrow agility tasks at 2 visits. One administrator recorded time to complete tasks (seconds) and HR responses were quantified by an Equivital Life monitor harness. A series of paired-samples *t* tests were conducted to compare HR response and EXiT performance between consecutive trials, and between the first trials across visits. A priori was set at $P = .05$ for statistical significance.

RESULTS: Forty-five athletes (21 female; mean $\pm$ SD age, 20.41 ± 3.95 years) completed the first visit and 32 completed both visits (8.1 ± 3.9 days between visits). HR response at visit 1 and 2 was equivocal across all tasks. At visit 1, we observed an improvement a box drill (23.32 ± 3.71 versus 22.32 ± 3.74 , $P < .01$) and worsened arrow agility (40.37 ± 5.59 versus 42.50 ± 5.17 , $P < .01$) performance between trials whereas all other agility tasks were stable ($P > .05$). The zig-zag drill improved ($P < .01$) across visits, but box drills, pro-agility, and arrow agility exhibited adequate stability ($P > .05$).

CONCLUSIONS: All of the EXiT agility tasks- except 1 (of 2) box drill, exhibited stable performances between consecutive trials and across time. HR response was also similar between visits, providing preliminary evidence of the EXiT as a stable, dynamic exertion assessment.

CLINICAL RELEVANCE: A stable, reliable dynamic exertion assessment such as the EXiT that screens the function of both autonomic and vestibular systems may address a gap in current approaches to postexertion evaluation of concussion and inform safer RTP.

SP0122

THE CLOSED-KINETIC-CHAIN UPPER EXTREMITY STABILITY TEST AS ASSESSMENT OF RETURN TO SPORT OF A PREADOLESCENT ATHLETE WITH CHRONIC ANTERIOR SHOULDER DISLOCATIONS

Aaron Snyder, Michael Vincent Gaddini, Jonathan Chiu, Linda J. Wanek

BACKGROUND AND PURPOSE: Shoulder dislocation and anterior instability are common in preadolescent and adolescent athletes. The Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) is a reliable test for upper limb stability. The CKCUEST uses normative data to compare subjects to their respective demographic, but there is no normative data nor information on threshold scores for return to sport (RTS) for preadolescents. The purposes of this case report are to demonstrate use of the CKCUEST as an assessment for RTS and to report treatment outcomes for a 13-year-old male basketball player with traumatic chronic shoulder instability.

CASE DESCRIPTION: The patient (pt) suffered a traumatic anterior shoulder dislocation and had 4 subsequent instability events over the past year. He received no rehab prior to the current PT encounter and remains a candidate for stabilization surgery post puberty. Prior level of function was independent with daily activities and recreational activities, but at examination he was unable to participate in recreational basketball. Pt goals were to improve confidence with contact in sport, prevent further instability events, and to RTS without pain. He was seen in outpatient PT for 6 visits for rotator cuff strengthening, neuromuscular re-education, and sport-specific drills.

OUTCOMES: The Quick Disabilities of Arm, Shoulder and Hand (QuickDASH) was used to evaluate self-reported arm function. The pt's QuickDASH score improved by 9.1 points following PT treatment, meeting the minimal clinically important difference of 9.0 to 11.3 points. The CKCUEST evaluates the number of hand-to-hand touches done in a push-up position in 15 seconds and computes a normalized score and power score. The minimal detectable change (MDC) for number of touches, normalized score, and power score are 6.0, 3.74, and 17.98, respectively. Pt improved hand touches by 8, normalized score by 4.9, and power score by 19.4, all exceeding the MDCs. The pt RTS after 4 visits upon physician clearance, prior to pt discharge from PT after visit 6. He continues to play recreational basketball without report of a recurrent instability event 15 weeks post discharge from PT.

DISCUSSION: The CKCUEST can be used to evaluate change in function in preadolescent athletes with shoulder instability events. Approximately 33% of athletes who RTS after an anterior shoulder instability event experience a recurrence and are unable to complete the season. Currently, PT does not have a gold standard to evaluate readiness to RTS following upper limb injury. CKCUEST is reliable for shoulder stability in adolescent populations and shown to be valid in adults. However, evidence for UE tests is limited particularly in preadolescent populations. When an athlete is evaluated for RTS, multiple variables must be considered across healthcare disciplines to ensure readiness. Use of a standardized outcome measure, such as the CKCUEST, will enable healthcare professionals to provide consistent objective data when making RTS recommendations. This test may be a valid tool for use in this population, but additional supporting research is needed.

SP0123

CLOSED-CHAIN JOINT REPOSITIONING AND DROP VERTICAL JUMP PERFORMANCE IN ANTERIOR CRUCIATE LIGAMENT-RECONSTRUCTED PATIENTS

David Steinbach, Kevin R. Ford, Audrey Westbrook, Elizabeth Owen, Jeffrey B. Taylor

PURPOSE/HYPOTHESIS: There are a number of clinical tests for neuromuscular control and proprioception that have been linked to second anterior cruciate ligament (ACL) injury, yet none of these tests simulate the closed-chain biomechanics associated with injury. Thus, there may be a need to develop a clinical test that can assess proprioception in the closed kinetic chain. The purpose of this study was to identify the relationship between a novel closed-chain joint repositioning test and lower extremity biomechanics during a jump landing task. It was hypothesized that bet-

ter joint repositioning would be related to less aberrant frontal plane hip and knee biomechanics.

NUMBER OF SUBJECTS: Eleven female participants with a history of ACL injury (mean $\pm$ SD age, 21.2 ± 3.2 years; height, 166.3 ± 6.0 cm; mass, 67.2 ± 8.3 kg; years since ACL reconstruction, 4.7 ± 2.8).

MATERIALS AND METHODS: Participants performed a drop vertical jump (DVJ) from a 31-cm box while instrumented for standard three-dimensional motion analysis. The Closed-Chain Joint Repositioning Test (CCJRT) was performed on a supine leg press track. While loaded with 55% of their body weight, participants attempted to reproduce knee flexion angles during 10 single-leg press trials while the tester chose varying degrees of knee flexion angles. The difference between the initial trial and repositioned trial was calculated as CCJRT error. Differences in side-to-side errors during the CCJRT were examined using a repeated measures ANOVA. Bivariate correlations were used to identify the relationship between error during the CCJRT test and hip and knee biomechanics of the surgically repaired limb during the DVJ task.

RESULTS: There were no significant side-to-side asymmetries in CCJRT errors ($P = .28$). There were large correlations between CCJRT error and (1) hip extensor moments ($r = 0.80$, $P = .003$), and (2) knee extensor moments ($r = 0.70$, $P = .02$). No significant relationships were identified between CCJRT error and sagittal or frontal plane hip or knee kinematics or frontal plane hip or knee joint moments ($P > .05$).

CONCLUSIONS: After ACL reconstruction, patients that landed with less hip and knee extension torque on their surgically repaired limb during a DVJ had greater error when asked to reproduce joint angles in a partially weight-bearing position.

CLINICAL RELEVANCE: Although there was no relationship between joint repositioning error and frontal plane biomechanics, this initial investigation of the CCJRT identified a relationship between joint repositioning error and sagittal plane landing biomechanics. While further analysis and validation of the CCJRT is needed, this highly accessible clinical test may provide useful information for clinicians in the rehabilitation and return-to-play decision making process of individuals after ACL reconstruction. Specifically, it may help identify patients that are not creating adequate hip and knee extensor torque during dynamic tasks.

SP0124

EFFECTIVENESS OF THE Y-BALANCE TEST IN PREDICTING RUNNING-RELATED INJURIES DURING A COLLEGIATE CROSS-COUNTRY SEASON

Hanz Tao, Steven Weber, Creighton James Thompson

PURPOSE/HYPOTHESIS: This study aims to examine the ability of the Y-Balance Test (YBT) to detect injury risk in Division I runners over the course of 1 collegiate cross-country season. Our hypothesis is that certain YBT reach directions, particularly anterior and posterior, may be predictive of running-related injuries (RRIs).

NUMBER OF SUBJECTS: Twenty-nine.

MATERIALS AND METHODS: Collegiate Division I runners volunteered to partake in this study. During the preseason, YBT performance of dominant and nondominant limbs was recorded in 4 reach directions: anterior (ANT), posteromedial (PM), posterolateral (PL), and posterior (POST). Composite scores, leg-length adjusted and unadjusted scores, and asymmetries were calculated. RRIs were tracked over the course of the cross country season. A receiver operating characteristic (ROC) curve analysis was utilized to investigate the effectiveness of YBT testing in predicting injury risk over the entire cross-country season. Cut scores (CS) and relative risk (RR) ratios were also calculated. Alpha was set to .05.

RESULTS: Nine of 29 (31%) runners developed an RRI during the cross country season. Several components of the YBT were found to predict injuries, including ND adjusted POST score (AUC = 0.756, $P < .05$; CS, 0.935; RR = 10.45), adjusted ANT asymmetry (AUC = 0.781, $P < .05$; CS, 3.5%; RR = 5.25), and adjusted PM asymmetry in males (AUC = 0.917, $P < .05$; CS, 7.5%; RR = 7.00).

CONCLUSIONS: YBT adjusted scores and percent limb asymmetries have fair predictive abilities (POST and ANT asymmetry) in all runners, as well as excellent predictive ability (PM asymmetry) in male runners over the course of 1 collegiate cross-country season. However, neither unadjusted scores nor composite scores were beneficial in predicting injury.

CLINICAL RELEVANCE: Physical therapists may use the YBT as a valid tool to predict RRIs in collegiate Division I runners. A posterior reach should be added to the traditional reach directions. Adjusting scores to limb length and calculating limb asymmetry is critical for injury screening for runners.

SP0125

COMPARISON OF BALANCE AND STRENGTH BETWEEN DIVISION I COLLEGIATE RUNNERS AND HEALTHY, ACTIVE INDIVIDUALS

Hanz Tao, Trevor Bollinger, Zackery John Olson, Carl Schumann

PURPOSE/HYPOTHESIS: The aim of this study was to compare static balance, ankle strength, and hip strength between Division I track and field runners (D1) and healthy, active college-aged individuals (AC). We hypothesized that Division I runners had better balance and strength.

NUMBER OF SUBJECTS: One hundred twelve.

MATERIALS AND METHODS: Division I track and field runners were recruited from a Midwestern university and tested on measures of balance, ankle strength and hip strength. These data were compared to that of a previous dataset from active college-aged individuals. Balance was tested using a modified version of the Balance Error Scoring System (mBESS). Strength was assessed under modified Manual Muscle Testing (MMT) positions for ankle inversion and eversion, and standardized MMT for hip abduction (gluteus medius) and extension (gluteus maximus). A hand-held dynamometer (HHD) was used to quantify strength. Data were analyzed through IBM SPSS. Independent t tests were utilized to compare test performance between D1 and AC. Statistical significance was set at an alpha of .05.

RESULTS: Seventy-one Division I runners (D1) and 41 healthy, active college-aged individuals (AC) were compared. Compared to AC, D1 had 42.17% lower ankle inversion strength ($P < .01$), 16.86% lower ankle eversion strength ($P < .01$), and 24.04% greater hip extension strength ($P < .01$). However, neither hip abduction strength nor balance differed between groups.

CONCLUSIONS: The groups had similar balance profiles, but different profiles in ankle strength and hip strength. The pattern of greater sagittal plane strength and equal or lower frontal plane strength might explain the unique, repetitive stresses imposed on runners, who primarily train and compete in a sagittal plane.

CLINICAL RELEVANCE: Physical therapists who work with Division I runners should use available runner-specific normative test values during evaluation, as many values significantly differ from a general, active population.

SP0126

VALIDATION OF PRONATION KINEMATICS DETERMINED BY A WEARABLE SENSOR DESIGNED FOR RUNNING

Jeremiah Jackson Tate, Austin Kercheville, Joshua Lehr, John Charles Gilpin, Kyle Ryan Snell, Robert Andrew Gean

PURPOSE/HYPOTHESIS: The purpose of this study was to validate measures of maximum pronation excursion and velocity calculated during treadmill running via the RunScribe wearable sensor to the same kinematic measures determined via 3-D motion analysis.

NUMBER OF SUBJECTS: Thirteen college-aged recreational runners (11 female) who were currently running an average of 26.9 km/wk participated in this study. Seven out of the 13 participants reported prior team membership at the high school level or both high school and collegiate levels.

MATERIALS AND METHODS: Maximum pronation excursion and pronation velocity data were calculated for each limb using a RunScribe sensor dur-

ing treadmill running for a period of 8 minutes at the runner's preferred speed. Maximum pronation excursion and pronation velocity were then determined for overground running using an 8-camera motion analysis system which included embedded force plates to determine foot contacts. Intraclass correlation coefficients (ICCs) were calculated to determine the level of agreement between the RunScribe and 3-D motion analysis system. Paired *t* tests were also used to analyze potential differences between the 2 measurement systems. Bland-Altman plots were constructed to provide a visual representation of the level of bias and agreement.

RESULTS: ICC estimates were fair for both left (0.51) and right (0.62) limbs for pronation excursion, while ICC estimates were good for left (0.70) and right (0.71) limbs for pronation velocity. Paired *t* tests indicated statistically significant differences between RunScribe and 3-D motion lab measures for left pronation excursion ($8.5^\circ \pm 3.3^\circ$ versus $11.4^\circ \pm 3.3^\circ$, $P = .008$) and left pronation velocity ($315.8^\circ/\text{s} \pm 100.4^\circ/\text{s}$ versus $205.2^\circ/\text{s} \pm 97.6^\circ/\text{s}$, $P < .0001$) and right pronation velocity ($335.9^\circ/\text{s} \pm 135.4^\circ/\text{s}$ versus $219.5^\circ/\text{s} \pm 105.3^\circ/\text{s}$, $P < .0001$). Right pronation excursion measures were similar ($10.0^\circ \pm 5.1^\circ$ versus $11.5^\circ \pm 3.3^\circ$, $P = .22$). Bland-Altman plots demonstrated that differences in RunScribe measures and 3-D motion analysis for maximum pronation excursion centered around zero; however, RunScribe maximum pronation velocity measures were consistently higher than 3-D motion analysis.

CONCLUSIONS: The RunScribe wearable sensor does not appear to be a valid device to measure maximum pronation excursion or velocity. Measures of pronation velocity made using the RunScribe, however, did indicate a good level of agreement with 3-D motion lab measures.

CLINICAL RELEVANCE: Maximum pronation velocity measurements within single subject test-retest design may be a viable option to demonstrate an objective change following intervention when using the RunScribe wearable sensor.

SP0127

CONFIDENCE FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IS INFLUENCED BY LANDING BIOMECHANICS AND MOVEMENT QUALITY

Benjamin Robert Thompson, Brooke E. Farmer, Dimitrios Katsavelis, Jennifer Joy Bagwell, Kimberly Turman, Terry Lee Grindstaff

PURPOSE/HYPOTHESIS: Diminished confidence and fear of reinjury are common following anterior cruciate ligament reconstruction (ACL-R), but contributing factors are not well understood. The purpose of this study was to determine the association between jumping biomechanics and landing quality on confidence during late stages of rehabilitation following ACL-R.

NUMBER OF SUBJECTS: Twenty-six individuals (mean $\pm$ SD age, 19.6 ± 5.1 years; mass, 71.3 ± 12.5 kg; height, 173.1 ± 8.9 cm; time since surgery, 8.5 ± 2.7 months) participated in this study.

MATERIALS AND METHODS: Participants performed a drop jump landing which was used to quantify lower extremity landing biomechanics (knee angle, knee joint moments) and movement quality using the Landing Error Scoring System (LESS). Participants also completed the Anterior Cruciate Ligament Return to Sport after injury scale (ACL-RSI) to assess confidence. Outcome variables included limb symmetry index (LSI = involved/uninvolved) for each biomechanical outcome measure and LESS scores. Pearson correlations were used to examine the association between ACL-RSI score and each outcome measure.

RESULTS: There was a significant correlation between ACL-RSI scores and Peak Knee Flexion Angle LSI ($r = 0.49$, $P < .01$). No association was found between ACL-RSI and other knee joint biomechanical measures: drop jump initial contact angle LSI ($r = 0.21$, $P = .17$), peak external knee flexion moment ($r = 0.07$, $P = .29$) or peak ground reaction force LSI ($r = 0.24$, $P = .12$). There was also no association found between ACL-RSI and LESS scores ($r = -0.27$, $P = .094$).

CONCLUSIONS: Peak knee flexion angle LSI was able to explain 24.2% of the variance in ACL-RSI scores. Patients with the higher ACL-RSI values displayed more symmetrical knee joint flexion angle when landing from a drop vertical jump. It is plausible that addressing underlying impairments in jumping performance and movement quality may better prepare individuals to more successfully return to physical activity following ACL-R.

CLINICAL RELEVANCE: Patient education and clinical strategies should be used to place attention on landing biomechanics. Focus for patients with lower ACL-RSI scores should be directed towards landing with symmetrical knee flexion. For example, clinicians may use equipment such as mirrors or video biofeedback to show patients correct landing biomechanics. Physical impairments that contribute to poor biomechanics may also be addressed in the clinic.

SP0128

DIFFERENCES IN LANDING FORCES BETWEEN MALE AND FEMALE HIGH SCHOOL ATHLETES

Adam W. VanZile, Daniel Jones, Thomas Gus Almonroeder

PURPOSE/HYPOTHESIS: Female athletes appear to be more susceptible to various acute and overuse lower extremity musculoskeletal injuries (eg, ACL injuries, patellofemoral pain), versus male athletes. Previous studies have identified sex differences in landing kinematics and joint kinetics which may help to explain this sex disparity in injury rates. Studies have also compared landing forces between male and female athletes, as high vertical ground reaction forces (vGRFs) and loading rates may contribute to acute/overuse musculoskeletal injury. Interestingly, findings from these previous studies have been inconsistent, with some reporting no difference in landing forces between male and female athletes, and others reporting higher vGRFs and/or loading rates for either males or females. The purpose of this study was to compare vGRFs and loading rates during landing in a relatively large sample of male and female high school athletes. In addition, we also wanted to examine if sex differences in vGRFs and/or loading rates are dependent on whether athletes are performing a drop landing or landing from a jump.

NUMBER OF SUBJECTS: Eighty-six male and 50 female high school athletes.

MATERIALS AND METHODS: Following a warm-up, male and female athletes completed 3 trials of a drop vertical jump task, which involved dropping from a 31-cm-high box, landing on both feet, and immediately performing a maximal vertical jump. A force platform was used to record ground reaction forces during the initial landing (drop landing) and the landing following the vertical jump (jump landing). The peak vGRFs and loading rates were identified for both the drop landing and the jump landing. Forces were normalized to body weight (BW) and loading rate was calculated by dividing the peak vGRF by the time to peak vGRF (BW/s). Vertical jump height was also calculated for each trial based on the time in the air. For the drop landings, independent *t* tests were used to compare the peak vGRFs and loading rates for the male and female athletes. For the jump landings, analysis of covariance was used compare the peak vGRFs and loading rates, with jump height included as a covariate. An alpha of .05 was used for all statistical tests.

RESULTS: Male athletes demonstrated higher peak vGRFs for both the drop landings ($P < .001$, 3.5 ± 0.8 BW versus 2.9 ± 0.7 BW) and the jump landings ($P < .001$, 4.7 ± 1.1 BW versus 3.4 ± 0.6 BW), compared to female athletes. There was no difference in loading rates between males and females for the drop landings ($P = .19$); however, male athletes demonstrated higher loading rates during the jump landings ($P < .001$, 80.2 ± 31.7 BW/s versus 51.5 ± 19.4 BW/s).

CONCLUSIONS: Male athletes demonstrated higher landing forces and loading rates compared to female athletes during performance of a drop vertical jump task.

CLINICAL RELEVANCE: While female athletes are at greater risk for musculoskeletal injury, it does not appear to be the result of higher landing forces

or loading rates. Sex disparities in injury rates may be related to other mechanical differences (eg, differences in joint kinematics/kinetics).

SP0129

THE ASSOCIATION BETWEEN LOWER EXTREMITY STRENGTH RATIOS AND THE HISTORY OF INJURY IN COLLEGIATE ATHLETES

Emily Vosburg, Michelle Dawn Hinkey, Rachel Meyers, Jennifer Csonka, Karla A. Salesi, Tara Siesel, Jose Fonseca, Robert Zarzour, Timothy Sell, Mallory S. Faherty

PURPOSE/HYPOTHESIS: In collegiate athletes, there is an overall musculoskeletal injury (MSKI) incidence of 63.1 per 1000 hours. Strength ratios are important because imbalances in opposing muscle groups can cause articular instability and subsequently increase the risk of MSKI. Therefore, the purpose of this study was to evaluate the association between lower extremity (LE) musculoskeletal isometric strength ratios and the history of LE MSKI in NCAA Division I athletes. It was hypothesized that in athletes with a previous LE MSKI the LE strength ratios on the injured LE will have a greater deviation from the normative values when compared to a LE of an athlete who has not suffered a LE MSKI. Between LE differences within each group (injured (INJ) versus noninjured (NINJ)) will also be presented.

NUMBER OF SUBJECTS: One hundred eighty-two NCAA Division I soccer, football, volleyball, and basketball athletes (INJ, $n = 49$; NINJ, $n = 133$; total, 182; male, $n = 122$; mean $\pm$ SD age, 19.5 ± 1.4 years; height, 185.4 ± 8.78 cm; weight, 85.0 ± 14.9 kg and female, $n = 60$; age, 19.35 ± 1.1 years; height, 173.7 ± 8.61 cm; weight, 68.65 ± 10.8 kg).

