

CSM Abstracts

The *Journal of Orthopaedic & Sports Physical Therapy* is pleased to publish abstracts of the 2022 Combined Sections Meeting (CSM), to be held February 2-5, 2022 in San Antonio, TX. 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.

Sincerely,



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

Academy of Orthopaedic Physical Therapy Platform Presentation Abstracts OPL1-OPL56

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

HIGHER KNEE MUSCLE COCONTRACTIONS ARE OBSERVED IN INDIVIDUALS EXHIBITING LOADING ASYMMETRY EARLY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Knee osteoarthritis (OA) after ACL reconstruction (ACLR) is common. Peak medial compartment force (pMCF) asymmetry 6 months after ACLR is associated with OA development 5 years after surgery. MCF after ACLR is also associated with cocontraction of knee muscles, which can be evaluated via cocontraction indices (CCIs), where greater magnitudes refer to greater cocontraction. The alterations in CCIs of medial/lateral knee muscles in individuals with pMCF asymmetries (involved [IN] – uninjured [UN]) after ACLR have not been examined. The purpose of this study was to investigate whether individuals having asymmetric pMCF walk with altered CCIs of medial/lateral knee muscles 3 months after ACLR. It was hypothesized that asymmetric-loaders (AL) would display higher CCIs of knee muscles compared to symmetric-loaders (SL), with higher CCIs in the involved limb (versus UN).

NUMBER OF SUBJECTS: Forty-five (29 AL: 17 male; mean $\pm$ SD age, 23 $\pm$ 7 years and 16 SL: 10 male; age, 22 $\pm$ 6 years).

MATERIALS AND METHODS: All participants completed gait analysis at a self-selected speed 3 month after ACLR. Kinematic, Kinetic, and electromyography (EMG) data were collected bilaterally. pMCF in both limbs was determined via a validated EMG-based neuromuscular model. Based on a minimum interlimb difference of pMCF determined previously (0.4 body weight), participants were divided into 2 groups based on loading symmetry: SL and AL. EMG data of rectus femoris (RF), vastus medialis (VM), vastus lateralis (VL), medial hamstring (MH), lateral hamstring (LH), medial gastrocnemius (MG), and lateral gastrocnemius (LG) were collected, filtered, and normalized. CCIs of the VM-MH, VM-MG, VM-LG, VL-LH, VL-LG, and VL-MG muscle pairs were calculated by dividing the smallest EMG signal by the largest EMG signal and multiplying by the sum of these signals. A 2-way (group by limb) ANOVA was performed to compare CCIs between groups in both limbs. If there was a significant interaction ($\alpha < .05$), post hoc paired and independent t tests (1 tailed) were used to evaluate CCIs between limbs and between groups, respectively.

RESULTS: There were significant interactions in the VM-LG and VL-LG CCIs ($P = .044$ and $.013$, respectively). Higher CCIs of these pairs occurred in the IN limb of asymmetric-loaders (versus SL) ($P = .018$ and $.011$, respectively). For the VL-LG pair, asymmetric-loaders showed higher CCIs in the IN limb (versus UN) ($P = .021$).

CONCLUSIONS: Higher quadriceps/LG cocontraction occurs in individuals with medial knee loading asymmetry 3 months after ACLR.

CLINICAL RELEVANCE: Individuals early after ACLR are more likely to walk with altered mechanics and neuromuscular control. Our findings show asymmetric-loaders walk with higher CCIs of quadriceps/LG pairs in the involved limb. The increased CCIs of these pairs early after ACLR may contribute to altered knee medial compartment loading, which eventually leads to knee cartilage degeneration. Thus, implementing early neuromuscular intervention to reduce the magnitudes of knee muscles CCIs after ACLR may help to prevent/delay the development of knee OA.

OPL2

INITIAL INVESTIGATION OF CARBON FIBER ORTHOSIS USE TO PREVENT ANKLE POSTTRAUMATIC ARTHRITIS

Kirsten M. Anderson, Molly A. Corlett, Donald Anderson, Jason Wilken

PURPOSE/HYPOTHESIS: Intra-articular tibia fractures often result in poor outcomes like pain, limited mobility, and decreased quality of life. These injuries increase the risk for posttraumatic osteoarthritis (PTOA) due to residual articular incongruities and elevated contact stress. Carbon fiber custom dynamic orthoses (CDOs) positively affect patient function and consist of a proximal cuff below the knee, a posterior carbon fiber strut, and a footplate. However, little is known about the effects of CDO use on tibiotalar contact stress, a prime determinant of PTOA risk.