MATERIALS AND METHODS: All isometric strength assessments were measured bilaterally using a handheld dynamometer. Strength assessments included: ankle inversion/eversion, ankle dorsiflexion/plantar flexion, knee flexion/extension, hip abduction/adduction, and hip external/internal rotation. Strength ratios between antagonist/agonist muscle groups were calculated by normalizing isometric strength measurements to body weight and dividing the antagonist muscle group by the agonist muscle group. LE MSKI history was collected through self-report; a report of the LE MSKI sustained in the 1 year prior to testing were collected. A Shapiro-Wilk test was utilized to test the data for normality. Group differences, between those with and without a LE MSKI were assessed using an independent-samples t test or Mann-Whitney U test. A paired-samples t test or Wilcoxon signed-rank test was used to describe differences within groups between LE. Significance was set a priori at $P < .05$.

RESULTS: There were no statistically significant differences for strength ratios between the INJ and NINJ groups. There was no statistically significant difference between the INJ LE and NINJ LE in the INJ group. The hip external/internal rotation ratio was statistically significant for side to side differences in the NINJ group ($P = .001$). The dominant leg of the NINJ group had a mean external/internal rotation ratio of 1.109 ± 0.221 , and the nondominant leg had a mean ratio of 1.177 ± 0.208 .

CONCLUSIONS: There were no statistically significant differences between the INJ and NINJ groups. This could indicate that injury history does not play a role in current strength ratios and could suggest that the athletes in the INJ group are performing successful rehabilitation for their injuries.

CLINICAL RELEVANCE: Due to no statistically significant differences between the INJ and NINJ groups, strength ratios are not a reliable outcome measure to determine return to sport criteria. Future research is needed to validate or invalidate these findings.

SP0130

FUNCTIONAL STRENGTH TESTING IS ASSOCIATED WITH ISOMETRIC KNEE STRENGTH IN ADOLESCENTS EARLY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Adam Pierce Weaver, Nicholas Gary Giampetruzzi

PURPOSE/HYPOTHESIS: The standard of care in ACL reconstruction (ACLR) typically involves a functional test at 6 months or later to assess a pa-

tient's readiness to return to sport using isokinetic and isometric testing, and functional strength testing. While there is some data that report findings of isometric and isokinetic strength at 3 months postoperative, there is limited data in the use of functional strength tests in adolescents. Therefore, the purpose of this study is to examine the relationship of isometric quadriceps femoris (QF) strength testing with functional strength tests in adolescent patients 3 months following ACLR.

NUMBER OF SUBJECTS: One hundred thirty-eight.

MATERIALS AND METHODS: A chart review was conducted on patients treated with ACLR between July 2017 and April 2019. Patients between 12 and 20 years of age who underwent ACL reconstruction and completed 3 month strength testing assessment were included in this study. Data were collected for involved and uninvolved extremities for the following tests: isometric QF strength testing at 60° of knee flexion, anterior step-down test (AS), Y-Balance testing (YBR) for anterior reach (AR), posteromedial reach (PMR), posterolateral reach (PLR), and, Y-Balance reach difference (YBR-DIFF). YBR-DIFF was defined as involved reach distance minus uninvolved reach distance. Spearman correlation was used to determine if: (1) there was an association between isometric peak torque quadriceps strength and YBR distance and YBR-DIFF (2) there was an association between isometric quadriceps strength and YBR distance.

RESULTS: Our cohort consisted of 138 patients, (68 female; mean $\pm$ SD age, 16.16 ± 1.88 years) tested at an average of 97.31 ± 16.12 days post ACLR. Peak torque isometric QF strength showed a moderate correlation with AR distance ($\rho = 0.455$, $P \leq .0001$), PMR distance ($r = 0.394$, $P \leq .0001$), and PLR distance ($\rho = 0.0397$, $P \leq .0001$). There was a weak positive correlation between isometric quadriceps strength deficit and YBR-DIFF for AR ($\rho = 0.254$, $P \leq .002$). There was weak positive correlation between isometric involved quadriceps strength and AS (21.09 ± 11.34 involved, 25.51 ± 8.95 uninvolved; $\rho = 0.25$, $P \leq .012$).

CONCLUSIONS: Isometric strength testing is associated with Y-Balance and anterior stepdown tests in adolescents.

CLINICAL RELEVANCE: Our results suggest that functional strength measures have clinical value but are likely best clustered to adequately assess QF strength. This data may suggest YBT asymmetries do not adequately assess QF strength deficits.

SP0131

INFLUENCE OF CONCUSSION HISTORY AND VISUAL AND SOMATOSENSORY INPUT ON POSTURAL CONTROL IN COLLEGIATE MALE ATHLETES

Katelyn Weisenberger, Matthew Paul Brancalione, Maria Talarico, Laura Boucher, James Onate

PURPOSE/HYPOTHESIS: To determine if concussion history, visual and somatosensory input affect static postural control performance in asymptomatic male collegiate club athletes. We hypothesized that eyes closed, foam surface and concussion history would elicit static postural control decrements.

NUMBER OF SUBJECTS: Thirty-nine male collegiate club athletes volunteered to participate in this study (mean $\pm$ SD age, 20.15 ± 1.60 years; height, 1.78 ± 0.08 m; weight, 85.03 ± 9.59 kg). Twenty athletes (51.28%) self-reported they sustained at least 1 concussion at least 6 months prior to testing and had no symptoms of concussion at time of testing. Athletes' most recent concussion was 40.86 ± 29.48 months from testing and the number of concussions sustained were 1.57 ± 0.87 .

MATERIALS AND METHODS: Athletes completed 20-second static postural control assessments on a triaxial force plate in double-limb stance with feet together and hands crossed over the chest under the following conditions: (1) eyes open (EO) on firm surface, (2) eyes closed (EC) on firm surface, (3) EO on foam surface, and (4) EC on foam surface. Center of pressure total, anteroposterior (AP), and mediolateral (ML) excursion, 95% ellipse sway area, and AP and ML amplitude root-mean-square (RMS) were calculated. Random intercepts generalized linear mixed models were performed for each outcome variable to determine the effects of vi-

sion, surface, and concussion history on static postural control performance. Statistical significance was determined a priori at $P \leq .05$.

RESULTS: A vision-by-surface interaction effect was observed on total excursion ($\beta = 33.58$; 95% CI: 25.55, 41.61), ML excursion ($\beta = 19.03$; 95% CI: 13.67, 24.39), AP excursion ($\beta = 23.86$; 95% CI: 18.41, 29.31), sway area ($\beta = 21.41$; 95% CI: 16.68, 26.14), and ML RMS ($\beta = 0.51$; 95% CI: 0.39, 0.64) whereby all variables increased under eyes closed and foam conditions. A vision-by-surface-by-concussion history interaction effect was observed on AP excursion ($\beta = 23.86$; 95% CI: 18.41, 29.31) and sway area ($\beta = -6.77$; 95% CI: -13.37, -0.16) where AP excursion was shorter and sway area was smaller under eyes closed and foam conditions with concussion history.

CONCLUSIONS: Elimination of visual input and/or alteration of somatosensory input significantly decreases an athlete's postural control. Contrary to our hypothesis, athletes with a history of concussion demonstrate reduced sway area and AP excursion indicating enhanced postural control relative to those without a history of concussion. Future studies with control-matched subjects are needed to validate this finding.

CLINICAL RELEVANCE: Altered visual and somatosensory input impact an athlete's static postural control. Athletes with a concussion history exhibit more stable postural control compared to those without a concussion history. It may be possible that static postural control assessments are not sensitive enough to detect lingering effects on postural control from a concussion following return to play. Future studies should include dynamic or more challenging balance tasks to determine the effect of concussion history on postural control.

SP0132

SEX-SPECIFIC ANTERIOR CRUCIATE LIGAMENT LOADS DURING DYNAMIC SPORT ACTIVITIES

John David Willson, Kendall Taylor, Virginia Renn Shearin, Drew Rutherford, Stacey A. Meardon, Thomas Kernozeck

PURPOSE/HYPOTHESIS: Anterior cruciate ligament (ACL) tears are common during sports participation with females having a higher risk of injury relative to males. However, sex-specific ACL kinetics have not been well reported, particularly across a continuum of dynamic activities performed during sport and return to sport (RTS) preparation. The purpose of this study was to compare ACL loading between males and females during activities associated with sport and RTS.

NUMBER OF SUBJECTS: Forty recreational athletes (mean $\pm$ SD age, 21.3 $\pm$ 2.0 years; 20 female).

MATERIALS AND METHODS: Three-dimensional lower extremity kinematics (200 Hz) and ground reaction forces (1000 Hz) were recorded during 5 trials of 8 activities: walking (1.5 m/s), running (3.5 m/s), sprinting (5.5 m/s), 45° cutting (3.5 m/s), double-leg (DL) jump (75% max jump height) and land, single-leg (SL) jump (75% max jump height) and land. Knee joint kinematics, joint reaction forces, and muscle forces derived via a static optimization routine were used as input to a musculoskeletal model to estimate ACL peak tensile force, impulse, and loading rate (LR) during each activity. Each ACL kinetic variable was evaluated using separate 2-factor (sex by activity) ANOVA, partial eta-square for effect sizes, and pairwise tests with a Sidak adjustment for multiple comparisons ($\alpha = .05$).

RESULTS: Peak ACL tensile force was 34% greater for males (0.28 ± 0.07 BW) than females (0.21 ± 0.05 BW, $P = .001$, $\eta^2 = 0.28$) during DL landings and 13% greater for males (0.55 ± 0.07 BW) than females (0.49 ± 0.06 BW, $P = .005$, $\eta^2 = 0.20$) during SL landings. Average ACL LR was greater for males during DL landings (3.3 ± 0.09 BW/s) and SL landings (8.0 ± 3.3 BW/s) compared to females (DL landing, 2.1 ± 0.6 BW/s; $P < .001$; SL landing, 5.6 ± 2.0 BW/s; $P = .009$). Large activity main effects were observed for ACL variables ($P < .01$, $\eta^2 = 0.76$ -0.87). Greater ACL peak force and LR were observed during all SL activities compared to DL activities ($P < .01$), with greatest ACL tension observed during SL landings ($P < .01$). Peak ACL tension was not different between the run, cut, and

sprint conditions ($P = .51$ -1.0). ACL impulse was greatest during SL landings ($P < .01$), with sprinting, DL jumping and DL landing producing the lowest ACL impulse ($P < .01$).

CONCLUSIONS: Peak ACL tensile force and LR were smaller for females during DL and SL landing. These results may underscore the significance of previously reported smaller ACL diameter and stiffness in females with regard to the etiology of ACL injury that would lead to greater ligament stress and strain and reduce cycles to structural fatigue and failure. For both sexes, ACL tension was present during each activity, but increased significantly during SL compared to DL activities, suggesting a need to monitor SL load cycles during RTS rehabilitation.

CLINICAL RELEVANCE: These results provide insight to sex-related ACL injury mechanisms during sport. Additionally, ACL tensile force profiles identified in this study can inform rehabilitation progression decision-making. For example, SL training activities develop significantly greater ACL tensile force and should be introduced later during rehabilitation with dosage being closely monitored.

SP0133

DOES A PREVIOUS EPISODE OF KNEE PAIN AFFECT BELIEFS ON THE CURRENT EPISODE OF PAIN IN ADOLESCENTS?

Robert Dane Wilson, Mitchell C. Selhorst

PURPOSE/HYPOTHESIS: Anterior knee pain is a common condition found with young active individuals. Approximately 60% to 90% of adolescents have continued knee pain even following formal rehabilitation. Recently it has been acknowledged that maladaptive beliefs including pain catastrophizing and pain related fear, are adversely associated with anterior knee pain. The purpose of this study was to determine if a previous episode of knee pain effects beliefs about the current episode of knee pain. We hypothesize adolescents that have experienced a previous knee injury will have a higher mean pain related fear and lower self-efficacy for their current episode of knee pain.

NUMBER OF SUBJECTS: Fifty-three adolescents with anterior knee pain (mean $\pm$ SD age, 14.5 $\pm$ 1.7 years; 62% female) were recruited.

MATERIALS AND METHODS: This was a prospective study assessing adolescents (12-18 years) with anterior knee pain. A previous episode of knee pain was identified through self-report from the patient and or family. Pain related fear was assessed by the Fear-Avoidance Beliefs Questionnaire Physical Activity Subscale (FABQ-PA), Pain Catastrophizing Scale (PCS) and Tampa Scale of Kinesiophobia-11 (TSK). Self-efficacy was measured on a 0-6 scale, with 0 meaning no confidence in resolution of current symptoms and 6 meaning complete confidence in resolution of current symptoms and return to previous level of activity.

RESULTS: A previous episode of knee pain was reported by 43% ($n = 23$) of the adolescents. The mean $\pm$ SD FABQ-PA score was 14.9 $\pm$ 6.8. The mean PCS score was 15.3 $\pm$ 9.2. The mean TSK score was 21.8 $\pm$ 5.0. Adolescents who experienced a previous knee injury reports significantly higher FABQ-PA (previous injury, 17.4 $\pm$ 6.6; no previous injury, 12.9 $\pm$ 6.4; $P = .02$) and TSK scores (previous injury, 23.7 $\pm$ 5.0; no previous injury, 20.3 $\pm$ 4.5; $P = .02$) although the PCS showed no significant differences between groups (previous injury, 17.1 $\pm$ 9.8; no previous injury, 13.9 $\pm$ 8.5; $P = .21$). No significant differences in self-efficacy were noted between adolescents who did and did not report a previous knee injury ($P = .92$).

CONCLUSIONS: This study found that a previous episode of knee pain resulted in higher levels of pain related fear, but did not affect pain catastrophizing or self-efficacy. As pain related fear has been shown to be associated with changes in pain and disability, adolescents reporting previous knee injury may influence physiological readiness to return to prior level of activity.

CLINICAL RELEVANCE: The findings of this study suggest patients who report a previous knee injury may have higher pain related fear. These patients may require supplementary psychological informed education addressing maladaptive beliefs.

SP0134

MULTIFIDUS FATTY INFILTRATE EFFECT ON BALANCE IN YOUNG ATHLETES WITH EXTENSION-BASED LOW BACK PAIN

John Joseph Winslow, Rumit Singh Kakar, Andrew Getzin, Joshua M. Tome, Jared David Bauer, Tyler John Winslow

PURPOSE/HYPOTHESIS: Approximately three quarters of young athletes presenting with low back pain (LBP) have extension-based low back pain (EBLBP). Nearly half of these athletes are imaging positive for pars interarticularis fracture, those without fracture present with similar symptoms. Evidence is now mounting to show that the pain associated with EBLBP may not come from the pars interarticularis defect. Due to the common neural innervation of the surrounding structures, lumbar multifidus muscles (LMM) have been shown to become inhibited after a low back injury causing atrophy and fatty infiltration. Fatty infiltrate has been shown to be a predictor in return to play in young athletes with EBLBP. This study was designed to investigate the effect of LMM fatty infiltrate on balance in young athletes with EBLBP. Specifically, this study investigated the hypothesis that increased fatty infiltrate in LMM caused by EBLBP leads to increased balance deficits.

NUMBER OF SUBJECTS: Fifteen.

MATERIALS AND METHODS: This pilot study included 15 athletes, 10 females and 5 males, mean age of 18.3 years, with a primary complaint of EB LBP. Prior to testing, participants underwent magnetic resonance imaging (MRI) of the low back. Participants performed 2 tests on the Neurocom Clinical Research System: limits of stability (LOS) and sensory organization test (SOT). End point excursion (ECE), maximum excursion (MXE), directional control (DCL) and movement velocity (MVL) for LOS and composite scores from SOT were correlated using Pearson's correlation coefficient (r) ($P < .05$) to fatty infiltrate in the LMM using Goutallier fat infiltration classification (GC) scores. GC scores were also compared at L4-L5 levels to L5-S1 levels bilaterally.

RESULTS: GC of the LMM revealed significantly higher scores ($P = .001$) for both right and left LMM at L5-S1 (right, 1.8 ± 0.9 ; left, 1.6 ± 1.0) vertebrae level compared to L4-L5 (right, 1.0 ± 0.7 ; left, 0.9 ± 0.7). A negative correlation was observed between GC score for L5-S1 levels on both sides ($r = -0.608, -0.640$) and only right side at L4-L5 level ($r = -0.547$) and SOT composite score. Other low to moderate correlations observed were not statistically significant.

CONCLUSIONS: Clinical trends were observed for a relationship between balance and LLM fatty infiltrate. A larger sample size may show a greater correlation and warrants further investigation.

CLINICAL RELEVANCE: Regardless of the pathoanatomic reason for extension-based low back pain, inhibition of the LMM causing atrophy and fatty infiltrate may affect balance, sports performance, and return to play. Management of athletes with EBLBP should focus on proprioceptive training during sport-specific activities regardless of imaging outcomes.

SP0135

SURFACE EFFECTS AND 3-D OUTDOOR RUNNING KINEMATICS

Caroline Yeomans, Andrew P. Newnam, Alex Fox, Joshua Mark Schiemann, John David Willson

PURPOSE/HYPOTHESIS: Three-dimensional lower extremity running kinematics are relevant to the prevention and treatment of running-related injuries. Running kinematics are typically evaluated indoors on a treadmill but treadmill running kinematics may differ from outdoor running kinematics on varied terrain. The purpose of this study was to compare 3-D lower extremity joint kinematics and temporospatial characteristics of treadmill running to outdoor running on concrete and grass.

NUMBER OF SUBJECTS: Twenty recreational runners (mean age, 23.8 years; 14 female; running experience, 9.6 years).

MATERIALS AND METHODS: Wireless inertial sensors placed on the sacrum, thigh, tibia, and foot recorded 3-D segment orientations of the right leg at 120 Hz as participants completed running trials at a consistent speed

on a treadmill and over 2 level-ground outdoor surface conditions: concrete and grass. Peak sagittal and frontal plane hip, knee, and ankle joint angles during the stance phase of ten gait cycles and temporospatial measures including step rate, step length, and stance duration were compared between surface conditions using separate repeated measures ANOVAs and follow-up pairwise comparisons ($\alpha = .05$). The magnitude of the difference between conditions for variables found to be statistically significant was compared to minimum detectable difference values (MDD_{95}) determined from test-retest reliability data from the same participants.

RESULTS: Peak hip flexion was greater on concrete ($37.5^\circ \pm 4.5^\circ$, $P = .01$) and grass ($37.0^\circ \pm 3.6^\circ$, $P = .01$) compared to treadmill running ($33.9^\circ \pm 5.1^\circ$). Peak knee flexion was also greater on concrete ($47.5^\circ \pm 4.0^\circ$, $P < .01$) and grass ($45.1^\circ \pm 4.5^\circ$, $P = .01$) compared to treadmill running ($42.7^\circ \pm 5.7^\circ$). Increased hip and knee flexion during both outdoor surface conditions exceeded the MDD_{95} for both peak hip (3.1°) and knee (3.2°) joint flexion. Runners also demonstrated decreased peak hip adduction during outdoor running on concrete ($11.1^\circ \pm 5.0^\circ$, $P = .03$) and grass ($7.1^\circ \pm 4.9^\circ$, $P < .01$) compared to treadmill running ($15.6^\circ \pm 6.9^\circ$). The difference between grass and treadmill conditions exceeded the peak hip adduction MDD_{95} (6.0°). Step rate and step length were not different between conditions but stance duration was longer during concrete (0.29 ± 0.02 seconds, $P < .01$) and grass conditions (0.28 ± 0.02 seconds, $P < .01$) versus treadmill running (0.27 ± 0.02 seconds). The difference between concrete and treadmill conditions exceeded the stance time MDD_{95} (0.019 seconds). Peak ankle joint kinematics were not different between conditions.

CONCLUSIONS: While running on grass and concrete, participants demonstrated unique kinematics compared to treadmill running including increased hip and knee joint flexion, decreased hip adduction, and increased stance time.

CLINICAL RELEVANCE: Kinematic differences associated with varied training surfaces likely affect the magnitude and distribution of lower extremity muscle, bone, and joint loads during running. Recognition of these kinematic differences during running on varied terrain may inform training recommendations for the prevention or treatment of running-related injuries.

SP0136

SEQUENTIAL INTEGRATION OF CERVICAL MANUAL THERAPY AND VISUAL-VESTIBULAR THERAPY FOR CONCUSSION SYMPTOMS: PRAGMATIC RETROSPECTIVE ANALYSIS

Lauren Jamie Ziaks, Tessia De Mattos, Samantha Dena Vargas, Chelsea F. Brown, Christopher K. Wong

PURPOSE/HYPOTHESIS: Protracted concussion recovery (PCR), defined by persistent symptoms beyond 3 weeks, can include cervical, visual or vestibular dysfunction, or mixed symptoms. Rehabilitative protocols address specific systems, but integrated treatment for cervical, vision, and vestibular dysfunction is just emerging. The purpose of this study was to assess patient response to pragmatic PCR treatment sequenced for cervical manual therapy and exercise, vision and vestibular therapy, using clinical and patient-reported outcomes.

NUMBER OF SUBJECTS: Records for 59 people with PCR were reviewed with data analyzed for 25 men and 13 women, aged 26.9 ± 19.7 years, after sport (61%), fall (18%), motor vehicle accident (13%), and assault (8%) injuries. Fifteen (40%) had prior concussions; 24 (63%) had mixed cervical, vision and vestibular symptoms; 10 (26%) had vision and vestibular symptoms; and 4 (11%) had only cervical symptoms.

MATERIALS AND METHODS: This retrospective pre-to-post study of patients with PCR analyzed outcomes after pragmatic treatment sequenced, as indicated by impairment, for cervical manual therapy and exercise, vision and vestibular therapy. Clinical findings and patient-reported outcomes were obtained by trained clinicians in a concussion rehabilitation clinic. Clinical findings included gross cervical range of motion (CROM); brock string convergence distance, phoria and abnormal saccades; benign paroxysmal positional vertigo (BPPV), and the Balance

Error Scoring System (BESS). Patient-reported outcomes included the Post-Concussion Symptom Scale (PCSS) for associated sequelae including headache; Convergence Insufficiency Symptom Scale (CISS) for visual impairment; aTBI Vision Questionnaire for vision and vestibular dysfunction; Dizziness Handicap Inventory (DHI) to assess impact on functional, emotional, and physical quality of life; and Activities-specific Balance Confidence (ABC) scale. Paired *t* tests run in Stata with Bonferroni correction used for familywise error ($P < .05$).

RESULTS: Patients received treatment for cervical dysfunction (4.0 ± 3.8), vision and vestibular dysfunction (4.8 ± 3.0), and combined symptoms (1.7 ± 0.8) over 57.6 ± 34.0 days. Improvements at posttest included CROM (normal for 15, 55.6%) and full resolution of BPPV (28/28, 100%); vision function—Brock string score ($P < .001$; 95% CI: 3.3, 6.3; and balance—BESS, $P < .001$; 95% CI: 5.5, 11.6). Patient-reported outcomes improved for overall postconcussion symptoms—PCSS ($P = .001$; 95% CI: 12.4, 30.6; dizziness—DHI, $P < .001$; 95% CI: 14.5, 33.2); and vision symptoms—CISS ($P < .002$; 95% CI: 7.1, 18.3 and aTBI, $P < .001$; 95% CI: 13.4, 28.0); and balance confidence ABC ($P < .024$; 95% CI: -0.3, -0.1). Abnormal saccades, fusion convergence and divergence were insignificant ($P > .05$).

CONCLUSIONS: Patients with PCR symptoms receiving pragmatic treatment sequenced to progress from cervical to visual and vestibular therapy improved in all systems.

CLINICAL RELEVANCE: Treatment sequenced to first apply manual therapy and exercise to reduce cervical dysfunction, followed by therapeutic training to reduce vision and vestibular dysfunction—which utilizes cervical motion—may improve both clinical and patient-reported measures for people with PCR.

SP0137

KNEE-RELATED SYMPTOM SCORE AS A MARKER OF FUNCTIONAL DECLINE AT 2 YEARS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Christin Marie Zwolski, Adam Michael Culiver, Laura C. Schmitt

PURPOSE/HYPOTHESIS: National registry data show that nearly one third of patients report poor knee function and concurrent knee symptoms as early as 2 years after anterior cruciate ligament reconstruction (ACLR). The association of these symptoms, which have been linked to potential risk for knee osteoarthritis, and modifiable joint-specific factors has not yet been investigated. The purpose of this study was to test the hypothesis that patients with higher knee-related symptoms would also demonstrate lower functional performance at 2 years after ACLR.

NUMBER OF SUBJECTS: Sixty-two participants from a longitudinal prospective study of outcomes following primary ACLR (mean $\pm$ SD age, 23.1 ± 4.0 years; 38 female).

MATERIALS AND METHODS: At 2 years after ACLR (mean $\pm$ SD time, 27.8 ± 7.6 months), all participants completed the Knee injury and Osteoarthritis Outcome Score (KOOS), International Knee Documentation Committee (IKDC) subjective knee form, and International Physical Activity Questionnaire (IPAQ). Isometric quadriceps strength testing and a battery of 4 single-limb hop tests (single hop [SH], triple hop [TH], cross-over hop [CH], timed hop [TiH]) were also performed. A limb symmetry index (LSI) was calculated for all strength and hop tests [(involved/uninvolved) $\times 100\%$]. Functional recovery of knee-related symptoms was defined by a score of ≥ 84 on the KOOS Symptoms subscale, as published by previous national registry data. Participants were categorized as FR-YES (score ≥ 84) or as FR-NO (score < 84). Independent-samples *t* tests (Mann-Whitney *U* tests for nonnormally distributed data) were used to detect between-group differences in demographics, IKDC and IPAQ scores, and all strength and hop LSIs ($\alpha = .05$).

RESULTS: At 2 years following ACLR, 35 subjects (56.5%) were classified as FR-YES. There were no differences in age, height, weight, body mass index, or time from ACLR to study enrollment between the groups (all, $P > .05$). The FR-YES group had higher IKDC scores (FR-YES, 90.7 ± 7.9 ; FR-NO, 77.2 ± 15.4 ; $P < .001$) and greater SH LSI (FR-YES, $96.9\% \pm 5.0\%$; FR-NO, $89.9\% \pm 18.1\%$; $P = .044$). Self-reported physical activity on IPAQ-calculated total weekly metabolic equivalent minutes (MET-min) was higher in the FR-YES group (MD, 7053.0 MET-min) compared to the FR-NO group (MD, 3562.5 MET-min) ($U = 354.0$, $z = -2.728$, $P = .006$, $r = 0.32$), as was IPAQ-calculated weekly moderate-to-vigorous physical activity (MVPA) (FR-YES: MD, 3652.5 MET-min; FR-NO: MD, 1680.0 MET-min; $U = 450.5$, $z = -2.526$, $P = .012$, $r = 0.29$).

CONCLUSIONS: As hypothesized, at 2 years following primary ACLR, patients in the FR-NO group demonstrated lower IKDC scores and self-reported MET-min for both weekly total physical activity and weekly MVPA. The FR-NO group also demonstrated lower SH limb symmetry; however, no differences were found between groups for all other LSI comparisons.

CLINICAL RELEVANCE: The KOOS Symptoms subscale may serve as an important indicator of functional decline 2 years following ACLR. Early identification of poor knee function and concurrent knee symptoms in the years following ACLR may mitigate early and progressive knee-related disability.

LETTER TO THE EDITOR-IN-CHIEF

Letters to the Editor are reviewed and selected for publication based on the relevance, importance, appropriateness, and timeliness of the topic. Please see submission guidelines at www.jospt.org for further information. J Orthop Sports Phys Ther 2020;50(1):47-48. doi:10.2519/jospt.2020.0201

AS IF “SIT UP STRAIGHT” WERE THE ONLY STRATEGY WE USE

In my opinion, Slater et al² make 2 valid statements: (1) physical therapists should not be encouraging people to adopt and maintain a single version of correct posture for all sitting, standing, and bending activities; and (2) clinicians need to be wary about using language that instills unnecessary fear and caution in people who are trying (and possibly failing) to comply. However, I found it difficult to find common ground with this Viewpoint on several points. I also had a problem with the black-and-white nature of the perspective and found myself asking, “Where are all the grays?”

The physical therapists I know do not look at “people with low back pain” as a homogeneous population. We consider factors such as the patient’s stage of healing (acute, subacute, or chronic), the diagnosis, and the positions and movements that are most provocative. Treatment and advice vary depending on these factors.

The physical therapists I know do not treat by imprinting a theoretically correct posture onto their patients. Rather, we guide treatment by what is symptomatic and what is not. We are also guided by structural variations of each person.¹ People come in different shapes, sizes, and curves. Our treatments need to respect each person’s unique anatomy. The patient’s personality also dictates how we instruct him or her. Does he have a fragile and cautious nature? Is she the daredevil type? Instructions will change accordingly. So, I found the repeated references to “people with low back pain” frustrating,

knowing that there are so many different types of these people.

Though Slater et al² advocate for a new narrative in discussing posture and make valid points, they did not convince me that our profession has a real dilemma on its hands that requires changing our narrative on posture. Adding a sidebar to this discussion, I ask why is it that research rarely matches clinical observations of alignments and movements impacting pain and injury? How do we ensure that research reflects the “real life” of clinical practice?

*Howard Nelson, PT
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The author certifies that he has no affiliations with or financial involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the letter.

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RESPONSE

We thank Mr Nelson for his interest in our posture Viewpoint.⁶ Critical appraisal and debate, including letters to the editor, are important to ensure rigorous research. However, it seems that Mr Nelson misunderstood the intent of the published article, as reflected in the 2 main points raised in his letter.

First, Mr Nelson is not convinced that there is a need for a change in the posture narrative. While it may be the case that physical therapists known to him do not “treat by imprinting a theoretically correct posture onto their patients,” this does not reflect the data. Studies^{2,4,5} from different countries indicate that health care profes-

sionals, manual handling trainers, and members of the public believe that flexed postures in sitting, bending, and lifting tasks should be avoided. For physical therapy to be an evidence-based profession, it must be informed by good clinical or research data, not only by opinion.

Second, Mr Nelson is concerned by our use of the phrase “people with low back pain” and has interpreted it to mean that we consider all such people to be the same. We find this perplexing, as key messages of the Viewpoint challenge the predominant “one-size-fits-all” approach to posture. We included statements such as “comfortable postures vary between individuals, so it is useful to explore different postures,” “one size does not fit all,” and “preferred lifting styles are influenced by the naturally varying spinal curvatures.” Similarly, he raises the point that many factors, including personality, need to be considered, which was also highlighted in the Viewpoint. We presented the nuances of posture and made reference to factors such as mood, vigilance, beliefs, and body image. Labels that facilitate effective discussion and communication about groups with a shared feature do not discount other intrapopulation differences.

Mr Nelson poses interesting philosophical questions about the mismatch between research and clinical observations of movement and alignment in “real life.” Such questions warrant a longer discussion than is possible in this response. The complexity of human nature and the inherent limitations of research methods constrain what we can currently achieve in research. There are many different types of bias that are relevant to experimental and observational research, and an improved understanding of these biases is required to improve reliability of research.¹ It is also important to acknowledge and understand the influence of beliefs and personal bias (biases of intuitive judgment) on our experience of what is “real” in the clinical setting.³

We disagree strongly with the contention that beliefs around “correct” spinal

LETTER TO THE EDITOR-IN-CHIEF

posture do not need to evolve, and with the claim that we suggested all “people with low back pain” are the same. As evidence-based clinicians, we use good-quality data, with a knowledge of limitations and biases, to appropriately inform our understanding of “real life.”

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SEND Letters to the Editor-in-Chief

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No Differences Between Individuals With Chronic Idiopathic Neck Pain and Asymptomatic Individuals on 7 Cervical Sensorimotor Control Tests: A Cross-sectional Study

The control and accuracy of head movements, also known as cervical sensorimotor control, have been suggested to be important in the assessment of physical impairment in individuals with neck pain.^{8,9,21,42} Sensorimotor control, defined as all afferent and efferent information streams contributing to joint stability,³⁴ consists of multiple subsystems: proprioception and

kinesthesia are responsible for the sensation of head orientation, the vestibular system is responsible for postural balance and spatial orientation, and the visuomotor system processes visual information used for head and neck movements. If clinicians can identify cervical sensorimotor impairments in individuals with neck pain that differ from normal sensorimotor function, they may use this information to select specifically tailored interventions, potentially improving the management of neck pain conditions.^{1,9}

Several authors have suggested that characteristics of cervical sensorimotor control differ between individuals with various types of neck pain and asymptomatic individuals; however, this is based on studies with a variety of research designs (eg, cross-sectional,¹⁸ intervention^{5,40}), neck pain populations (eg, chronic³¹ and acute,²⁵ insidious⁴² and traumatic onset⁵⁰), participant groups (eg, older adults,³² adolescents,³⁹ Air Force pilots²⁸), and, notably, cervical sensorimotor control tests (eg, joint position error [JPE],³³ postural balance⁴⁹). A large proportion of these

• **OBJECTIVE:** Cervical sensorimotor outcomes have been suggested to be important in the assessment of individuals with neck pain. However, the large variety of sensorimotor control tests used in varying populations makes it difficult to draw conclusions about their clinical value. We aimed to compare cervical sensorimotor control outcomes between individuals with chronic idiopathic neck pain and asymptomatic individuals using a battery of recommended tests, and to investigate the correlation between cervical sensorimotor control outcomes and pain intensity and neck disability.

• **DESIGN:** Case-control study.

• **METHODS:** Fifty participants with chronic idiopathic neck pain and 50 age- and sex-matched asymptomatic controls completed 7 cervical sensorimotor control tests: joint position error (including joint position error torsion), postural balance, subjective visual vertical, head-tilt response, "the Fly," smooth pursuit neck torsion, and head steadiness. Between-group differences were investi-

gated with the Mann-Whitney *U* test. Correlations between tests and levels of neck pain and disability were investigated using the Spearman rho.

• **RESULTS:** There were no differences in cervical sensorimotor outcomes between participants with chronic idiopathic neck pain and asymptomatic controls for any test ($P = .203-.981$). For each test, "poor performers" consisted of both individuals with and without neck pain. Correlations were weak between tests and levels of neck pain ($r = 0.010-0.294$) and neck disability ($r = 0.007-0.316$).

• **CONCLUSION:** These findings suggest that sensorimotor control disturbances in individuals with chronic idiopathic neck pain may not be present, spawning debate on the clinical usefulness of these tests. *J Orthop Sports Phys Ther* 2020;50(1):33-43. Epub 23 Aug 2019. doi:10.2519/jospt.2020.8846

• **KEY WORDS:** cervical spine, chronic pain, proprioception

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neck pain studies have reported findings based on relatively small samples,⁴³ often without justification for sample size. There is little consistency between study findings, with some studies reporting differences in cervical sensorimotor control between individuals with neck pain and asymptomatic individuals^{9,21,31,36} and others reporting no differences.^{26,42,54} In studies with larger samples, heterogeneity of participants may confound findings, as pain mechanisms and vestibular function differ between neck pain conditions,⁴¹ and studies have included individuals across traumatic/nontraumatic, chronic/acute, and a range of severities of neck pain.^{24,37,55} Therefore, the body of evidence investigating differences in cervical sensorimotor control between individuals with neck pain and asymptomatic individuals lacks consistency in the findings between studies.

One specific type of neck pain, termed *idiopathic neck pain*, occurs without a clear reason for the onset of pain and generally develops gradually over time. It has been suggested that individuals with idiopathic neck pain may present with a sensorimotor control deficit.^{16,21} However, it is unlikely that the results of cervical sensorimotor control tests can be generalized across different neck pain populations.¹⁰ Of the studies that investigate cervical sensorimotor control in homogeneous samples, few focus solely on individuals with idiopathic neck pain,^{16,26,38} a condition that warrants more informed explanations of its etiology and pathophysiology.¹⁵ Findings across studies of individuals with idiopathic neck pain are inconsistent, with recent meta-analyses identifying only one test (JPE) that differentiated individuals with idiopathic neck pain from asymptomatic controls, albeit with questionable clinical relevance.^{8,43} However, as cervical sensorimotor control tests are being used clinically in individuals with idiopathic neck pain and numerous studies use these outcome measures in individuals with idiopathic neck pain, evidence regarding the attributes they assess and their applicability

to individuals with idiopathic neck pain is needed.

It is difficult to make clinical decisions about individuals with idiopathic neck pain due to the varying results of different cervical sensorimotor control tests from studies that differ across participant characteristics (duration and type of neck pain). Therefore, a study with a large homogeneous sample incorporating multiple cervical sensorimotor control test outcomes is needed. The present study reports outcomes from 7 cervical sensorimotor control tests (JPE, postural balance, subjective visual vertical, head-tilt response, “the Fly” test, head steadiness, and smooth pursuit neck torsion) and investigates whether there are differences in these outcomes between individuals with chronic idiopathic neck pain and asymptomatic individuals. It was hypothesized that there would be differences in cervical sensorimotor control between the 2 groups. To address the clinical relevance of cervical sensorimotor control outcomes, correlations between these tests and neck pain intensity and neck disability were analyzed.

METHODS

Design

THIS WAS A CROSS-SECTIONAL STUDY conducted between July 2016 and June 2017 approved by the Human Research Ethics Committee of The University of Newcastle (H2016-0099). All participants provided written informed consent.

Sample Size

With 7 cervical sensorimotor control tests as dependent variables, 7 sample-size calculations were conducted, using estimates of variable distributions from a meta-analysis⁸ or individual studies^{26,51} to determine the minimum sample size required to detect a difference between groups at an alpha level of .05 and power of 0.8. Of these, the largest sample-size estimate used a 0.75° variability in score on the subjective visual vertical test⁵¹ to

indicate that a 0.5° difference between groups would be detected with 36 participants per group. As this study was part of a larger study with follow-up measurements, 50 participants per group were recruited to allow for withdrawals.

Participants

Participants were recruited via flyers posted around the university where the study was conducted, a local research participant volunteer registry, through local newspaper and social media advertising, and from among patients attending local physical therapy practices. Participants with chronic idiopathic neck pain were eligible if they were 18 years of age or older, reported neck pain of at least 4/10 on a numeric rating scale at the time they inquired about the study, and had experienced pain for 12 weeks or longer. Neck pain was considered idiopathic when the onset was spontaneous and the cause was unknown. Asymptomatic participants had no current neck pain, had never sought treatment for neck pain, and were matched for sex and age with individuals with neck pain. Exclusion criteria for both the pain and asymptomatic groups were limited vision after correction, diabetes, migraine headaches, history of neck trauma or surgery, and other neurological or musculoskeletal conditions considered to affect sensorimotor control, such as low back pain, scoliosis, neuralgia, complex regional pain syndrome, joint reconstructions, or anterior cruciate ligament repairs. **TABLE 1** reports the characteristics of participants.

Cervical Sensorimotor Control Tests

Seven cervical sensorimotor control tests were included: JPE (both conventional³³ and with neck torsion⁴), postural balance,⁴⁹ subjective visual vertical,⁵¹ head-tilt response,¹¹ “the Fly,”²³ smooth pursuit neck torsion,⁴⁸ and head steadiness.⁵⁴ **TABLE 2** provides a description of all tests (including 21 outcomes representing different conditions for tests), the equipment used, and the outcome measures calculated for each test.

Procedure

Physical activity levels were quantified using the Godin-Shephard Leisure-Time Physical Activity Questionnaire.¹² Participants with neck pain completed three 100-mm visual analog scales (VASs), each anchored by “no pain” on the left and “worst pain imaginable” on the right, to assess (1) current pain, (2) average pain over the last 7 days, and (3) average pain over the last 4 weeks, as it has been shown that VAS response varies with different recall periods in individuals with neck pain.¹⁹ The Neck Disability Index (NDI [scored 0-50]) assessed perceived disability.⁵² Height was measured with a stadiometer to the nearest centimeter (Surgical and Medical Supplies Pty Ltd, Rose Park, Australia) and weight with a standard analog scale to the nearest kilogram (model 762 1019009; Seca GmbH, Hamburg, Germany). Cervical range of motion (ROM) in rotation (left and right), flexion, and extension was quantified with the Cervical Range of Motion instrument (Performance Attainment Associates, Lindstrom, MN), which has good test-retest reliability.² For each di-

rection, 3 measures were recorded, and the average of 3 trials was used to calculate the total ROM in the transverse (rotation) and sagittal (flexion/extension) planes. Range of motion was assessed because it is a physical measure that is commonly impaired in individuals with chronic idiopathic neck pain and allowed for a comparison of our neck pain sample with previously reported samples. All tests were administered by one assessor, and blinding to group was not possible.

The order of ROM test directions and cervical sensorimotor tests was randomized using a script written in MATLAB (R2015a; The MathWorks, Inc, Natick, MA).

Data Analysis

Data were checked for normality prior to analyses, and nonparametric tests were used where appropriate. Mann-Whitney *U* tests determined differences in ROM and cervical sensorimotor test outcomes between groups. For participants with neck pain, the Spearman rho determined correlations between cervical sensorimotor test outcomes and levels of pain and

disability. As the majority of distributions of cervical sensorimotor tests were positively skewed (few participants with high scores, indicating poor performance), we further examined the data for individuals who were considered “poor performers.” Subgroups were determined by a cutoff score, selecting all (neck pain and asymptomatic) participants whose score was in the highest 10% of observations (ie, poor performers). Additionally, the number of tests where a participant performed poorly was summed, to determine whether poor performance on multiple tests was related to pain, disability, or other participant characteristics. Differences in proportions of poor performers within the neck pain and asymptomatic groups were determined using chi-square tests. All statistical analyses were performed using SPSS Version 24.0 (IBM Corporation, Armonk, NY).

RESULTS

Cervical Sensorimotor Control Outcomes

TABLE 3 DETAILS THE OUTCOMES FOR ROM and all cervical sensorimotor control tests. Range of motion (for all movement directions measured) was significantly less for individuals with idiopathic neck pain compared to asymptomatic controls. There were no significant differences between individuals with idiopathic neck pain and asymptomatic individuals for any of the tests. Only weak correlations between cervical sensorimotor control tests and levels of neck pain and disability were found (**TABLE 4**). Except for 2 significant correlations between head-tilt response and current neck pain intensity ($\rho = 0.294$, $P = .042$) and neck disability ($\rho = 0.316$, $P = .029$), all other correlations were not significant (**TABLE 4**).

Participant scores for JPE tests were normally distributed, but for all other cervical sensorimotor tests, scores were right skewed, indicating few poor performers. Histograms with cutoff scores for subgroups of poor performers for each test are illustrated in the **FIGURE**. The proportions of poor performers

TABLE 1

CHARACTERISTICS OF THE PARTICIPANTS^a

	Control (n = 50)	Neck Pain (n = 50)	P Value ^b
Sex (female), n	27	30	.55 ^c
Age, y	34.5 (26.0-58.0)	35.5 (24.0-55.3)	.86 ^d
Body mass index, kg/m ²	25.0 (22.9-27.8)	24.8 (21.6-29.3)	.86 ^d
Physical activity, n ^e			.82 ^c
Insufficiently active	13	11	
Moderately active	8	10	
Active	29	29	
VAS (0-100 mm): current pain ^f	NA	30.16 ± 18.77	NA
VAS (0-100 mm): 7-d pain	NA	49 (26-62)	NA
VAS (0-100 mm): 4-wk pain ^f	NA	50.78 ± 20.06	NA
Pain duration, mo ^f	NA	130 ± 148	NA
NDI (0-50) ^f	NA	14.96 ± 6.19	NA

Abbreviations: NA, not applicable; NDI, Neck Disability Index; VAS, visual analog scale.

^aValues are median (interquartile range) unless otherwise indicated.

^bBetween-group differences: no statistically significant differences were found.

^cPearson chi-square test.