NUMBER OF SUBJECTS: Six healthy able-bodied individuals were recruited and provided written informed consent for this study.

MATERIALS AND METHODS: This study was approved by the local institutional review board. Kinematic and kinetic data were captured using motion capture (120 Hz, Vicon) and force measurement (1200 Hz, AMTI Inc) systems and processed using Visual3D (C-Motion). Participants were tested in 4 conditions: (1) No CDO (2) CDO of moderate to low stiffness (ML) (3) CDO of moderate stiffness (MOD) and (4) CDO with firm stiffness (FIRM). The Gait2392 musculoskeletal model was used to simulate walking and determine joint reaction forces in OpenSim Version 4.0 (SimTK.org) using experimental data, after a coordinate limit force representing the CDO was added to the model. Discrete element analysis was performed in MATLAB (MathWorks Inc) to evaluate tibiotalar cumulative contact stress-time exposure, using segmented tibial articular surface geometries from CT scans of each participant.

RESULTS: All comparisons were made against the No CDO condition. Soleus muscle force significantly decreased in the MOD (30.0%, $P = .004$) and FIRM (34.7%, $P = .002$) conditions. All CDOs reduced joint reaction forces (ML: 16.3% decrease, $P = .009$; MOD: 21.9% decrease, $P =$

.001; FIRM: 24.9% decrease, $P = .002$), mean cumulative contact stress-time exposure across the tibiotalar surface (ML: 5.6% decrease, $P = .045$; MOD: 17.2% decrease, $P = .001$; FIRM: 18.0% decrease, $P = .025$), and forefoot loading (ML: 10.4% decrease, $P = .028$; MOD: 26.2% decrease, $P = .004$; FIRM: 31.3% decrease, $P = .001$).

CONCLUSIONS: Plantar flexor muscles are a primary contributor to joint reaction force (JRF). Reducing soleus muscle force with CDOs can decrease JRF and ankle joint contact stress. All bracing conditions had significant effects, although MOD and FIRM results were generally similar. This suggests stiffness above a threshold may not influence limb mechanics when attempting to reduce articular contact stress.

CLINICAL RELEVANCE: Results show that CDOs can reduce tibiotalar cumulative contact stress-time exposure during gait which may delay or prevent PTOA onset among individuals with residual incongruities after intra-articular fracture. Initial testing in a healthy cohort indicates that moderate to firm stiffness CDOs are likely needed to reduce contact stress to desired levels, and that testing in patients at risk for PTOA is warranted.

OPL3

DIFFERENCES IN BODY IMAGE AND PERCEPTION BETWEEN ADULTS WITH AND WITHOUT PHANTOM-LIMB PAIN

Emma Beisheim-Ryan, Gregory Evan Hicks, Ryan T. Pohl, Jared Medina, Jaclyn Megan Sions

PURPOSE/HYPOTHESIS: Adults with lower-limb loss (LLL) often experience body image dissatisfaction and distorted body perception, which may be augmented by phantom limb pain (ie, pain perceived as coming from the amputated portion of the limb; PLP). To determine if impaired body perception may be a target for rehabilitation among adults with PLP, this study compared body image and perception between adults with and without PLP and explored associations among body image, body perception, and PLP interference. We hypothesized (a) adults with PLP would demonstrate more negative body image, more negative emotions towards the phantom limb, and greater phantom limb attention and awareness as compared to pain-free peers; and (b) negative body image and distorted body perception would be associated with increased PLP intensity and interference.

NUMBER OF SUBJECTS: Seventy-two adults ≥ 1 year post unilateral-LLL ($n = 42$ with PLP; $n = 30$ pain-free, age-matched peers).