^dMann-Whitney *U* test.

^ePhysical activity was measured by the Godin-Shephard Leisure-Time Physical Activity Questionnaire.

^fValues are mean ± SD.

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within the neck pain and asymptomatic groups for each test were not significantly different (TABLE 5). Mean values for the number of tests with participants performing poorly were not different between groups (neck pain mean $\pm$ SD, 1.4 ± 1.5 ; asymptomatic, 1.6 ± 1.6 ; $P = .660$). The number of tests where a participant performed poorly correlated only weakly with group demographics (sex, $\rho = -0.014$; age, $\rho = 0.193$; body mass index, $\rho = 0.107$; physical activity level, $\rho = -0.154$), with cervical ROM (transverse plane, $\rho = -0.243$; sagittal plane,

$\rho = -0.174$), and with pain and disability levels (current pain, $\rho = 0.083$; 7-day average pain, $\rho = 0.040$; 4-week average pain, $\rho = 0.046$; NDI, $\rho = 0.104$).

DISCUSSION

THIS STUDY FOUND NO DIFFERENCES in cervical sensorimotor control test outcomes between individuals with chronic idiopathic neck pain and age- and sex-matched asymptomatic control participants. Each test was only weakly correlated with pain and disabil-

ity, consistent with recent studies investigating JPE.^{4,26,29} All tests (except for JPE) were positively skewed, indicating that most participants performed well. Thus, the tests may not be sufficiently challenging to discriminate between individuals with and without neck pain. Alternatively, individuals may have an inherent performance ability on these tests, and neck pain might not influence this. As cervical sensorimotor control tests cannot be validated due to the lack of a gold standard, it is possible that the available tests are not valid tools to as-

TABLE 2

DESCRIPTION OF CERVICAL SENSORIMOTOR CONTROL TESTS

Test	Description	Equipment	Data Collection and Analysis ^a
JPE (conventional and torsion)	Conventional: the participant was seated 90 cm from a target on the wall. A laser pointer facing straight ahead was placed on top of the head using a head mount. ³³ The seat and target were positioned so that the laser pointer was exactly in the center of the target. The participant was instructed to rotate (to the right or left), flex, or extend the neck, moving away from the center of the target, and then return to the starting position. Participants were blindfolded to exclude any visual information. A foam cushion was placed under the feet to limit sensory reference information Torsion ^a : a laser pointer facing straight ahead was attached to the mid-sternum region and the participant was blindfolded. In a neutral position, the center of the target was lined up with the position of the laser pointer. While the examiner gently held the head with 2 hands to maintain it in neutral, the participant was asked to rotate the trunk away from the target and rotate back to the starting position	A custom-made circular target ⁴ was used to record errors from the starting position. A standard laser pointer (Electus Distribution Pty Ltd, Rydalmere, Australia) on a custom head mount was used	The distance (millimeters) identified by the laser on the target between the start position (manually placed in neutral) and end (return) position was measured for the head (conventional) and trunk (torsion). This distance was used to calculate the JPE in degrees, averaged over the 3 trials for each movement direction (right, left, up, down) Psychometrics (conventional) Intrarater: ICC = -0.01 to 0.50; 0.59-0.81 ³⁰ ; SEM, 1.5°-3.5° ⁴⁶ and interrater: ICC = -0.20 to 0.64; SEM, >0.5° ⁴⁵
Postural balance (conventional and torsion)	The participant was asked to stand in a comfortable stance for 30 seconds ⁴⁹ under the following 6 conditions: • Eyes open, straight ahead • Eyes closed, straight ahead • Eyes open, torsion left • Eyes closed, torsion left • Eyes open, torsion right • Eyes closed, torsion right To achieve the neck torsion stance, ⁵³ the examiner held the participant's head in its neutral position while the participant rotated the trunk and lower limbs 45°. Paper tape strips on the force platform marked the reference positions to align the participant's feet	A force platform (model 9260AA6; Kistler Group, Winterthur, Switzerland) and ARS (S2P Ltd, Ljubljana, Slovenia) software were used to record center of pressure	Sway area (mm ²) was recorded over 30 seconds for each of the 6 conditions
Subjective visual vertical	In a virtual reality device, 2 dots representing the end points of a 20° tilted imaginary line were presented within a square that was tilted 18°. Both the tilted square and dots were positioned either clockwise or counterclockwise, which was randomized by custom software (Treleaven and Takasaki ⁵¹). The computer mouse could be used to rotate a button by clicking and holding, allowing rotation of the dots by a minimum of 0.01°. The participant was instructed to reposition the dots so that the imaginary line was positioned vertically (ie, dots right above each other)	An Oculus Rift (SDK 2.0; Facebook Technologies, LLC, Menlo Park, CA) virtual reality device was used	The rotational deviation of the imaginary line represented by the 2 dots from the true vertical (degrees) was recorded as the outcome, and the average of 20 repetitions was calculated

Table continues on page 37.

sess sensorimotor control in people with idiopathic neck pain. In contrast to cervical sensorimotor control outcomes, ROM was reduced in all directions in individuals with neck pain compared to controls, consistent with previous studies.^{6,17,26,28,55} The collective results from the current study question the clinical utility of cervical sensorimotor control tests for individuals with chronic idiopathic neck pain.^{38,55}

Previous Research

Sensorimotor control is complex and believed to comprise multiple subsystems, including proprioception, kinesthesia, and the visuomotor and vestibular systems.^{3,34,35,44} Although most studies addressing cervical sensorimotor control have reported outcomes for single tests,^{16,22,31,36,46,54} using a single test to evaluate the subsystems of cervical sensorimotor control provides a limited rep-

resentation of their complexity. Recently, however, 2 studies have evaluated cervical sensorimotor control using combinations of different tests in participants with idiopathic neck pain.^{26,47}

Meisingset et al²⁶ used 4 tests to evaluate cervical sensorimotor control in 166 participants: JPE, the Fly, head steadiness, and postural balance. Only 1 cervical sensorimotor test outcome (head steadiness) significantly differed between

TABLE 2

DESCRIPTION OF CERVICAL SENSORIMOTOR CONTROL TESTS (CONTINUED)

Test	Description	Equipment	Data Collection and Analysis ^a
Head-tilt response	A white line, tilted either 5° or 15° clockwise or 25° or 15° counter-clockwise, was displayed in the virtual reality device. The participant was instructed to laterally flex the neck so that the presented line was positioned exactly vertically in space. While holding the head still in the required position, the head position was recorded before the next line was presented. Testing was performed using custom software (Libra@Home, Jerusalem, Israel) as described by Geisinger et al ¹¹	An Oculus Rift (SDK 2.0; Facebook Technologies, LLC, Menlo Park, CA) virtual reality device was used	Head position (error of the line from the true vertical in degrees) was recorded using the Oculus Rift's head-tracking sensors, with the average over 20 repetitions calculated
The Fly	On a computer screen, a representation of the head position was displayed with a plus sign, as well as a moving target (the "Fly"). ^{22,23} The participant was instructed to move the head (and thus the plus sign) in order to follow the target, aiming to place the "+" over the target	The original Fly test software was used, as introduced by Kristjansson and Oddsdottir, ²³ together with an electromagnetic tracking device (LIBERTY and FASTRAK; Polhemus, Colchester, VT) to record head movement	Movement accuracy (error from target in millimeters), being the distance between the "+" sign and the target, was measured continuously, with the accuracy being the average error over the duration of the test. This was repeated for 3 different movement patterns—easy, medium, and difficult—which differed in trajectory length, duration, and complexity <u>Psychometrics</u> Intrarater: ICC = 0.74–0.81 ²³
Head steadiness	The participant was asked to lift the head approximately 1 cm off the table and hold it stationary for 40 seconds. Two conditions were investigated: low load, with the participants seated on a treatment table with the back and head supported at a 60° angle, and high load, with the participant lying supine on a horizontal treatment table ^{26,54}	An electromagnetic motion-tracking device (LIBERTY and FASTRAK; Polhemus, Colchester, VT) was used to record head movement	Participants who were not able to hold the lift position for a minimum of 10 seconds were excluded from the analysis. Raw data from continuous sensor recordings collected at 240 Hz were used to calculate average movement velocity in millimeters per second over 40 seconds
Smooth pursuit neck torsion	Custom-made equipment (identical to that used in Tjell and Rosenhall ⁴⁶ and Treleaven et al ⁴⁸) consisted of a laser pointer attached to a motor positioned behind the participant, who was seated facing a wall 100 cm away. The laser pointer, which was just above the head, was projected on the wall and oscillated smoothly left and right with a consistent speed of 20°/s, with a visual angle of 40° and a frequency of 0.2 Hz. The participant was asked to follow the moving target with the eyes, while keeping the head still in its neutral position. Eye movements were recorded while the target moved left to right 10 times. This was done in 3 conditions: with the body straight ahead and also in a (right and left) torsion position in which the body was rotated 45° on the chair while the head was kept still	Eye muscle movements were recorded with Ag/AgCl surface electrodes (Cleartrace; CONMED Corporation, Utica, NY) placed bilaterally just lateral to the lateral corners of the eyes, using PowerLab (ADInstruments, Dunedin, New Zealand)	Gain difference of eye saccades, calculated as the difference between the gain in neutral position and the gain in average torsion (left and right) position, was recorded using surface electro-oculography

Abbreviations: ICC, intraclass correlation coefficient; JPE, joint position error; SEM, standard error of measurement.

^aPsychometric data were available only for the JPE test and the Fly test.

individuals with idiopathic neck pain and asymptomatic individuals. However, the head-steadiness test, which requires individuals lying supine to lift their head off the plinth and hold it for 40 seconds, might be considered a test of muscle endurance rather than cervical sensorimotor control. Thus, these findings provide little evidence for sensorimotor control changes in individuals with idiopathic neck pain. The findings of the current study agree with those of Meisingset et al,²⁶ except we also found no difference between groups for the head-steadiness test. This conflicting finding may be attributable to slightly different participant samples, as the current study recruited via advertising and Meisingset et al²⁶ recruited from private physical therapy clinics and a specialized pain clinic. Nevertheless, the notion of changes in cervical sensorimotor control in individuals with chronic idiopathic neck pain is not supported by the findings reported by Meisingset et al²⁶ and those in the current study, which calls into question the clinical relevance of cervical sensorimotor control testing in individuals with idiopathic neck pain. Only 1 other study⁴⁷ reported outcomes from multiple cervical sensorimotor control tests (smooth pursuit neck torsion, JPE, and postural balance). That study lacked an asymptomatic control group, so we cannot determine whether the tests can discriminate individuals with idiopathic neck pain from asymptomatic individuals.

Studies have compared cervical sensorimotor control outcomes between individuals with idiopathic neck pain and traumatic neck pain (mainly whiplash injuries). Most reported no differences between groups,^{21,23,42} but some reported (small) differences for postural balance^{10,27} and the subjective visual vertical test,⁵¹ though it is unclear which group had greater deficits in cervical sensorimotor control. Field et al¹⁰ found greater postural sway in individuals with traumatic neck pain in normal stance, whereas in narrow stance (increased difficulty) the idiopathic neck pain group performed worse. They suggested that a general stiffening strat-

egy in individuals with traumatic neck pain might explain this phenomenon. Treleven and Takasaki⁵¹ found that individuals with idiopathic neck pain performed worse than those with whiplash on the subjective visual vertical test. They hypothesized that higher disability levels (39.9 versus 21.5 on the 50-point NDI) in individuals with whiplash may contribute to their perception of the task as difficult, possibly causing them to increase their mental effort to perform well. Alternatively, they suggested that the often unilateral nature of idiopathic neck pain (as opposed to the bilateral pain common in whiplash) may be the reason that indi-

viduals with idiopathic neck pain perform worse on balance and spatial orientation tasks, though they did not report the proportions of those with unilateral pain in their sample.⁵¹ Alternatively, there may be no differences between the neck pain and asymptomatic groups, and varying results may be due to different samples, bias, or noise in the data.

Cervical Sensorimotor Control and Idiopathic Neck Pain

Evidence on cervical sensorimotor control tests in individuals with idiopathic neck pain is ambiguous and inconsistent.⁸ Several studies have found differences be-

TABLE 3

OUTCOMES OF PHYSICAL TESTS

	Control (n = 50) ^a	Neck Pain (n = 50) ^a	P Value ^b
Range of motion, deg			
Right rotation	71.0 (64.7-78.0)	62.0 (48.0-69.3)	<.001 ^c
Left rotation	68.0 (60.0-76.7)	60.7 (50.7-68.0)	.001 ^c
Total, transverse plane	139.3 (125.5-153.8)	124.3 (97.8-137.7)	<.001 ^c
Flexion	69.7 (62.0-81.3)	59.3 (50.0-65.3)	<.001 ^c
Extension	69.0 (58.0-78.0)	65.0 (50.7-70.7)	.03 ^c
Total, sagittal plane	141.0 (125.7-151.3)	125.3 (103.7-134.2)	<.001 ^c
Cervical sensorimotor control test			
Joint position error, deg			
Conventional	3.92 (3.11-4.75)	3.83 (3.20-4.58)	.866
Torsion	4.38 (3.48-5.83)	4.88 (3.54-6.83)	.238
Postural balance, mm ²			
Eyes open	227.50 (180.75-275.75)	227.50 (176.50-298.50)	.945
Eyes closed	280.00 (242.00-365.25)	280.00 (208.75-391.25)	.981
Torsion, eyes open	254.00 (209.63-285.75)	261.00 (211.50-311.88)	.751
Torsion, eyes closed	300.00 (236.63-367.63)	314.50 (260.25-401.25)	.506
Subjective visual vertical, deg	4.01 (2.91-6.07)	3.74 (1.92-6.08)	.236
Head-tilt response, deg	2.64 (1.96-3.64)	2.90 (2.01-4.42)	.515
The Fly, mm			
Pattern A (easy)	2.07 (1.81-2.74)	2.10 (1.86-2.50)	.912
Pattern B (medium)	2.34 (1.96-3.28)	2.16 (1.94-2.66)	.222
Pattern C (difficult)	3.06 (2.24-3.71)	2.82 (2.42-3.53)	.625
Head steadiness, mm/s			
Low load	0.51 (0.37-0.76)	0.41 (0.35-0.62)	.247
High load	0.66 (0.46-0.91)	0.61 (0.50-0.78)	.76
Smooth pursuit neck torsion, gain difference	0.012 (0.004-0.025)	0.009 (0.002-0.022)	.203

^aValues are median (interquartile range).

^bBetween-group differences: all P values were based on independent-samples Mann-Whitney U tests.

^cStatistically significant (P ≤ .05).

tween individuals with idiopathic neck pain and asymptomatic individuals for JPE,^{21,31,36,42} postural balance,¹⁶ subjective visual vertical,⁵¹ and the Fly,^{22,23} whereas others found no differences for JPE,^{21,26,31,55} postural balance,^{16,26,27} subjective visual vertical,⁵¹ head steadiness,⁵⁴ and the Fly.²⁶ The assumption that cervical sensorimotor control is altered in individuals with chronic idiopathic neck pain is based on cross-sectional studies with inconsistent findings,^{13,14,18,27,31,36,37,42} Small sample sizes, as well as a large number of statistical tests^{4,5,18,26} and a lack of blinding,^{20,36} may possibly lead to studies finding significant differences between pain and asymptomatic groups based on chance alone.

The test with the most support in the literature for discriminating individuals with neck pain is the JPE test, with 2 recent meta-analyses^{8,43} reporting small but statistically significant differences (0.1°-3.0°^{9,43} and 0.5°⁹⁸) indicating greater JPE in individuals with idiopathic neck pain compared to asymptomatic controls.

However, these small mean differences may not be clinically meaningful. A systematic review⁷ found that only 50% of included studies reported significant differences in JPE between individuals with idiopathic neck pain and asymptomatic individuals. These findings question the clinical utility of assessing JPE in individuals with idiopathic neck pain.

One possible explanation for nonsignificant findings is that the tests may not be sensitive enough to discriminate between individuals with chronic idiopathic neck pain and asymptomatic individuals. Alternatively, on observing the distributions of the outcome values, the tests may have an inherent ceiling effect and might not be capable of discriminating a very good performance from a good performance. However, assuming we could develop tests with better sensitivity to detect smaller differences in cervical sensorimotor control between individuals with idiopathic neck pain and asymptomatic controls, the magnitude of these differences would be

small, bringing into question their clinical relevance. If a new test, measuring a different construct of cervical sensorimotor control, could detect a meaningful difference between people with neck pain and asymptomatic individuals, it may be useful in differentiating these 2 groups.

Another possible explanation for the findings in the present study is that there is, in fact, no difference in cervical sensorimotor control between individuals with idiopathic neck pain and asymptomatic individuals. It could be that the distributions found in this study, including the poor performers, represent a normal spread of biological responses. The finding that the tests do not discriminate between groups in the current study is strengthened by the weak correlations found between cervical sensorimotor outcomes and levels of neck pain and neck disability.

Strengths and Limitations

A strength of this study is its large, homogeneous sample of individuals with

TABLE 4

CORRELATIONS BETWEEN CERVICAL SENSORIMOTOR CONTROL TEST OUTCOMES AND PAIN (3 RECALL PERIODS) AND DISABILITY

Cervical Sensorimotor Control Test	Current Pain VAS		7-d Pain VAS		4-wk Pain VAS		NDI	
	ρ	P Value	ρ	P Value	ρ	P Value	ρ	P Value
Joint position error								
Conventional	-0.081	.575	-0.118	.418	0.176	.225	0.119	.409
Torsion	-0.058	.69	-0.124	.397	-0.089	.542	-0.034	.817
Postural balance								
Eyes open	0.02	.89	-0.045	.759	0.022	.878	0.176	.222
Eyes closed	-0.155	.282	-0.129	.375	-0.038	.794	-0.044	.762
Torsion, eyes open	-0.074	.608	-0.051	.729	0.126	.389	0.129	.373
Torsion, eyes closed	0.029	.841	0.059	.688	0.229	.114	0.125	.387
Subjective visual vertical	0.181	.208	0.082	.575	0.034	.817	0.116	.424
Head-tilt response	0.294	.042 ^a	0.227	.124	0.093	.532	0.316	.029 ^a
The Fly								
Easy	0.05	.732	-0.028	.848	-0.073	.619	-0.113	.433
Medium	0.13	.367	0.1	.492	0.123	.402	0.09	.534
Difficult	0.237	.097	0.106	.47	0.125	.391	0.063	.665
Head steadiness								
Low load	-0.125	.388	-0.149	.308	-0.149	.307	-0.083	.568
High load	-0.174	.237	-0.247	.094	-0.13	.384	-0.141	.339
Smooth pursuit neck torsion	-0.01	.363	0.135	.15	0.122	.949	0.007	.475

Abbreviations: NDI, Neck Disability Index; VAS, visual analog scale.

^aStatistically significant ($P \leq .05$).

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chronic idiopathic neck pain. Groups were well matched for sex, age, body mass index, and physical activity level, which might be thought to influence cervical sensorimotor control. Pain and disability scores for participants with neck pain were sufficient, and are similar to those reported in previous studies.^{9,18,21,26,27,36,42,53} Furthermore, the median ages for both

groups are similar to the populations of previous studies.^{21,26,27,36,49,51,53}

Another strength was that the cervical sensorimotor test methods were replicated from the original reported test methods (TABLE 2) by closely collaborating with the research groups that developed each test. Identical materials and software were used for conventional and

torsion JPE⁴ and the Fly,²³ for which the complete set of original testing equipment was sent to our lab for use. Original software (with similar hardware) was used for the subjective visual vertical,⁵¹ head-tilt response,¹¹ and smooth pursuit neck torsion⁴⁸ tests.

Though assessor blinding was not possible, bias during testing was unlikely,

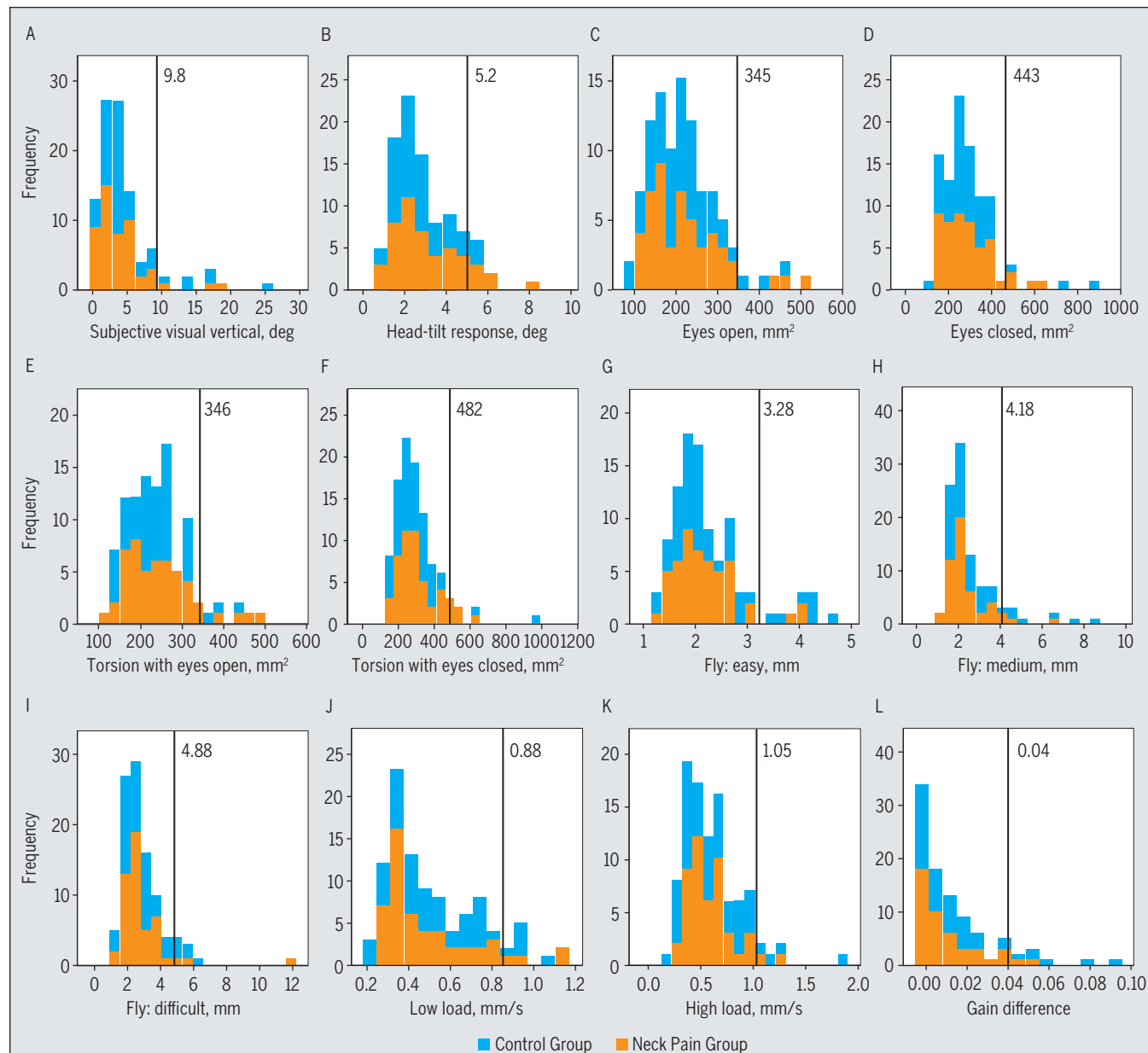


FIGURE. Distribution for all skewed outcomes with cutoff values (highest 10%) for "poor performers." (A) Subjective visual vertical, (B) head-tilt response, (C) postural balance with eyes open, (D) postural balance with eyes closed, (E) postural balance torsion with eyes open, (F) postural balance torsion with eyes closed, (G) the Fly: easy, (H) the Fly: medium, (I) the Fly: difficult, (J) head steadiness: low load, (K) head steadiness: high load, and (L) smooth pursuit neck torsion.

as most tests utilized computerized data collection. Other than JPE, the assessing researcher had no influence on the recording or calculation of outcomes, and based on expectations of a difference between groups from previous studies, bias toward a nil result is unlikely. To eliminate potential bias in the manual identification of saccades in the analysis of smooth pursuit neck torsion data, all electro-oculography recordings were deidentified by a researcher (S.S.) not involved in the identification of these signals.

The current sample is larger compared to previous studies reporting these outcomes in individuals with idiopathic neck pain. Participants were mainly recruited through advertising, with only 1 of the 50 participants with neck pain referred by a physical therapist. The neck pain group in this study could have differed from a treatment-seeking patient sample. However, the majority of previous studies testing cervical sensorimotor control have also recruited through advertising,^{4,5,10,18,24,32,37,40,47-51,53} so our sample

is likely to be similar to those of the studies used for comparison.

Participants performed all tests in 1 session (approximately 75 minutes), so cervical sensorimotor skills may have improved throughout the session. To prevent a practice effect, the order of tests was randomized. Furthermore, no previous study has reported any learning effects from practice with any of the tests.

The neck pain group in the present study reported high levels of physical activity, similar to the asymptomatic control group. Higher levels of physical activity might contribute to better performance on cervical sensorimotor control tests, despite the presence of neck pain. However, as physical activity level is not a commonly reported outcome in neck pain research, it is unknown whether our sample differs from others in this aspect.

CONCLUSION

THIS STUDY FOUND THAT THE OUTCOMES OF 7 cervical sensorimotor control tests are not significantly

different between individuals with chronic idiopathic neck pain and asymptomatic age- and sex-matched controls. Cervical sensorimotor control test outcomes were only weakly correlated with neck pain intensity and neck disability. These results question the clinical utility of cervical sensorimotor control tests in individuals with chronic idiopathic neck pain. ●

KEY POINTS

FINDINGS: This study found no differences in cervical sensorimotor control outcomes between individuals with chronic idiopathic neck pain and asymptomatic sex- and age-matched individuals. None of the outcomes correlated strongly with neck pain intensity or neck disability.

IMPLICATIONS: The clinical usefulness of tests that do not differentiate between patients and asymptomatic controls, and that do not correlate with pain intensity or disability, is questionable.

CAUTION: As the pathophysiology of chronic idiopathic neck pain may be considerably different compared to other neck pain conditions, it is unknown whether the outcomes would be similar in other neck pain populations, such as acute neck pain and traumatic neck pain.

STUDY DETAILS

PATIENT/PUBLIC INVOLVEMENT: Patients were not involved in the design, conduct, interpretation, or translation of this research.

AUTHOR CONTRIBUTION: Dr de Zoete collected the data and wrote the manuscript. Drs Osmotherly, Rivett, and Snodgrass contributed to and approved the final version of the manuscript. Drs de Zoete, Osmotherly, Rivett, and Snodgrass conceived the design of the manuscript.

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TABLE 5

CUTOFF VALUES SUGGESTING POOR PERFORMERS AND PROPORTIONS OF POOR PERFORMERS WITHIN EACH GROUP

Cervical Sensorimotor Control Test	Cutoff Value	Control (n = 50) ^a	Neck Pain (n = 50) ^a	P Value ^b
Postural balance, mm ²				
Eyes open	345	5 (10)	5 (10)	.1000
Eyes closed	443	4 (8)	6 (12)	.505
Torsion, eyes open	346	5 (10)	5 (10)	.1000
Torsion, eyes closed	482	3 (6)	4 (8)	.695
Subjective visual vertical, deg	9.76	7 (14)	3 (6)	.182
Head-tilt response, deg	5.21	3 (6)	7 (14)	.182
The Fly, mm				
Pattern A (easy)	3.28	7 (14)	3 (6)	.182
Pattern B (medium)	4.18	6 (12)	4 (8)	.505
Pattern C (difficult)	4.88	7 (14)	3 (6)	.182
Head steadiness, mm/s				
Low load	0.88	6 (12)	4 (8)	.505
High load	1.05	6 (12)	3 (6)	.295
Smooth pursuit neck torsion, gain difference	0.042	6 (12)	4 (8)	.505

^aValues are n (percent).

^bAll P values were based on chi-square tests for differences in proportions for each group.

Eythor Kristjánsson, for making available software and hardware that allowed us to use the original version of the Fly; that head-tilt response testing was undertaken with custom software (Libra@Home, Jerusalem, Israel); and the support of Dr Julia Treleaven for making available test and analysis software (subjective visual vertical, smooth pursuit neck torsion) and for training Dr de Zoete in the analysis of electro-oculography recordings for the smooth pursuit neck torsion test.

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FIGURE 1. Oblique fluoroscopic view of the right hand showing an apparent oblique fracture (arrow).

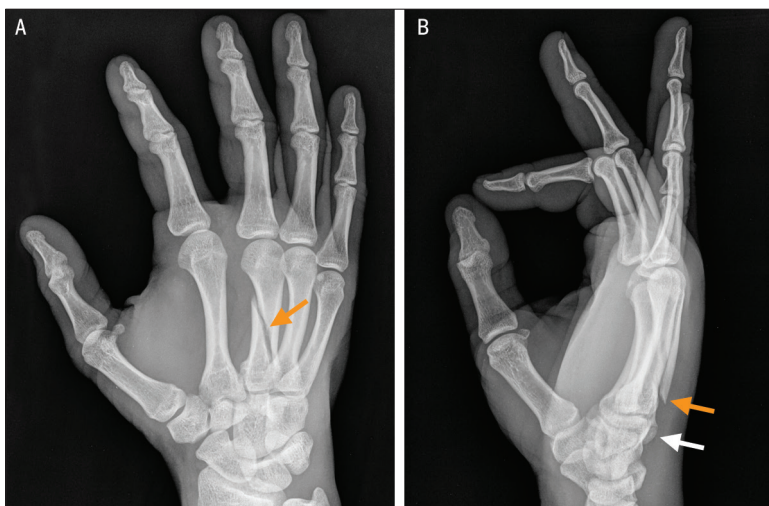


FIGURE 2. (A) Oblique and (B) lateral radiographs demonstrating a displaced oblique fracture (orange arrows) through the third metacarpal, with mild volar angulation of the distal segment. Mild dorsal carpal bossing is also noted (white arrow).

Acute Fracture of the Third Metacarpal in a Handball Player

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A 20-YEAR-OLD RIGHT HAND-DOMINANT male military cadet presented to the direct-access physical therapy clinic complaining of pain and swelling of his right hand. He reported that, while competing in a team handball match the day before, he suffered an axial load to his third metacarpal from his opponent's palm while trying to block a shot.

Examination findings included edema and ecchymosis to the dorsal and palmar surfaces of his right hand. Manually tested grip strength was decreased in the right hand compared with the left, with increased pain during this activity. Upon visual inspection, there was nominal digit

shortening, a loss of knuckle contour,² and marked tenderness to palpation over the third metacarpal. Due to suspicion of a third metacarpal fracture, fluoroscopy was performed on the cadet's hand in the physical therapy clinic, and an apparent oblique fracture was noted (**FIGURE 1**). Confirmatory images were ordered (**FIGURE 2**), in addition to an orthopaedic referral. Three days after the orthopaedic consultation, the cadet underwent an open reduction internal fixation (**FIGURE 3**, available at www.jospt.org). The cadet wore a brace for 4 weeks; thereafter, he began hand and forearm strengthening before returning to unrestricted activities 6 weeks after surgery.

It is important that physical therapists differentiate a metacarpal fracture from other common hand injuries, such as phalangeal fractures and scapholunate dissociation, by identifying signs and symptoms such as digit shortening and loss of knuckle contour. Standard posterior-to-anterior, oblique, and lateral radiographs are usually sufficient to assess the hand for fractures.¹ Surgery is indicated for closed metacarpal fractures to achieve successful reduction when malrotation and substantial shortening of the metacarpal are present.² *J Orthop Sports Phys Ther* 2020;50(1):44. doi:10.2519/jospt.2020.9034

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- The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the US Army or Department of Defense.

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The Role of Physical Therapists in Fighting the Type 2 Diabetes Epidemic

Diabetes is a serious disease that has been identified by world leaders as 1 of 4 noncommunicable diseases to be targeted for action.¹¹⁰ Worldwide prevalence of diabetes nearly quadrupled from 108 million persons in 1980 to 422 million in 2014, while the age-adjusted prevalence nearly doubled from 4.7% to 8.5% during the same period.¹¹⁰ As it has in the past 2 decades, the prevalence of diabetes is expected to rise further as the population ages and adult obesity rates continue to increase.^{46,76} Implementation of effective interventions to delay the onset of diabetes and reduce the effects of established diabetes is desperately needed.

It is estimated that up to 80% of patients referred to outpatient physical

therapy have diabetes, prediabetes, or diabetes risk factors,⁶¹ providing the perfect opportunity for physical therapists to intervene. Diabetes has the potential to negatively impact every tissue important for maintaining optimal function of the body's systems required to produce hu-

man movement, collectively known as the human movement system (eg, musculoskeletal, nervous, endocrine, pulmonary, cardiovascular, integumentary).

Given the impact of diabetes on health and well-being, it is vital that physical therapists assert their role as front-line providers for patients with or at risk for diabetes. We therefore asked, "What is the role of physical therapists in fighting the diabetes epidemic?"

We propose that physical therapists intervene in 3 important ways.

Provide Guidance on Physical Activity Participation for Patients Who Have or Are at Risk for Diabetes

Physical activity is an important component in the treatment of chronic diseases, including diabetes, reducing morbidity and mortality.⁸⁴ However, for patients with diabetes, physical activity programs must be carefully prescribed, such that they account for diabetes-associated pathophysiology and complications.

Regularly Screen Patients for Risk Factors for Diabetes and Diabetes-Related Complications

Once risk factors are identified, physical therapists can provide treatment that includes education in self-management strategies and prescription of safe and rewarding physical activity, an effective treatment for diabetes and associated comorbidities.

• **BACKGROUND:** In 2014, the total prevalence of diabetes was estimated to be 422 million people worldwide. Due to the aging population and continued increase in obesity rates, the prevalence is expected to rise to 592 million by 2035. Diabetes can lead to several complications, including cardiovascular disease, stroke, peripheral arterial disease, nephropathy, neuropathy, retinopathy, lower extremity amputation, and musculoskeletal impairments.

• **CLINICAL QUESTION:** Up to 80% of patients referred for outpatient physical therapy have diabetes or are at risk for diabetes, providing an opportunity for physical therapists to intervene. Therefore, we asked, "What is the role of physical therapists in fighting the diabetes epidemic?"

• **KEY RESULTS:** Physical therapists commonly prescribe physical activity for the treatment of diabetes and other chronic diseases, such as cardiovascular disease and osteoarthritis. Physical

therapists may also screen for risk factors for diabetes and diabetes-related complications and modify traditional musculoskeletal exercise prescription accordingly. Physical therapists must advocate for regular physical activity as a key component of the treatment of chronic diseases in all patient interactions.

• **CLINICAL APPLICATION:** This commentary (1) describes the diabetes epidemic and the health impact of diabetes and diabetes-related complications, (2) highlights the physical therapist's role as front-line provider, and (3) provides recommendations for physical therapists in screening for diabetes risk factors and diabetes-related complications and considerations for patient management. We focus on type 2 diabetes. *J Orthop Sports Phys Ther* 2020;50(1):5-16. Epub 28 Nov 2019. doi:10.2519/jospt.2020.9154

• **KEY WORDS:** complications, diabetes mellitus, disease management, epidemiology, physical therapist

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Advocate Regular Physical Activity as a Key Component of the Treatment of Chronic Diseases in All Patient Interactions

In this clinical commentary, we highlight the diabetes epidemic and provide recommendations for screening, examination, and preventive care practices that can be immediately implemented by physical therapists to reduce the impact of diabetes and its associated complications. Additionally, we highlight published, evidence-based recommendations to promote physical activity among people with diabetes.

PATHOPHYSIOLOGY OF DIABETES MELLITUS

DIABETES MELLITUS IS A GROUP OF chronic metabolic conditions all characterized by elevated blood glucose levels resulting from the body's inability to produce insulin, resistance to insulin action, or both (TABLE 1).⁹ This group of conditions consists of 4 clinically distinct types: (1) type 1 diabetes, which results from autoimmune beta-cell destruction in the pancreas and is characterized by a complete lack of insulin production; (2) type 2 diabetes, which develops when there is increased resistance to the action of insulin and the body cannot produce enough insulin to overcome the resistance; (3) gestational diabetes, which is a form of glucose intolerance that affects some women during pregnancy; and (4) a group of other types of diabetes caused by specific genetic defects of beta-cell function or insulin action, diseases of the pancreas, drugs, or chemical toxicity.⁵ We focus on type 2 diabetes in this commentary.

Type 2 diabetes accounts for 90% to 95% of all diagnosed diabetes cases.¹⁷ Type 2 diabetes typically begins as insulin resistance. As the body is unable to produce enough insulin to address the resistance, the pancreas may reduce or eventually stop the production of insulin.⁸⁰ The term “prediabetes” is used to define individuals with a high risk of

future diabetes. However, not all individuals who meet the definition of prediabetes will develop diabetes.¹ Prediabetes includes people with elevated but subdiabetic fasting glucose levels (ie, “impaired fasting glucose”), impaired glucose tolerance, elevated glycated hemoglobin (HbA1c), or a history of gestational diabetes. The diabetes epidemic has been attributed to increasing sedentary behavior, a diet that provides excess energy (simple carbohydrates and saturated fats), and obesity.¹¹³ Laboratory values used to di-

agnose diabetes and prediabetes are provided in TABLE 1.

RISK FACTORS FOR TYPE 2 DIABETES MELLITUS

THERE ARE NONMODIFIABLE AND modifiable risk factors for development of type 2 diabetes (TABLE 2). Nonmodifiable risk factors include age, sex, socioeconomic position, race/ethnicity, genetic predisposition, history of gestational diabetes, and low birth

TABLE 1

DIAGNOSIS OF PREDIABETES AND DIABETES^{7,8}

	Normal	Prediabetes	Diabetes
Fasting plasma glucose, mg/dL	<100	100-125	>126
2-h plasma glucose after 75-g OGTT, mg/dL	<140	140-199	>200
Random plasma glucose, mg/dL	...	140-199	>200
Glycated hemoglobin, %	<5.7	5.7-6.4	≥6.5

Abbreviation: OGTT, oral glucose tolerance test.

TABLE 2

RISK FACTORS FOR DIABETES THAT ARE MODIFIABLE AND NONMODIFIABLE WITH PHYSICAL THERAPIST-LED INTERVENTION

Modifiable	Nonmodifiable
Overweight/obesity • Body mass index, ≥25 kg/m² • Visceral fat • Waist circumference - Female, >35 inches - Male, >40 inches	Age • >45 y Sex • Male
Inactivity • <30 min of moderate to vigorous activity per day, 5 d/wk	Socioeconomic • Lower level of education, occupation, housing conditions, and income
Hypertension • Elevated, 120-129/<80 • Hypertension stage 1, 130-139/80-89 • Hypertension stage 2, ≥140/≥90 • Hypertension stage 3, >180/>120 (requires emergency care)	Race/ethnicity • American Indian, Alaska Native, African American, Hispanic, Asian American, Pacific Islander
Smoking	Family history/genetic predisposition
Diet • Refined grains, red/processed meat, sugar-sweetened beverages, lack of moderate alcohol intake	History of gestational diabetes
Psychosocial • Depression, increased stress, low social support, poor mental health	Low birth weight
Abnormal fasting cholesterol • Triglyceride, ≥150 mg/dL • High-density lipoprotein - Female, <50 mg/dL - Male, <40 mg/dL	

weight.^{36,113} While European studies show a higher risk of diabetes in men compared with women,⁵³ this was not consistently observed in the United States.⁶⁸ In the United States, the risk of developing type 2 diabetes was higher among those in lower socioeconomic positions, including lower levels of education, occupation, and income.³ American Indians/Alaska Natives have the highest prevalence of diabetes, followed by non-Hispanic blacks and Hispanics. African Americans are more likely to develop diabetes than white and Asian individuals.³⁶ For American Indians, the rates of diagnosed diabetes range from 5.5% to 33.5% in different tribes and population groups.²² Although genetic factors also play a role, primary risk factors appear to be those that are not genetic.⁹³

Modifiable risk factors include higher body mass index, physical inactivity, poor nutrition, hypertension, smoking, and alcohol use, among others.¹¹³ Increased body mass index is consistently one of the strongest risk factors for the development of diabetes.⁵² Additionally, distribution of body fat,⁸⁸ specifically an increased waist-to-hip ratio, increases the risk of diabetes.⁵⁸ Lower levels of physical activity and more television viewing time increase the risk of type 2 diabetes.^{45,55} Smoking increases the risk of diabetes, regardless of age.¹⁰⁹ Psychosocial factors such as depression, increased stress, lower social support, and poor mental health are also associated with an increased risk of developing diabetes.^{11,33,35,42,72,100} Different aspects of the environment have also been linked to type 2 diabetes development. Increased levels of noise, poor housing conditions, and air pollution were associated with increased risk.^{30,92}

Identifying and addressing modifiable risk factors can reduce the risk of diabetes. People who achieve recommended levels of moderate activity are about 30% less likely to develop diabetes than their inactive counterparts.⁵⁵ Brisk walking for at least 2.5 hours per week was associated with reduced risk of type 2 diabetes compared to almost no walking, independent of body mass index.⁵⁵ Higher levels of

walkability and green space were associated with lower diabetes risk.^{30,92} A person's risk of diabetic complication can be reduced up to 12% with a 10-mmHg decrease in blood pressure.²² Diets favoring higher intake of whole grains, green, leafy vegetables, and coffee; lower intake of refined grains, red and processed meat, and sugar-sweetened beverages; and moderate intake of alcohol have been linked with reduced risk of type 2 diabetes.⁶⁸ A healthier diet can help to reduce HbA1c levels. For each percentage-point reduction in HbA1c level, there can be a 40% reduction in risk of microvascular complications.²² A Mediterranean diet with extra-virgin olive oil supplementation reduced diabetes risk by 40% compared to a low-fat control diet.⁹¹

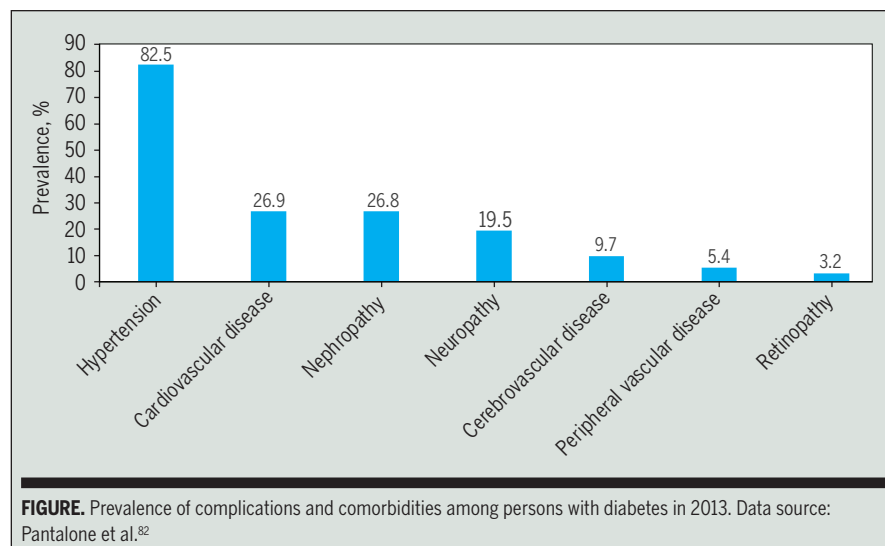
HEALTH COMPLICATIONS

DIABETES MAY AFFECT MANY DIFFERENT organ systems and can lead to serious microvascular and macrovascular complications, such as (1) cardiovascular disease, (2) stroke, (3) peripheral artery disease (PAD), also referred to as peripheral vascular disease, (4) nephropathy or chronic kidney disease, (5) diabetic peripheral neuropathy (DPN), (6) nontraumatic lower extremity amputations (NLEAs), and (7) retinopathy.³¹ The prevalence of the most

common diabetes complications among people with type 2 diabetes is shown in the **FIGURE**.⁸² Complications can be either episodic (eg, foot ulcers or infections), those that can be treated and may recur, or progressive (eg, nephropathy), those that result in further damage to the organ and greater loss of functionality that are generally irreversible.