MATERIALS AND METHODS: Participants completed self-reported outcome measures via an online, experimental platform (ie, Gorilla). Body image was reported via the Amputee Body Image Scale-Revised, and phantom limb perception (ie, ownership, awareness, attitude, emotional feelings) was reported via a modified version of the BATH CRPS Body Perception Disturbance Scale. Participants with PLP reported pain interference via the Brief Pain Inventory-Short Form. In SPSS 26, between-group differences in outcome measure scores were evaluated using Mann-Whitney U tests, and effect sizes were calculated. Correlations among measures of body image, body perception, and PLP were also evaluated using Kendall's τ_b correlation coefficients ($\alpha \leq .05$).

RESULTS: Participants (43% female) had undergone largely transtibial amputations several years prior (median time since LLL, 9 years). Demographics and amputation-specific details were similar between groups ($P > .050$). Adults with PLP reported more negative body image than pain-free peers ($U = 364.0$, $P = .004$, effect size [r] = 0.34). With respect to phantom limb perception, adults with PLP reported greater phantom limb ownership, attention, and awareness as compared to pain-free peers ($U = 175.5-297.0$, $P < .001-.034$, $r = 0.26-0.49$). Negative body image and emotional feelings towards the limb were significantly associated with increased PLP interference ($\tau_b = 0.25-0.26$, $P = .023-.026$).

CONCLUSIONS: Following LLL, body image dissatisfaction and phantom limb hyper-vigilance may be amplified by PLP. As negative body image was associated with increased PLP interference, future studies may consider targeting negative body image via cognitive behavioral therapy and mind-body interventions to reduce PLP-related disability.

CLINICAL RELEVANCE: Negative body image and heightened phantom limb attention and awareness may be key impairments for clinical intervention among adults with PLP. Mind-body interventions (eg, motor imag-

ery) have shown promise in ameliorating pain intensity; future research may reveal additional beneficial effects on negative body image and phantom limb hyper-vigilance.

OPL4

A COMPARISON OF PAIN, FATIGUE, AND FUNCTION IN POST-COVID-19 SYNDROME, FIBROMYALGIA, AND CHRONIC FATIGUE SYNDROME

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PURPOSE/HYPOTHESIS: Over 100 million people have been diagnosed with the COVID-19 and 30% may develop post-COVID-19 syndrome (PCS) characterized by persistent symptoms after acute infection. People with PCS report impaired function and reduced quality of life with 35% to 65% reporting fatigue and 10% to 30% reporting pain. However, little is known of the functional impact of pain and fatigue in PCS. PCS shares pain and fatigue symptomatology as other enigmatic disease processes such as fibromyalgia (FMS) and chronic fatigue syndrome (CFS) which may have multifactorial manifestations. Despite these comparisons most of the research into PCS has compared symptoms to healthy cohorts which limits clinical relevance of reporting functional implications associated with fatigue and pain. This survey study compared pain, fatigue, and functional impact among people with PCS, FMS, and CFS.

NUMBER OF SUBJECTS: Two hundred three people with PCS (mean $\pm$ SD age, 35.1 ± 10.5 years), 98 FMS (age, 41.7 ± 15.0 years), and 86 CFS (age, 35.5 ± 13.5 years) completed this survey study.

MATERIALS AND METHODS: Participants completed surveys using REDCap, including PROMIS Version 2.0 Physical Function (PROMIS-PF), Multidimensional Inventory of Subjective Cognitive Impairment (MISCI), 2016 modified Fibromyalgia Diagnostic Criteria Survey-widespread pain index (WPI), PROMIS Version 1.1 Pain Interference (PROMIS-PI), Brief Pain Inventory (BPI), Symptom Impact Questionnaire-Revised (SIQR), visual analogue fatigue scale (VAFS), and PROMIS Version 1.0 Fatigue. Differences among groups were analyzed using 1-way ANOVA with Bonferroni adjustment for post hoc multiple comparisons. Data are presented as means and standard deviations.