Heart Disease and Stroke

Cardiovascular diseases account for up to 65% of all deaths in people with diabetes.⁴¹ According to the Centers for Disease Control and Prevention, people with diabetes are about twice as likely to die from heart disease or stroke compared to those without diabetes.²⁰ Over 70% of people with diabetes, which is significantly higher than the rate in those without diabetes, have high blood pressure.⁸² While risk factors for cardiovascular disease development among people with diabetes are similar to those for people without diabetes (ie, hypertension, hypercholesterolemia, and smoking), the presence of just one of these risk factors leads to poorer outcomes among people with diabetes compared to those without diabetes.⁹⁹ Over the past 20 years, preventive care (self-care management strategies, diet, and participation in physical activity) targeting diabetes and the risk factors that cause these complications has improved



significantly in the United States. The rates of complications from heart disease and stroke declined in adults with diagnosed diabetes from 1990 to 2010, with myocardial infarction accounting for the greatest reduction (68%).⁴³

Peripheral Artery Disease

Peripheral artery disease results from narrowing of peripheral arterial vasculature, affecting primarily the limbs, stomach, and kidneys. Early in the process, PAD may be asymptomatic and is often underdiagnosed.⁸¹ Once symptoms are present, they are of 2 types: (1) intermittent claudication, which presents as pain, ache, or discomfort occurring during physical activity, such as walking, but resolving with rest; and (2) pain at rest caused by limb ischemia, which indicates poor blood flow to the affected limb.⁶⁰ During 1999 to 2004, prevalence of PAD was about 11%.¹⁶ The risk of PAD increases with older age, smoking, and longer duration of diabetes.^{29,81} People with PAD are at an increased risk of lower extremity amputation and mortality.^{75,81} Patients with intermittent claudication, considered to benefit from exercise, improved their walking time and distance after participation in exercise compared to placebo or usual care.⁶⁷

Retinopathy (Vision Loss)

Diabetic retinopathy is 1 of the 5 most common causes of severe visual impairment (visual acuity of 20/200 or worse) in the United States—an estimated 286 000 people aged 40 years or older had diabetic retinopathy during 2005 to 2008.⁶² As one of the longest-duration prospective studies of the epidemiology of diabetic retinopathy, the Wisconsin Epidemiologic Study of Diabetic Retinopathy reported a 10-year incidence of retinopathy of 74%.⁶³ The 25-year follow-up of this cohort showed that 97% developed diabetic retinopathy, with about half progressing to sight-threatening disease.^{64,65} Risk factors for diabetic retinopathy include hyperglycemia, hypertension, dyslipidemia, longer duration of diabetes, pregnancy, puberty, and cataract surgery.²³ If detected early,

diabetic retinopathy's progression can be slowed dramatically, and eyesight can be retained in many patients.⁵⁷ The American Diabetes Association (ADA) recommends an eye examination every 2 years for those who have no signs of diabetic retinopathy. If there is evidence of diabetic retinopathy, the ADA recommends annual examinations.

Nephropathy (Renal Disease)

Nephropathy is a chronic condition characterized by a gradual increase in proteinuria in patients without other conditions that directly cause proteinuria.^{69,89} Over time, nephropathy may progress to the development of end-stage renal disease and renal transplant. Diabetes is the leading cause of end-stage renal disease, accounting for 4 in every 10 new end-stage renal disease cases. Overall, the incidence and prevalence of end-stage renal disease have increased in recent decades among people with diabetes.⁷⁸

Metabolic regulation, hypertension, cigarette smoking, obesity, and anemia are all modifiable risk factors for nephropathy.⁵⁶ Genetic factors also increase risk for diabetic nephropathy.⁵⁶ In persons with type 2 diabetes, strict metabolic control leads to a significant reduction in the risk of developing microalbuminuria and the risk of progression to persistent proteinuria.^{32,38,107}

Peripheral Neuropathy

Diabetic peripheral neuropathy, a neurodegenerative disease of the peripheral nervous system, is estimated to affect up to 75% of individuals with diabetes.^{2,19,44,86} Chronic sensorimotor distal symmetric polyneuropathy, the most common DPN,¹⁵ can lead to muscle weakness, sensory loss, and pain in the extremities. The predominant early manifestation of DPN is a gradual onset of sensory impairment, including burning and numbness in the feet. Diabetic peripheral neuropathy may go undetected for years due to its gradual progression. Neuropathic pain, present in 1 in 3 people with DPN, can be severe.^{34,97,106}

Diabetic peripheral neuropathy is associated with substantial physical impairments, activity limitations, and reduced quality of life. The presence of DPN increases the risk of foot ulceration and lower extremity amputation^{10,83} and is associated with greater health care resource use, health care costs, and an inability to work due to physical limitations.^{19,90} Other potential complications of DPN, such as mobility impairments and falls, can result in significant limitations in activity and participation. Hyperglycemia is the primary risk factor for DPN.^{86,95} Additional risk factors include older age, longer duration of disease, cigarette smoking, hypertension, elevated triglycerides, higher body mass index, alcohol consumption, and taller height.^{2,85,95,101,102,112}

Lower Extremity Amputations

Nontraumatic lower extremity amputations are associated with high morbidity and mortality among people with diabetes. The 5-year mortality rate after NLEA ranges from 52% to 100%.¹⁰³ The incidence of NLEA among people with diabetes is estimated to be as high as 704 per 100 000 person-years.⁷⁷ Individuals with diabetes are 7.4 to 41.3 times more likely to have an NLEA compared to those without diabetes.⁷⁷

With increased awareness of diabetes-related complications and subsequent implementation of preventive care strategies, the age-adjusted NLEA rates have decreased in the United States, from 70.4 per 10 000 adults with diagnosed diabetes in 1995 to 28.4 per 10 000 in 2010.⁴³ Although overall NLEA rates have decreased, disparities between black and nonblack patients increased between 2007 and 2011, with the amputation-free survival rate being lower among black patients.⁷⁹ Lower extremity amputation rates also differ significantly by the patient's geographical location, highlighting the need to address both racial and regional disparities.⁷⁹

Risk factors for NLEA include increasing age, being male, being African American or Hispanic, having peripheral

neuropathy, and having chronic foot ulcers.⁷⁷ Eighty-five percent of all NLEAs among people with diabetes were preceded by a chronic, nonhealing foot ulcer.^{83,87} Diabetic foot ulcers are common, with the lifetime risk of a person with diabetes developing an ulcer being as high as 1 in 4.⁹⁶ Peripheral vascular disease underlies approximately half of all amputations in people with diabetes,⁸³ and is associated with higher mortality after NLEA.¹⁰³

Musculoskeletal Complications

Musculoskeletal complications associated with diabetes are common. Yet, they may go undetected and impact the ability to participate in physical activity.⁹⁴ Foot and ankle musculoskeletal complications related to diabetes place the foot at risk for ulceration and amputation. Intrinsic foot muscle deterioration, in the form of reduced muscle volume and increased fat volume, is associated with metatarsophalangeal hyperextension deformity,²⁵ collapse of the midfoot, and decreased foot function during a heel-raise task.⁴⁸ Metatarsophalangeal hyperextension deformity has a prevalence as high as 85% in those with diabetes and a history of ulcers and amputations.⁵¹ Extensive foot joint destruction associated with Charcot neuropathic osteoarthropathy is less common (approximately 1% of people with diabetes) but, when severe, prevents weight bearing.⁵¹ Early detection and treatment of musculoskeletal impairments of the foot and ankle may improve the patient's current and future ability to participate in physical activity and should be addressed. Additionally, physical activity participation may need to be modified when diabetes-associated complications prevent or limit weight-bearing ability. Individuals with diabetes and a history of foot ulcers were found to be 46% less active than control participants matched by age, sex, and body mass index.⁷¹

Patients with diabetes are 4 times more likely to have musculoskeletal complications of the shoulder and hand (eg, adhesive capsulitis, Dupuytren's contrac-

ture, and flexor tenosynovitis) compared to those without diabetes.¹⁸ There is also an increased prevalence of low back pain in individuals with diabetes.³⁷ Musculoskeletal impairments may be associated with joint mobility limitation and tissue changes, due to the accumulation of non-enzymatic advanced-glycation end products.^{73,94} Advanced-glycation end-product accumulation results in thicker and stiffer collagen tissues, in particular those

with low turnover, such as tendons, skin, and discs,⁵⁴ thus increasing the risk of contracture and musculoskeletal injury.

TABLE 3 provides comprehensive information to screen for diabetes-associated complications and highlights the physical therapist's role in patient management. We also provide recommendations that will assist the physical therapist in developing safe and effective programs to promote physical activity and exercise

TABLE 3

SCREENING FOR DIABETES-RELATED COMPLICATIONS AND CONSIDERATIONS FOR PATIENT MANAGEMENT^{4,9,27,66,84,105}

Screening Items Related to Diabetes and Diabetes-Related Complications	Physical Therapist Role and Responsibility
Psychosocial Factors ^a	
Depression - The PHQ-2 may be used as a "first-step" screening. Patients who answer yes to either question should be further evaluated by a mental health provider¹⁰⁸ "During the last 2 weeks, have you been bothered by feeling down, depressed or hopeless?" "During the last 2 weeks, have you been bothered by little interest or pleasure in doing things?"	- Annual screening for depression among all patients diagnosed with diabetes. Screening should also be performed at any time depression is suspected - Assist patient in developing an appropriate program to increase physical activity
Anxiety disorder Patients who exhibit anxiety or worries regarding their diabetes-related complications or ability to participate in a lifestyle management program	Screen for anxiety disorder and refer for treatment if warranted
Disordered eating behaviors (binging, intentional omission of insulin) - Hyperglycemia - Unexplained weight loss	Screen for disordered eating behavior, eating disorders, and disrupted eating and refer to appropriate health care providers if warranted
Cognitive impairment/dementia	Screen for cognitive impairments and tailor management to improve understanding and optimize the patient's ability to adhere to a lifestyle management program. All patients older than 65 y should be screened for cognitive impairments
Socioeconomic Factors	
Lower social support Poor housing conditions	- Assess barriers to physical activity participation and problem solve with patient to address barriers - Customize the patient's activity program based on the patient's goals and preferred activities - Assist in accessing community resources
Diabetes: General	
All diabetes-related complications	- Monitor blood pressure and glucose at the initial visit and as indicated at subsequent visits - Educate patient to monitor blood pressure and glucose daily, including response to exercise - Encourage lifestyle modifications to decrease caloric intake and increase physical activity for weight loss - Know medications, their side effects, and their effect on exercise response

Table continues on page 10.

among patients with diabetes and diabetes-associated complications.

THE PHYSICAL THERAPIST'S ROLE

AS PART OF THE MULTIDISCIPLINARY team, physical therapists should be front-line providers in diabetes prevention and management. Physical therapists should be the provider of choice to assist patients who have been diagnosed with diabetes or who are at risk for diabetes in achieving their physical activity goals. Physical therapists' education provides both broad and in-depth content covering the pathophysiology of diabetes and associated comorbidities, screening for and treatment of diabetes complications, and prescription of physical activity for individuals with specific and important limitations of the human movement system that moderate physical activity tolerance.

Patients may not be regularly referred to physical therapists for guidance on the development of physical activity programs for chronic conditions, such as diabetes.⁶¹ Only 2% of referrals to outpatient physical therapy in the United States were for diabetes as the primary health condition to be treated.⁶¹ While it is true that the vast majority of patients seen in outpatient settings have diabetes or are at risk of diabetes,⁶¹ these patients are often referred for treatment of a specific impairment or limitation, such as pain or limited mobility. Patients may not be referred to a physical therapist for management of diabetes. Physical therapist-led intervention, including guidance on safe physical activity, should be a key component in the treatment of diabetes. The fact that only 2% of referrals for physical therapy are for management of diabetes perhaps reflects the failure of medical providers to recognize diabetes as an underlying mechanism contributing to many of the diagnosed conditions physical therapists commonly examine and treat (eg, stroke, frozen shoulder, carpal tunnel syndrome, myocardial infarction). Physical therapists

TABLE 3	
SCREENING FOR DIABETES-RELATED COMPLICATIONS AND CONSIDERATIONS FOR PATIENT MANAGEMENT ^{4,9,27,66,84,105} (CONTINUED)	
Screening Items Related to Diabetes and Diabetes-Related Complications	Physical Therapist Role and Responsibility
Cardiovascular	
Peripheral vascular disease	• Annual comprehensive foot examination by a diabetes specialist • Educate patient to perform daily foot examinations to look for unnoticed injury and determine need for nail care and moisturizer • If vascular screen is positive for any item, refer for a vascular assessment
• Absent dorsal pedis and/or posterior tibial pulse • Capillary refill: ≥ 4.5 s to refill the nail bed • Color of skin: pale	
Vision	• Refer to ophthalmologist for eye exam if the patient is not receiving annual eye exams and prior to initiating a vigorous exercise program
• Ask about - Changes in vision - Retina damage from microvascular disease - Frequency of receiving an eye exam	
Cardiac autonomic neuropathy	• Refer to cardiologist prior to initiating a vigorous exercise program if abnormalities are measured⁶
• Blood pressure response from supine to stand, drops ≥ 30 mmHg • Heart rate >100 beats/min after resting 15 min	
Kidney	
Ask about	• Refer to nephrologist or primary care physician if the patient is not receiving regular kidney function screening
• Glomerular filtration rate • Frequency of kidney function assessment (urinary albumin and glomerular filtration rate)	
Peripheral Neuropathy of Feet	
Light touch (Semmes-Weinstein monofilaments)	• Annual comprehensive foot examination by diabetes specialist • Educate patient to perform daily foot examinations to look for unnoticed injury and determine need for nail care and moisturizer • If the patient lacks protective sensation, provide education about the need for wearing protective footwear when walking in the home or community and the lack of ability to detect damaging temperatures (cold and hot)
• Loss of protective sensation: can't feel 5.07 monofilament • Absent: can't feel 6.10 monofilament	
Tuning fork (128 Hz) on dorsal great toe interphalangeal joint: time between when the patient and examiner stop feeling vibration	
• Reduced: ≥ 10-s difference • Absent: the patient is unable to feel vibration	
Biothesiometer	
• Unable to feel ≤ 25 V	
Achilles reflex	
• Present with reinforcement: Jendrassik maneuver required • Absent: no reflex with Jendrassik maneuver	
Muscle (see below)	
Integumentary	
Callus: indicator of high pressure and risk of injury	• See recommendations above for peripheral neuropathy
Dry/cracked: indicator of autonomic neuropathy and increased risk of skin breakdown	
Foot wounds	
• Neuropathic: plantar surface, area of high pressure, callus • Vascular: lateral surface, poorly perfused, absent pulse	

Table continues on page 11.

pists have an opportunity to expand practice, provide valuable contributions to the management of diabetes, and counter the global burden of disease.

Physical therapists must consider the impact of diabetes and diabetes risk factors in patients who are referred for other health conditions, such as mus-

TABLE 3

SCREENING FOR DIABETES-RELATED
COMPLICATIONS AND CONSIDERATIONS FOR
PATIENT MANAGEMENT^{4,9,27,66,84,105} (CONTINUED)

Screening Items Related to Diabetes and
Diabetes-Related Complications

Physical Therapist Role and Responsibility

Musculoskeletal

Joint

- Deformity of toes (metatarsophalangeal joint hyperextension) and foot (midfoot collapse); palpation of plantar surface for bony prominences that can be a site of high pressure and skin breakdown^{24,25,48,49}
- Range-of-motion limitations^{18,59,94}
 - Hands: prayer sign: the patient is unable to fully extend the fingers when placing the hands together in front of the chest in a prayer position
 - Shoulders: limited active and passive shoulder flexion range of motion
 - Ankle/foot: limited ankle dorsiflexion and plantar flexion, decreased extensor digitorum longus length
- Ask about current or history of prevalent musculoskeletal injuries in diabetes (frozen shoulder, Dupuytren's contracture, carpal tunnel, trigger finger)

Muscle

- Visible atrophy of the thenar/hypothenar eminence of the hand
- Loss of muscle strength
 - Calf and foot: decreased ability to complete full heel raise and lack of plantar flexion of the forefoot on the hindfoot during heel raise^{48,50}
 - Hands: decreased grip and/or pinch strength

Function

- Slow gait speed (10-m walk time, <12.5 s³⁹)
- 2-minute walk test¹⁴ (see Bohannon et al¹⁴ for age- and sex-specific normative data)
- Slow 5-times sit-to-stand (≥10 s⁷⁰)

Abbreviation: PHQ, Patient Health Questionnaire.

^aA comprehensive list of measures to assess psychosocial factors is provided in a recent American Diabetes Association position statement¹¹¹

- Determine whether the patient has any current pain or significant risk factors for musculoskeletal injury
- Examine and address contributing factors to toe and foot deformity, including a short extensor digitorum longus and weak foot intrinsic muscles contributing to metatarsophalangeal joint hyperextension and limited ankle dorsiflexion contributing to foot and toe deformity
- Develop regular stretching program to address limited joint mobility of the hands, shoulders, and ankles
- Provide exercises specific to limitations in daily functional activities (sit-to-stand, stair and curb ascent and descent, walking speed and endurance)
- Develop or connect the patient to community programs to increase physical activity that is appropriately dosed to reduce risk for injury and encourage participation

culoskeletal pain and mobility limitations, that are frequent among persons with diabetes. Diabetes and associated complications affect the type, duration, intensity, and precautions of physical activity that is prescribed. Screening for diabetes and diabetes risk factors provides an opportunity to promote diabetes prevention and/or management through physical activity, and informs treatment of musculoskeletal pain or mobility limitations. Physical therapists should advocate for regular physical activity as a key component of the treatment of chronic diseases in all patient interactions.^{98,105}

Recommendations for
Physical Therapists

The standard for excellent physical therapist-led intervention care within our current model of practice must include screening patients for risk factors for diabetes and diabetes-related complications, and educating each patient about his or her specific risks (TABLE 2). Modifiable risk factors such as physical inactivity, obesity, and hypertension can be directly addressed by physical therapists, by assisting the patient in developing and implementing programs to increase physical activity. The physical therapist should work with the patient to

identify and address barriers to exercise. The barriers are often related to comorbidities that require specific accommodations or modifications to the exercise program. TABLE 3 provides key assessment items and recommendations that physical therapists might consider when providing patient education about lifestyle management and physical activity.

Lifestyle Management Lifestyle management may include diabetes self-management education and support, medical nutrition therapy, physical activity, smoking cessation counseling, and psychosocial care. Components of lifestyle management (eg, diet, physical activity, medication, invitation to smoking cessation courses) may reduce disease severity and improve self-assessed quality of life.⁴⁰ People who receive diabetes self-management education and support (as a one-to-one interaction, in a group setting, or through internet-based interactions) may experience lower HbA1c, improved quality of life, and lower all-cause mortality risk.^{6,28} Substantial evidence exists of the benefits of physical activity, which we will discuss in the next section.

Although there is clear benefit to preventive strategies, implementation in routine medical care is often lacking. In 2015, only 54% of people with diabetes attended a self-management class, 63% self-monitored their blood glucose, 62% received an annual eye examination, 72% received an annual foot examination from a professional, 55% performed daily foot self-examinations, 71% had their HbA1c checked more than 2 times per year, and 66% participated in physical activity in addition to their daily and work activities.²¹ Physical therapists can guide patients to implement an effective lifestyle management program. While interviewing the patient to gather the pertinent medical history, determine whether the patient with diabetes has a comprehensive lifestyle management program in place. If so, assess the patient's ability to follow the program and address any perceived barriers to maintaining this program. If the patient does not have a program in place,

communicate with the patient's health care team and assist in the development of a program by providing appropriate referrals and guiding the development and implementation of physical activity participation. For more information on lifestyle management programs, refer to the ADA⁶ and the Centers for Disease Control and Prevention website (<https://www.cdc.gov/diabetes/prevention/lifestyle-program/experience/index.html>).

Physical Activity and Exercise Prescription Physical activity is an effective “medicine” for diabetes and other chronic diseases.^{12,28,84,104} Given that patients likely have 2 or more comorbidities,¹³ the benefit of physical activity may go far beyond that of treating diabetes alone. Benefits of physical activity include improved glucose control, insulin sensitivity, maximum rate of oxygen consumption, and blood pressure.⁸⁴ The improvements may require modifications to the patient's pharmacologic management plan. Therefore, the physical therapist should facilitate patient follow-up visits with the primary care physician when needed. Important information to communicate with the physician includes glucose monitoring logs, resting and exercise blood pressure and heart rate, and key physical performance measures (eg, 6- or 2-minute walk test, 5-times sit-to-stand). A full review of the effects of physical activity on diabetes and other chronic diseases is available.⁸⁴

As a component of lifestyle management, physical therapists should assess the patient's current level of physical activity and screen to determine the safest and most appropriate regimen for the patient. Recommendations by the ADA include 150 minutes per week of moderate- to vigorous-intensity aerobic activity.^{9,104} The activities should be spread over 3 days per week, with no more than 2 consecutive days without any activity. In addition, 2 to 3 sessions per week each of resistance exercise and flexibility/balance training are recommended.⁹ It is also important to decrease the time being sedentary⁴⁷; therefore, encourage physi-

cal activity throughout the day (eg, avoid sitting all day).^{9,47} Customize the physical activity program to the patient's specific goals, preferred activities, comorbidities, and risk of complications (TABLE 4).

Additional information regarding prescription of physical activity can be found in the *Standards of Medical Care in Diabetes* published by the ADA,⁹ and in the joint position statement from the ADA and the American College of Sports Medicine titled “Exercise and Type 2 Diabetes.”²⁶ The resources provided by the ADA and American College of Sports Medicine are consistent with the recently updated Physical Activity Guidelines for Americans¹⁰⁵; however, they provide additional specific-

ity for patients with diabetes. Additionally, Kluding et al⁶⁶ recently published specific recommendations for physical training in people with DPN. An online tool developed by the US Department of Health and Human Services may assist patients to record and monitor their physical activity (<https://health.gov/moveyourway/>).

The physical therapy profession should consider how we expand our professional reach within our current and future health care system. There are many opportunities for partnering and developing relationships with medical professionals within the established health care system, including endocrinologists, diabetes clinicians, and diabetes

TABLE 4

KEY RECOMMENDATIONS FOR PHYSICAL ACTIVITY PRESCRIPTION FOR PEOPLE WITH DIABETES AND DIABETES-RELATED COMPLICATIONS^{4,6,9,27,66,84,105}

Patient Characteristic	Recommendation for Physical Activity Prescription
Diabetes: general	- Customize program for patient goals, comorbidities, and complication risk - Prescription of physical activity must take into account baseline activity level in order to avoid injury and maximize long-term compliance - Activity monitors are a useful tool to determine baseline activity and to monitor and encourage activity prescription compliance - Physical activity should be progressed gradually, with the goal to achieve 150 min/wk of moderate- to vigorous-intensity aerobic activity⁶ - Monitor blood pressure and glucose during and after performing new aerobic and/or resistance exercises - Exercise equipment must accommodate the size and weight of the patient - Decrease sedentary time by getting up and out of the chair every 30 min^{6,9}
Lower extremity musculoskeletal impairments, neuropathy, and/or a history of foot ulcers/fractures	- Weight-bearing exercise is not contraindicated; however, patients may be more at risk for skin breakdown when there is foot deformity or a history of foot wounds²⁴ - Select activities that minimize lower extremity load, including - Pool-based exercise - Stationary cycling - Elliptical - Seated aerobic activities - If patients have an open sore or injury on their foot, non-weight-bearing exercise is preferred⁶
Autonomic neuropathy or medication (eg, beta blockers, nitrates, calcium-channel blockers, digoxin, diuretics, ACE inhibitors) that blunts heart rate and blood pressure response to physical activity	Use rate of perceived exertion in addition to heart rate and blood pressure to monitor exercise response
Proliferative and severe nonproliferative diabetic retinopathy	High-intensity aerobic exercise may be contraindicated due to the potential to exacerbate eye damage⁶
Obesity	Resistance training has many of the same benefits as aerobic exercise⁸⁴ and is often better tolerated by those who are obese or untrained

Abbreviation: ACE, angiotensin-converting enzyme.

educators. There are also community partners and outreach opportunities that would benefit from the skills and knowledge of physical therapists (eg, community-based exercise programs for individuals with diabetes). Physical therapists have the expertise required to safely and effectively prescribe physical activity and oversee exercise in medically complex individuals.

SUMMARY

DIABETES AND ITS COMPLICATIONS are major causes of morbidity and mortality and contribute significantly to rising health care costs. The dramatic increase in diabetes, paired with high rates of diabetes complications, will contribute to higher health care costs that are only made worse by high rates of modifiable risk factors, such as obesity and physical inactivity. Physical therapists play a central role in the multidisciplinary health care team in at least 3 ways: (1) providing guidance on physical activity participation that is safe and rewarding to the patient, (2) assessing risk factors for diabetes and diabetes-related complications that modify traditional musculoskeletal exercise prescription, and (3) advocating for regular physical activity as a key component of the treatment of chronic diseases in all patient interactions. ●

KEY POINTS

FINDINGS: Physical therapists are key members of the health care team in the treatment of diabetes. Physical therapists should screen for diabetes risk factors and diabetes-related complications that modify traditional musculoskeletal exercise prescription. Physical therapists must also advocate for regular physical activity as a key component in the treatment of chronic diseases in all patient interactions.

IMPLICATIONS: This commentary highlights physical therapists' role as front-line providers, and provides recommendations for physical therapists

in screening for diabetes risk factors and diabetes-related complications, and considerations for patient management.

CAUTION: Given the prevalence of diabetes and diabetes risk factors among patients seen in the outpatient physical therapy setting, it is imperative that physical therapists screen patients for diabetes risk factors and diabetes-related complications, and educate each patient about his or her specific risks. Failure of physical therapists to recognize their role as front-line providers in diabetes prevention and management increases the risk of injury from inappropriate exercise prescription and limits the health potential of patients.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: All authors contributed to the conception and design of the work, including preparation and final approval of the manuscript. The corresponding author takes responsibility for the integrity of the work as a whole, from inception to the finished article.

DATA SHARING: There are no data available.

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STEVEN J. KAMPER, PhD¹

Generalizability: Linking Evidence to Practice

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The basic concept of generalizability is simple: the results of a study are generalizable when they can be applied (are useful for informing a clinical decision) to patients who present for care. Generalizability is the coalface of evidence-based practice, where research evidence influences patient management.

Internal Validity and External Validity

It is worth distinguishing between generalizability (sometimes called external validity) and study quality (internal validity or methodological quality). Internal validity is how confident the reader can be that the study provides an unbiased result. Researchers employ design features such as randomization and blinding to reduce the risk of bias and improve internal validity. These design features are the subject of previous Evidence in Practice articles,¹⁻³ and the next article will describe how to assess internal validity. Assessing internal validity and generalizability serves 2 critical but different purposes; internal validity determines whether the estimate of effect in the study is likely to be accurate, and generalizability determines whether the findings are applicable to people outside the study sample.

Samples and Populations

Understanding generalizability requires an appreciation of the difference between samples and populations. The terms *sample* and *population* are sometimes used interchangeably, but they mean different things.

A population is a group of people who all share an important characteristic. In

demographic terms, this characteristic might be where they live. The population of a country includes everyone who lives in that country. With respect to clinical research, the population is usually defined by a certain health condition, for example, everyone who has had a shoulder dislocation.

Because it is usually impossible to include an entire population in a study, researchers aim to use a representative sample. A sample is the group of people, from the population of interest, who participate in a study. The study is conducted on the sample, and the results are only useful to the extent that they reflect what happens in the entire population. This is generalizability (FIGURE).

Representativeness

The ideal sample is a “representative sample”; it is the same as the population in every way, except there are fewer individuals. For example, the proportion of women, the mean and variability of the condition severity, and the distribution of beliefs and attitudes are the same in the sample as in the population. The concept of representativeness is the extent to which the sample is representative of the population with respect to all the characteristics important to the study.

Researchers aim to recruit a sample that is as representative as possible of the population. Representativeness of the sample will depend on the inclusion and exclusion criteria of the study and the methods used to recruit participants into the study. These will be the subjects of future Evidence in Practice articles.

Practical Application

Generalizability is a continuum, not a dichotomy; a study’s results are more or

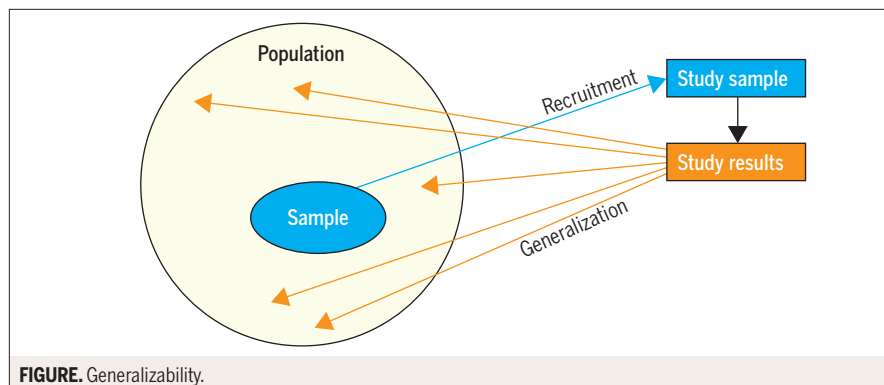


FIGURE. Generalizability.

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[EVIDENCE IN PRACTICE]

less generalizable, as opposed to generalizable or not. Clinicians can always argue that the findings of a study are not generalizable to their patients. This often happens when the findings conflict with usual practice. In evidence-based practice, the objective is to sensibly assess how the results of research will guide treatment decisions and inform the prognosis of a particular patient.

Should I Apply the Findings of This Study to the Patient in Front of Me? When appraising a study, a reader should ask whether the study sample is representative of the population of interest. This is often not completely straightforward because the study population may not be defined explicitly by the authors. Determining representativeness involves understanding the inclusion and exclusion criteria, reading the recruitment methods, and looking at the descriptive data that summarize the clinical characteristics of the people in the sample.

The capacity, skills, and resources available to the clinician are also relevant to generalizability. Study results will be applicable to the patient in front of you as long as you can deliver the intervention in the same way as in the study.

If you believe the sample is sufficiently representative of the population of interest, the findings can then be considered representative of those in the population. The next step is to assess whether the patient in front of you is part of the population; if so, the findings should be generalizable to the patient. In this case, the study provides evidence about the treatment that can be integrated with patient values and your own experience to guide clinical decisions.

What Evidence Should I Use to Inform Management of the Patient in Front of Me? The idea of generalizability as a continuum is an important one. Those who apply research should not be overly dogmatic or narrow in their interpretation of research evidence, especially in cases where there may not be a high-quality study conducted in a particular patient population. In such situations, understanding generalizability can help identify the best available evidence, as per the central tenet of evidence-based practice. The absence of a study in the population precisely defining your patient does not mean research evidence can be completely ignored for that clinical encounter.

Clinicians must make reasoned decisions about generalizability of research findings beyond a study population. This requires nuanced understanding of the condition that defines the population, the study intervention, and the patient. For example, it might be reasonable to apply the findings of a study investigating an exercise program for people following an ankle fracture to a patient with ankle arthritis. Depending on the type of intervention, there might be value in applying the findings from a study of people with chronic back pain to people with a different chronic pain condition. Ultimately, clinicians must decide the level of generalizability of a study and determine how to weight the information in arriving at a treatment decision. ●

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The Elephant in the Room: Too Much Medicine in Musculoskeletal Practice

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Advances in assessment and management of musculoskeletal conditions (eg, fracture management) have improved care for many people. We contend that there have been other, less beneficial developments in the provision of care for people with musculoskeletal pain conditions—one is the worrying tendency to provide too much medicine.

There are overlaps and confusion regarding the usage and definitions of terms.⁸ In this Viewpoint, we will use the term “too much medicine” as an umbrella term that includes overdiagnosis, misdiagnosis, false positives, diagnostic overmedicalization, and overdetection. Too much medicine has led to overtreatment, overutilization, interventional overmedicalization, and low-value care.¹²

Many musculoskeletal conditions require a level of investigation and intervention. Too much medicine occurs when the provision of either (or both) is unjustifiably excessive, for example, referring an individual experiencing non-specific low back pain with no red flags for magnetic resonance imaging. Another concern in musculoskeletal health care is

medicalizing normality—when a normal human function or condition is labeled as abnormal.¹⁰

In this Viewpoint, we argue that too much medicine and medicalizing normality in contemporary musculoskeletal practice have become the “elephant in the room.” Medicalizing normality creates health concerns where none exist. Too much medicine involves provision of care where benefits do not outweigh harms, and wastes precious health care resources. We (1) list 2 common examples of too much medicine, and 2 examples of medicalizing normality, relevant to physical therapy practice; (2) outline the drivers of too much medicine and medicalizing normality; and (3) make suggestions for change.

Two Examples of Too Much Medicine Relevant to Physical Therapy Practice

Nonsurgical Interventions for Pain Musculoskeletal pain management costs continue to rise. Individuals may have been misinformed that myriad nonsurgical health care options, including acupuncture, manual therapy, myofascial trigger point therapy, injections, pharmacology, among others, will, in isolation, “fix” the problem. Use of opioids has been at the forefront of the drive to eradicate pain. Worldwide, use of prescription opioid analgesics more than doubled between 2001 and 2013, leading to an opioid epidemic in many countries.¹⁴ In the United States in 2017, health care providers (principally general practitioners) prescribed opioid pain medication 191 million times (59 prescriptions per 100 people). Twenty-nine million people were taking nonsteroidal anti-inflammatory medications, accompanied by 100 000 hospitalizations and 17 000 related deaths.^{4,19}

Orthopaedic Surgery Many surgical procedures perform no better than skin in-

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cisions and arthroscopy without the “fix” (sham surgery), especially when the patient’s main complaint is pain.⁷ Examples include repairs for nontraumatic medical meniscal tears, arthroscopic debridement for knee osteoarthritis,¹³ type II superior labral tear from anterior to posterior lesions,²⁰ biceps tenodesis for long-head-of-biceps pathology,²⁰ and acromioplasty for subacromial impingement.¹⁶

Prioritizing expensive surgical procedures when cheaper, equally effective alternatives exist is concerning. Non-surgical management, principally in the form of graduated activity and exercise, is consistently as effective as surgery for shoulder pain, knee pain, and the majority of grade I to III ankle sprains. Surgery may be a reasonable treatment option, but it is associated with increased clinical risk and increased costs for health systems and patients, often without providing increased clinical benefits. For many musculoskeletal conditions, too much medicine can be avoided if appropriate condition-specific education, lifestyle advice, and evidence-based non-surgical management are prioritized.

Two Examples of Medicalizing Normality Relevant to Physical Therapy Practice

Musculoskeletal aches and pains are common. Up to 70% of people experience shoulder pain and 90% experience low back pain at some stage in their lives. One might argue that these common musculoskeletal conditions could be considered unpleasant yet “normal” occurrences. In this section, we summarize 2 examples of the mislabeling of normal and age-related variations in posture and structure as “pathological” and/or the basis for presenting symptoms.

Postural “Abnormalities” Ankylosing spondylitis and severe kyphosis and scoliosis may be associated with symptoms. However, for the majority of musculoskeletal presentations, most posture “abnormalities” are likely to be variations of normal and do not differentiate between people with and without pain.¹¹ Observing a person’s static posture based on the

plumb-line assessment of cervical, thoracic, and shoulder posture, then advising that the symptoms are due to subtle variations in postural alignment, is medicalizing normality.

“Abnormalities” Detected by Imaging There has been an increase in the identification of “abnormalities” in magnetic resonance imaging and ultrasound as the explanation for presenting symptoms. However, this practice has medicalized normality on an unprecedented scale.^{1,2} Examples include lumbar disc protrusions, disc bulges, facet joint degeneration, and spondylolisthesis in people without low back pain; labral abnormalities and rotator cuff tendon pathology in baseball pitchers without shoulder pain; osteophytes, cartilage damage, bone marrow lesions, and synovitis in people without knee pain; and labral tears in young people without hip pain. These findings suggest that many changes labeled as “abnormalities” are normal and may not be associated with pain or symptoms. Many interventions may be performed on people who have normal age-related changes, and most probably on tissues that are not the cause of the symptoms.

Drivers of Too Much Medicine

There are many drivers of too much medicine, including the belief of clinicians and patients that more health care (in the form of imaging and investigations, prescribing medicine, injections, multiple passive interventions and electrotherapy modalities, and surgery) is better than

prioritizing condition-specific and lifestyle advice; that “doing something” is better than “waiting and watching”⁶; that the origin of pain can always be identified with clinical tests and imaging; that once identified, pain can be “fixed”; that symptoms are caused by “abnormalities” in static posture and structure; and that not addressing “abnormalities” risks further tissue damage or exacerbation of the condition.³

When more expensive interventions are recommended that offer equivalent or worse outcomes than lower-cost alternatives, profit and remuneration become drivers of sectors of the health care industry, insurers, pharmaceutical companies, and some clinicians. For sections of the media, drivers include sensationalism and revenue.⁹ Politicians may not wish to disenfranchise voters by appearing to reduce or withdraw health care alternatives considered fundamental by the electorate or advocated by lobby groups.^{15,18}

Suggestions for Change

Reducing the sequelae of too much medicine will require continuous effort from all stakeholders.¹⁷ We must all consider sustainability and acknowledge that health care resources are finite. In this section, we outline suggestions for how patients, policy makers, clinicians, educators, the health care industry, and the media can drive change. We have included a recommended reading list (**APPENDIX**, available at www.jospt.org) and resources (**TABLE**) to help reduce the impact of too

TABLE

RESOURCES TO BETTER UNDERSTAND AND HELP REDUCE TOO MUCH MEDICINE AND MEDICALIZING NORMALITY

Provide a card or leaflet with possible questions or discussion points for patients: <https://www.nhs.uk/using-the-nhs/nhs-services/gps/what-to-ask-your-doctor/>
 Discuss the value and importance of shared decision making in musculoskeletal practice⁶
 Too much medicine: <https://www.bmj.com/too-much-medicine> and https://www.youtube.com/watch?v=FDffclD_BsA
 Better medicine: <https://www.bmj.com/bettermedicine>
 Improving critical thinking about health care: <https://www.healthnewsreview.org>
 Online guides for reporting medical research: <https://www.smh.com.au/national/our-guidelines-for-reporting-medical-research-20190603-p51tw2.html>
 Discuss musculoskeletal management in social media forums⁵

much medicine and medicalizing normality in musculoskeletal practice.

What Can Patients Do?

- Ask questions relating to the different management options for your condition, focusing on the anticipated benefits, time scales, and harms
- Ask what you can do to help manage your condition
- Ask if “wait and watch” is an appropriate option
- When fully informed of the benefits, harms, and costs of the management options, contribute to codesigning the provision of health care at local and national levels
- Share experiences and journeys through the health care system to promote improvements in delivery of care

What Can Policy Makers Do?

- Withdraw the financial incentive to offer unnecessary assessment and intervention
- Defund low-value care (eg, subacromial decompression surgery¹⁶)
- Prioritize funding high-value care (eg, exercise programs for rotator cuff-related shoulder pain⁶)

What Can Clinicians Do?

- Ensure patients are aware of and understand all reasonable diagnosis and management options, and the harms, benefits, and expected outcomes of each
- Avoid emotive language and outdated explanations when explaining symptoms and making recommendations for management
- Establish what matters most to the patient and discuss this as part of decision making
- Understand the natural course of the condition
- Know the investigations that should and should not be considered, and age-related norms for investigation findings
- Discuss the impact an intervention may have on the individual (eg, the number of sessions a patient may need to attend for an exercise class and how much self-directed exercise he or she would need to complete, any limita-

tions to activity following an injection or surgery, and for how long)

What Can Educators Do?

- Ensure that curricula are contemporary and reflect current evidence
- Teach critical appraisal skills so clinicians can effectively and efficiently incorporate new evidence into practice
- Teach shared decision-making skills

What Can the Health Care Industry Do?

- Use common language and explanations for patients, based on an unbiased assessment of research
- Promote interprofessional practice

What Can the Media Do?

- Recognize the harm and the distress that can occur when health care issues are sensationalized or misrepresented

SUMMARY

TOO MUCH MEDICINE BURDENS health care systems and deprives societies of resources. Overcoming too much medicine requires stakeholders (patients, clinicians, educators, health care funders, media, policy makers, industry, insurers, politicians, etc) to appropriately prioritize low-risk, cost-effective care over higher-risk and more expensive care of equal clinical effectiveness. Professional bodies, government agencies, clinicians, and patients must collaborate to discuss and synthesize the available evidence, share decisions, and translate knowledge. We do not underestimate the challenge of the task. Reducing the harm of medicalizing normality and avoiding the temptation to provide too much medicine in current musculoskeletal practice depend on all of us. ●

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APPENDIX

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Eight in Every 10 Abstracts of Low Back Pain Systematic Reviews Presented Spin and Inconsistencies With the Full Text: An Analysis of 66 Systematic Reviews

Systematic reviews are widely read by health care professionals to guide clinical decision making.¹⁴ However, systematic review abstracts that selectively report results—“spin”³¹—can mislead the reader.^{4,8,22} Sometimes the abstract is the only available source of information to readers, who cannot refer to the full text when searching for detailed study results.⁷

Spin is “a misrepresentation of study results, regardless of motive (intentional or unintentional) that overemphasizes the beneficial effects of the intervention

and overstates safety compared with that shown by the results.”¹² In systematic reviews,³³ spin occurs where the title, recommendations, or conclusions claim a

beneficial effect of the intervention that is not supported by the findings. Spin may also occur where selectively reported outcomes favor the beneficial effect of the intervention and downplay its harms, and in extrapolation of the findings to a different intervention.

The consistency of an abstract can be measured by the percentage of agreement or categorized rating (high, medium, or low inconsistency) between the reporting and/or interpretation of results in the abstract and the corresponding full text.¹⁷ A scoping review of biomedical reviews indicated that there was poor consistency of reporting between abstracts and full texts.⁷ However, the consistency of reporting between abstract and full text in the rehabilitation field warrants investigation. An understanding of how findings are reported in the rehabilitation field will help journal editors, peer reviewers, and authors improve the overall quality of abstracts.

The amount of spin in the abstracts of systematic reviews⁶ and the consistency between an abstract and its respective full text⁷ in the rehabilitation field are unknown. Physical therapy interventions are the most common nonpharmacological

• **OBJECTIVE:** To evaluate whether abstracts of low back pain reviews contained spin, whether these abstracts consistently represented the full text, and whether the spin in these abstracts was associated with the type of conclusion.

• **DESIGN:** Overview study.

• **LITERATURE SEARCH:** We searched the Physiotherapy Evidence Database on January 10, 2018.