RESULTS: All groups reported physical (1) and cognitive (2) dysfunction, pain (3), and fatigue (4). The PCS group reported (1) similar physical dysfunction (PROMIS-PF, 40.3 ± 8.6) compared to FMS (39.5 ± 5.5) and CFS (39.5 ± 7.2), (2) statistically worse cognitive function (MISCI, 29.8 ± 8.0) compared to CFS (33.8 ± 7.5 , $P < .001$) but similar to FMS (31.4 ± 6.2), (3) less widespread pain to FMS (WPI: PCS, 1.5 ± 2.0 ; FMS, 5.4 ± 4.6 ; $P < .001$; CFS, 2.0 ± 3.3), less pain interference to FMS (PROMIS-PI: PCS, 60.3 ± 9.6 ; FMS, 63.6 ± 5.4 ; $P = .014$; CFS, 60.8 ± 7.2) (BPI-interference: PCS, 3.4 ± 2.4 ; FMS, 4.9 ± 2.1 ; $P < .001$; CFS, 4.0 ± 2.4), less pain severity to FMS (BPI-intensity: PCS, 3.3 ± 2.2 ; FMS, 4.5 ± 1.7 ; $P < .001$; CFS, 3.8 ± 2.2), less symptom impact to FMS and CFS (SIQR: PCS, 38.7 ± 18.4 , FMS, 48.3 ± 15.5 ; $P < .001$; CFS, 46.4 ± 15.0 ; $P = .001$), (4) less fatigue intensity (VAFS, 5.1 ± 2.6) to CFS (VAFS: FMS, 5.7 ± 1.9 ; CFS, 6.1 ± 2.2 ; $P = .003$), and similar impact of fatigue on function (PROMIS-F, 60.6 ± 8.1) compared to FMS (61.4 ± 6.9) and CFS (62.7 ± 7.1).

CONCLUSIONS: People with post-COVID syndrome experience similar physical and cognitive dysfunction as those with FMS and CFS despite having lower pain and fatigue severity. Further investigation comparing these clinical cohorts may lead to improved understanding and treatment of pain, fatigue, and functional limitations in people with post-COVID syndrome.

CLINICAL RELEVANCE: People with post-COVID syndrome commonly report symptoms of pain and fatigue that impact daily function and may benefit from rehabilitation strategies to improve pain, fatigue, and function.

OPL5

ALTERED WALKING PERFORMANCE IS ASSOCIATED WITH HIGHER PERCEIVED LOW BACK PAIN INTENSITY AND DISABILITY

Katie Ann Butera, Steven Z. George, Janki Patel, Mark Donald Bishop, Stephen Coombes, Emily Jane Fox

PURPOSE/HYPOTHESIS: Low back pain (LBP) is a leading cause of global disability, yet it is unclear how altered performance of functional tasks (eg,

walking) contributes to pain and disability. Moreover, performance-based measures often do not align with perceived measures. Better understanding of the relationship between altered performance of functional tasks and pain and disability perception is needed to optimize prognosis, monitoring, and treatment of LBP-related functional deficits. Accordingly, the purpose of this secondary analysis was to determine the associations between walking performance and (1) perceived pain intensity, (2) perceived pain interference, and (3) perceived disability in adults with LBP.

NUMBER OF SUBJECTS: Cross-sectional secondary analysis of a community sample of 76 adults with LBP (51% female; 62% chronic LBP; mean age, 45 years; mean pain intensity, 3/10; mean disability, 19%).

MATERIALS AND METHODS: Participants performed 3 trials of walking 10 m at a self-selected pace. Three-dimensional kinematics were recorded using a 12-camera motion capture system. Peak sagittal plane lower extremity joint angles and step characteristics were quantified. Self-reported pain intensity and pain interference were obtained via the Brief Pain Inventory, and self-reported disability was measured via the Oswestry Disability Index. To determine the associations between walking performance and self-report measures, 3 separate, multiple regression models were generated. Age, sex, peak joint angles, and step characteristics were the independent variables and each self-report measure served as a dependent variable ($\alpha = .05$). Variance inflation factors and tolerance estimates were inspected, and peak hip flexion and step length were removed from the final models due to concerns for multicollinearity.

RESULTS: Greater hip extension ($\beta = 0.38$) and increased double limb support time ($\beta = 0.42$) were independently associated with higher pain intensity ($P < .05$). Slower walking speed ($\beta = -0.30$) was independently associated with higher perceived disability ($P < .05$). None of the variables in this analysis were associated with pain interference ($P > .05$).