• **STUDY SELECTION CRITERIA:** Systematic reviews of physical therapy interventions for low back pain published between 2015 and 2017.

• **DATA SYNTHESIS:** Spin was assessed using a 7-item checklist. We evaluated consistency by comparing information in the abstract with that in the full text using the 7-item checklist and kappa coefficient analysis. We used logistic regression analysis to evaluate the association between spin in the abstract and type of conclusion. We evaluated methodological quality using the revised

version of the AMSTAR (A Measurement Tool to Assess systematic Reviews) tool.

• **RESULTS:** We included 66 eligible systematic reviews, subdivided into Cochrane (n = 9) and non-Cochrane (n = 57) reviews. There was some form of spin in 80% of abstracts. Abstracts of non-Cochrane reviews were not consistent with the full text (fair to moderate agreement). Cochrane review abstracts had substantial to almost perfect agreement with the full text. Spin was not associated with type of conclusion in all systematic reviews ($P < .05$). The methodological quality ranged from “high” to “critically low.”

• **CONCLUSION:** The abstracts of systematic reviews evaluating physical therapy interventions for low back pain need improvement. *J Orthop Sports Phys Ther* 2020;50(1):17-23. Epub 23 Aug 2019. doi:10.2519/jospt.2020.8962

• **KEY WORDS:** abstracts, bias, data interpretation, low back pain, research design, research reporting, systematic reviews

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and nonsurgical treatment for low back pain.^{2,3,5,9,13} Low back pain is the most burdensome global health condition in terms of disability, and has a high prevalence.^{11,13,18} We asked 3 questions: (1) Do abstracts of low back pain systematic reviews contain spin? (2) Do abstracts of low back pain systematic reviews consistently represent the full text? (3) Is abstract spin associated with type of conclusion (positive, negative, neutral, or indeterminate)?

METHODS

Data Sources and Searches

THIS OVERVIEW STUDY INCLUDED ABSTRACTS from 66 systematic reviews. The eligibility criteria for the reviews were full publication (abstract and full text); evaluation of physical therapy interventions for the treatment of low back pain; published between January 2015 and December 2017, inclusive; and written in English, Spanish, or Portuguese. We searched the Physiotherapy Evidence Database (PEDro) on January 10, 2018, using the search strategy “systematic review” for method, “lumbar spine, sacroiliac joint or pelvis” for body part, “pain” for problem, and 2015 to 2017 for year of publication. The 2015-2017 period was chosen because the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for Abstracts reporting checklist⁴ was published in 2013, which raised the standards of reporting in the abstracts of systematic reviews compared to those previously published. We searched PEDro because it is one of the most comprehensive indexes of published systematic reviews in physical therapy.¹⁹

Data Extraction and Quality Assessment

Two independent raters assessed the methodological quality, spin of information in the abstract, consistency of reporting between the abstract and full text, and the type of conclusion for each of the included systematic reviews. Any disagreements were resolved by a consen-

sus discussion or, if necessary, arbitration by a third author. Both raters were physical therapists with at least 8 years of experience in research methods. In 2016, both raters completed a training program in article appraisal,²⁵ and both attended lectures on advanced research methodology during their research training.

We used the second version of the 16-item A MeaSurement Tool to Assess systematic Reviews (AMSTAR-2)²⁹ checklist to evaluate the methodological quality of each systematic review. The AMSTAR-2 has established validity and reliability.²⁸ The 16 items are (1) inclusion of the components of PICO (Participants, Interventions, Comparisons, and Outcomes) in the research question, (2) review methods established prior to the conduct of the review, (3) selection of the study designs, (4) literature search strategy, (5) duplicate study selection, (6) duplicate study data extraction, (7) list of excluded studies, (8) characteristics of included studies, (9) risk-of-bias assessment, (10) report on the sources of funding for included studies, (11) methods to combine data, (12) impact of risk of bias in individual studies on meta-analysis results, (13) impact of risk of bias in individual studies when interpreting the results, (14) discussion about heterogeneity, (15) publication bias, and (16) conflicts of interest and funding stated. Each item was judged as “yes,” “partial yes,” “no,” or “not applicable.”

We rated the methodological quality of each systematic review as “high” (no weaknesses or 1 noncritical weakness), “moderate” (more than 1 noncritical weakness), “low” (1 critical flaw, with or without noncritical weakness), or “critically low” (more than 1 critical flaw, with or without noncritical weakness) based on the AMSTAR-2 scores.²⁹ The noncritical weakness items were 1, 3, 5, 6, 8, 10, 12, 14, and 16. The critical flaws items were 2, 4, 7, 9, 11, 13, and 15.

Assessing Spin and Consistency

Spin in Systematic Review Abstracts We combined items that indicated the pres-

ence of spin in abstracts and used them in a 7-item checklist. We assessed abstracts in isolation, because readers should be able to interpret the review based on the Results section of an abstract. The items in our 7-item checklist were those selected by Yavchitz et al³³ using a consensus process of qualitative and quantitative methods. Members of the Cochrane Collaboration judged the most severe types of spin, out of 21 types, that could occur in systematic review abstracts.³³ We evaluated the presence of spin by comparing the abstract results to the abstract conclusion, using the following 7-item checklist (item 3.2.2³³):

1. The conclusion formulates recommendations for clinical practice not supported by the findings
2. The title claims or suggests a beneficial effect of the experimental intervention not supported by the findings
3. Selective reporting of or overemphasis on efficacy outcomes or analysis favoring the beneficial effect of the experimental intervention
4. The conclusion claims safety based on nonstatistically significant results with a wide confidence interval
5. The conclusion claims a beneficial effect of the experimental treatment despite high risk of bias in primary studies
6. Selective reporting of or overemphasis on harm outcomes or analysis favoring the safety of the experimental intervention
7. The conclusion extrapolates the review's findings to a different intervention (ie, claiming efficacy of one specific intervention although the review covers a class of several interventions)

We answered each item as yes (spin was clearly present or information was omitted or not reported) or no (spin was not present). We calculated the percentage of each item presenting spin for all abstracts. We measured the reliability between the 2 independent raters evaluating spin of information in the abstracts and full texts before consensus was evaluated.

Consistency Between Systematic Review Abstract and Full Text We evaluated the abstract and full text independently, using the 7-item checklist.³³ We then compared the 7-item checklist result from the abstract to the result from the full text. We also used the 7-item checklist to evaluate the presence of spin in the full text, so that we could compare information reported in the abstract to the information presented in the full text of the systematic review. We compared each item from the 7-item checklist between abstract and full text to assess consistency. Item 2 (systematic review title) of the checklist was omitted from this analysis.

Association of Abstract Spin With Systematic Review Conclusion To investigate whether conclusions were influenced by abstract spin, we built logistic regression models, using presence of spin in the abstract (dichotomous variable, categorized as yes or no) as the dependent variable and type of conclusion in the abstract (categorized as dummy variables of “positive,” “neutral,” “negative,” or “indeterminate”) and type of conclusion in the full text (the same dummy variables for the abstract) as independent variables. We classified the type of conclusion for both the abstract and the full text. A “positive” conclusion was determined when systematic review authors stated that there was evidence of effectiveness, “neutral” when authors stated no evidence of effectiveness or reported no opinion, “negative” when authors advised against the use of the intervention or did not recommend it, or “indeterminate” when authors stated that there was insufficient evidence or that more research is required.³⁰

Data Analysis

Frequencies of “high,” “moderate,” “low,” and “critically low” scores were reported using the AMSTAR-2. We reported frequencies for all reviews, for Cochrane reviews, and for non-Cochrane reviews. We used SPSS software (IBM Corporation, Armonk, NY) for all analyses.

Abstract Spin and Consistency With the Full Text The percentage of abstracts of included reviews achieving each item of the 7-item checklist (spin of information) was tabulated. We used kappa coefficients^{17,20} to evaluate reliability between the 2 independent raters. The following criteria were used for interpreting the kappa scores: less than 0, “less than chance”; 0.01 to 0.20, “slight”; 0.21 to 0.40, “fair”; 0.41 to 0.60, “moderate”; 0.61 to 0.80, “substantial”; and 0.81 to 0.99, “almost perfect” agreement.^{17,20}

For abstract consistency, we used kappa coefficients^{17,20} to calculate the agreement between the abstract and full text for items 1 and 3 through 7 of the 7-item checklist (item 2 is related to the title). We considered an item to be consistent when the kappa value was 0.61 or higher (ie, “substantial” to “almost perfect” agreement).

Association of Abstract Spin With Type of Conclusion There was an association between variables when the independent variable reached a *P* value less than .05. We reported odds ratios with 95% confidence intervals for the logistic regression models.

We performed secondary analyses with data from the Cochrane and non-Cochrane reviews separately. Non-Cochrane reviews are twice as likely to have positive conclusions compared to Cochrane reviews,³⁰ and Cochrane reviews

of physical therapy have higher reporting and methodological quality.²¹

RESULTS

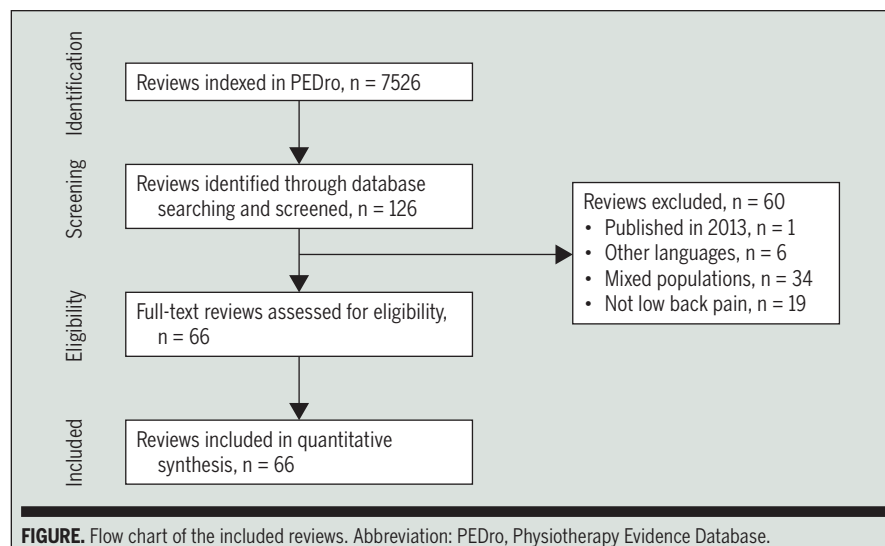
FROM THE 7526 REVIEWS INDEXED IN PEDro on January 10, 2018, 126 fulfilled our search criteria. Sixty reviews were excluded²³ and our final sample included 66 reviews (**FIGURE**). Both data sets were detailed in appendices of a previous study.²³

The AMSTAR-2 quality rating was critically low for 50 (76%) reviews, low for 7 (11%), high for 5 (8%), and moderate for 4 (6%). Cochrane reviews had higher quality ratings than non-Cochrane reviews. The quality ratings for Cochrane reviews ranged from moderate to high, while the quality ratings for non-Cochrane reviews ranged from critically low to low. Achievement of AMSTAR-2 individual items is detailed in a previous study.²³

All included reviews were published in English. The types of conclusion of the 66 reviews, collectively and separated into non-Cochrane (*n* = 9) and Cochrane (*n* = 57) reviews, are shown in **TABLE 1**.

Spin in Systematic Review Abstracts

The number and percentage of reviews that met each item of the 7-item checklist for the abstract are presented in **TABLE 2**. Some form of spin was observed



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in 53 (80%) of 66 abstracts. Selective reporting of harm outcomes of the experimental intervention was the most common type of spin, presented in 48 (73%) of 66 abstracts. Thirteen (20%) of 66 systematic reviews had abstracts that were free of spin (6/57 non-Cochrane reviews and 7/9 Cochrane reviews). Reliability between the 2 independent authors ranged from slight ($\kappa = 0.09$) to almost perfect agreement ($\kappa = 1.0$), with a mean kappa of 0.55 (detailed in the APPENDIX, available at www.jospt.org).

Consistency Between Systematic Review Abstract and Full Text

One item of the 7-item checklist (safety based on nonstatistically significant results) had substantial agreement between the abstract and full text for the 66 systematic reviews. All other items had fair to moderate agreement. Consistency between abstracts and full texts of Cochrane reviews was superior to that of non-Cochrane reviews (TABLE 3).

An incidental finding of our study was that 4 of the 9 Cochrane reviews had been

republished in other journals.^{10,26,32,34} Compared to the original Cochrane reviews, the republications had lower AMSTAR-2 ratings. Three of the 4 Cochrane review abstracts were free from spin; 4 republications presented at least 1 positive item on the 7-item checklist. The Cochrane republications had higher levels of spin in the abstracts than the original Cochrane versions.

Association of Abstract Spin With Type of Conclusion

Spin in the abstract was not associated with the type of conclusion (positive, neutral, negative, or indeterminate) in the abstract or full text ($P > .05$). The secondary analysis was performed for the non-Cochrane reviews only and had similar results ($P > .05$).

DISCUSSION

MOST ABSTRACTS OF SYSTEMATIC REVIEWS evaluating physical therapy interventions for low back pain contained spin. Abstracts of non-Cochrane reviews were less consistent with the full text (fair to moderate agreement) than Cochrane review abstracts (substantial to almost perfect agreement). The

TABLE 1

TYPE OF CONCLUSION FOR THE TOTAL SAMPLE AND NON-COCHRANE AND COCHRANE REVIEWS^a

Variable	Total Sample (n = 66)	Non-Cochrane Reviews (n = 57)	Cochrane Reviews (n = 9)
Conclusions in the abstract			
Positive	25 (37.9)	24 (42.1)	1 (11.1)
Neutral	4 (6.1)	4 (7.0)	0 (0.0)
Negative	2 (3.0)	2 (3.5)	0 (0.0)
Indeterminate	35 (53.0)	27 (47.4)	8 (88.9)
Conclusions in the full text			
Positive	21 (31.8)	20 (35.1)	1 (11.1)
Neutral	4 (6.1)	4 (7.0)	0 (0.0)
Negative	1 (1.5)	1 (1.8)	0 (0.0)
Indeterminate	40 (60.6)	32 (56.1)	8 (88.9)

^aValues are n (percent).

TABLE 2

NUMBER AND PERCENTAGE OF REVIEWS WITH SPIN IN THE ABSTRACT SECTION FOR THE TOTAL SAMPLE AND NON-COCHRANE AND COCHRANE REVIEWS^a

7-Item Checklist	Description	Total Sample (n = 66)	Non-Cochrane Reviews (n = 57)	Cochrane Reviews (n = 9)
1. Recommendation	Recommendation for clinical practice not supported by the findings	16 (24.2)	15 (26.3)	1 (11.1)
2. Title claims a beneficial effect not supported by the findings	The title claims a beneficial effect of the experimental treatment not supported by the findings	0 (0.0)	0 (0.0)	0 (0.0)
3. Selective reporting of outcomes	Selective reporting of outcomes favoring the beneficial effect of the experimental intervention	21 (31.8)	19 (33.3)	2 (22.2)
4. Safety based on nonstatistically significant results	The conclusion claims safety based on nonstatistically significant results	26 (39.4)	26 (45.6)	0 (0.0)
5. Beneficial effect reported despite high risk of bias	The conclusion claims a beneficial effect of the experimental treatment despite high risk of bias in primary studies	32 (48.5)	32 (56.1)	0 (0.0)
6. Selective reporting of harm outcomes	Selective reporting of harm outcomes of the experimental intervention	48 (72.7)	48 (84.2)	0 (0.0)
7. Conclusion extrapolates findings to a different intervention	The conclusion extrapolates the review's findings to a different intervention	5 (7.6)	5 (8.8)	0 (0.0)

^aValues are n (percent).

presence of spin was not associated with type of conclusion. Abstracts of Cochrane reviews had higher methodological quality and consistency, and contained less spin, than abstracts of non-Cochrane reviews.

The abstracts of systematic reviews of physical therapy interventions for low back pain have similar deficiencies to abstracts in other areas of health care.^{15,16,27} Our comparison of the abstracts of Cochrane and non-Cochrane reviews is consistent with previous studies, suggesting that Cochrane reviews have higher methodological quality²¹ and contain less spin.^{21,30} The difference might be explained by the rigorous editorial processes, higher word limits for better reporting of results, use of appendices, and inclusion of fewer study designs (randomized controlled trials only) in Cochrane reviews.²⁴

Editors and peer reviewers should emphasize the use of reporting checklists for abstracts (such as the PRISMA for Abstracts checklist⁴) to guide the review process. Authors might consider writing the abstract after completing their systematic review to ensure that results are consistent and free from spin. Future research could test the impact of these

suggestions by comparing different editorial processes. Our suggestions are in accordance with a recent scoping review,⁷ which recommended that authors, peer reviewers, and editorial staff strictly inspect the consistency of abstracts during the submission process; flexibility with word counts; and guidance on the use of checklists for abstracts.

Limitations

To strengthen the quality of our study, we used robust methods in our data collection, including duplicate data extraction using contemporary methodological evaluation and exploration of recent concerns in the literature regarding spin of information^{31,33} and the consistency of abstracts.⁷ Despite similarities with other areas of health care,^{1,7,15,16,31,33} our results may not be generalizable to other systematic review abstracts (other than physical therapy interventions) for low back pain in recent years.

Our findings are based on 7 items that aimed to measure the most severe types of spin. Although these items have good face validity, the 7-item checklist was not fully tested for its measurement properties. Therefore, our results should be interpreted with caution. Future research

should investigate the validity and reliability of instruments evaluating spin in results and conclusions, as our reliability results add to previous research on the subjectivity of evaluating spin. Our results add to the findings of Yavchitz et al,³³ who ranked the 7 items according to perceived severity and made more data available to support the validity of the items. Our research group is currently addressing this limitation by evaluating the concerns raised in the literature regarding abstracts of both systematic reviews and randomized controlled trials across a broad spectrum of health care areas.²²

Implications

We advise readers to read the full text when using systematic reviews to guide practice. Journal editors and peer reviewers may consider following and checking both full-text and abstract reporting checklists, and ensuring that abstracts are free from spin. We suggest that authors write the abstract only when the manuscript has been completed, paying due attention to consistency and removal of spin. Abstracts must be a reliable summary of the systematic review for clinicians with time constraints.

CONCLUSION

THE ABSTRACTS OF SYSTEMATIC REVIEWS evaluating physical therapy interventions for low back pain need improvement. Eight of every 10 abstracts presented spin of information and did not consistently represent the full text (fair to moderate agreement). Spin was not associated with type of conclusion. ●

KEY POINTS

- FINDINGS:** Abstracts presented spin of information and were not consistent with the full text. Spin was not associated with type of conclusion.
- IMPLICATIONS:** Readers should read the full text to guide practice. Editors and reviewers should follow abstract reporting checklists and check for spin.

TABLE 3 CONSISTENCY SCORES BETWEEN ABSTRACT AND FULL TEXT FOR THE TOTAL SAMPLE AND NON-COCHRANE AND COCHRANE REVIEWS ^a			
7-Item Checklist	Total Sample (n = 66)	Non-Cochrane Reviews (n = 57)	Cochrane Reviews (n = 9)
1. Recommendation	0.27	0.27	0.89
2. Title claims a beneficial effect not supported by the findings ^b	NA	NA	NA
3. Selective reporting of outcomes	0.32	0.34	0.78
4. Safety based on nonstatistically significant results	0.62	0.60	1.00
5. Beneficial effect reported despite high risk of bias	0.34	0.38	1.00
6. Selective reporting of harm outcomes	0.52	0.37	1.00
7. Conclusion extrapolates findings to a different intervention	0.55	0.55	1.00
Abbreviation: NA, not applicable. ^a Values are kappa coefficient. Values in bold are classified as being “consistent” (κ≥0.61). ^b Item 2 of the 7-item spin checklist is NA because it is related to the title.			

CAUTION: Our results may not be generalizable to other systematic review abstracts.

STUDY DETAILS

PATIENT/PUBLIC INVOLVEMENT: There was no direct patient involvement in this study. Our study aims to improve the overall quality of abstract reporting and interpretation, directly affecting health professionals' clinical decisions on treating their patients. Furthermore, this study also aims to affect health care journal policies, which should be stricter in terms of reporting and methodological quality.

AUTHOR CONTRIBUTION: Dr Nascimento was responsible for study conception and study design; performed data extraction, data checking, and statistical analyses; and wrote the first and final drafts of the paper. Drs Gonzalez and Araujo performed data extraction, data checking, and statistical analyses and contributed to the final draft of the paper. Dr Costa was responsible for study conception, contributions to study design, supervision of research, drafting the paper, and writing the final draft of the paper. Drs Maher and Moseley contributed to the study conception and to the final draft of the paper.

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[LITERATURE REVIEW]

APPENDIX

RELIABILITY OF DATA EXTRACTION BETWEEN THE 2 AUTHORS WHO COLLECTED THE DATA, BEFORE CONSENSUS^a

Spin/Item	Kappa Coefficient
7-item checklist applied to abstracts	
1. Recommendation	0.45
2. Title claims a beneficial effect not supported by the findings	1.0
3. Selective reporting of outcomes	0.48
4. Safety based on nonstatistically significant results	0.42
5. Beneficial effect reported despite high risk of bias	0.64
6. Selective reporting of harm outcomes	0.67
7. Conclusion extrapolates findings to a different intervention	0.09
7-item checklist applied to full texts	
1. Recommendation	0.42
2. Title claims a beneficial effect not supported by the findings	1.0
3. Selective reporting of outcomes	0.49
4. Safety based on nonstatistically significant results	0.54
5. Beneficial effect reported despite high risk of bias	0.54
6. Selective reporting of harm outcomes	0.67
7. Conclusion extrapolates findings to a different intervention	0.25

^aValues are presented for each item of the 7-item checklist for abstracts and full texts ($n = 66$ reviews).