CONCLUSIONS: Interestingly, altered walking kinematics and slower gait speed were associated with higher pain intensity and higher perceived disability, but not pain interference. This adds to established evidence that performance and perceived measures should not be expected to align.

CLINICAL RELEVANCE: Individuals with more severe LBP may alter their walking performance, but this may not impact their perceived capacity for mobility activities. Further, the unique relationship between slower walking speed and higher perceived disability extends prior work citing slower walking speed as a risk factor for adverse health events. Future work to establish walking performance and walking speed risk cutoff scores for individuals with LBP is warranted.

OPL6

THE LOCATION OF SUPRASPINATUS TENDON COMPRESSION OR MINIMAL DISTANCE DURING SUBACROMIAL IMPINGEMENT TESTS

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PURPOSE/HYPOTHESIS: Subacromial impingement tests purportedly elicit mechanical compression of the supraspinatus tendon (SST) under the coracoacromial (CA) arch. This mechanism, especially in elevation angles greater than 60°, has recently been challenged as researchers have begun utilizing 3-D anatomic modeling. Cieminski et al noted little SST compression in the Hawkins-Kennedy (HK) or Neer tests, while compression was present for alternative HK test positions. The purpose of this descriptive study was to determine the anatomic location of SST compression or minimal distance during impingement tests.

NUMBER OF SUBJECTS: A retrospective review of the kinematics from shoulder impingement tests from 30 healthy subjects applied to 20 shoulder models was undertaken.

MATERIALS AND METHODS: Three-dimensional kinematic data from 30 healthy subjects was gathered for the following tests: (1) HK; (2) Alternative HK (Alt HK) in 45° of shoulder elevation; (3) Modified HK (Mod HK) in the scapular plane; (4) Alternative Modified HK (Alt Mod HK) in 45° of shoulder elevation in the scapular plane; and (5) Neer. Kinematic data were overlaid onto the twenty 3-D anatomic shoulder models, creating an end-range image for each model for each test. These images were analyzed independently by 5 raters who observed the location of compression or minimum distance between the SST and CA arch, using a numer-

ical score of 1 to 6 for the zones where it occurred (from anterior-posterior or zones 1 to 3 corresponded to equal thirds of the CA ligament; zones 4 to 6 were equal thirds of the acromion process from anterior-posterior).

RESULTS: The interrater reliability ($ICC_{2,1}$) between the 5 raters was 0.98. Nine of 20 models experienced SST compression or a minimum distance less than 1.5 mm in the HK test (location of all 9 models under the CA ligament); this number increased to 15 of 20 models during the Alt HK test, with the location of the majority of these 15 models under the CA ligament, but 4 moved posteriorly to the acromion process. Nine of 20 models experienced SST compression or a minimum distance less than 1.5 mm in the Mod HK test (location of all 9 models under the CA ligament); this number increased to 11 of 20 models during the Alt Mod HK test, with the location of all 11 models under the CA ligament. None of the models during the Neer test experienced SST compression or a minimum distance less than 1.5 mm.

CONCLUSIONS: Both alternative HK tests had more models experience SST compression or a minimum distance less than 1.5 mm when compared to traditional versions of the HK test, with the Alt HK test experiencing the greatest number. The location of SST compression or minimum distance for most subacromial tests was under the CA arch; this site moved posteriorly to the acromion process for some of the models during the Alt HK test.

CLINICAL RELEVANCE: The alternative HK tests may be more appropriate tests to assess for mechanical subacromial impingement of the SST compared to currently utilized positions, however, the psychometric properties of these alternative HK tests should be determined. The Neer test does not appear to be a valid subacromial impingement test.

OPL7

INTEGRATING INTERNET-BASED SELF-MANAGEMENT WITHIN PHYSICAL THERAPY AS A PSYCHOLOGICALLY INFORMED MODEL: A PILOT STUDY

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PURPOSE/HYPOTHESIS: Psychologically informed physical therapy (PIPT) uses cognitive-behavioral strategies to address psychosocial barriers to recovery. However, PIPT implementation requires clinician training, time, and support that may not be feasible in all settings. We have previously combined an internet-based self-management (IBSM) program focused on cognitive-behavioral principles with physical therapy (PT) as a potential PIPT model of care. Our data showed low patient engagement with the IBSM program, with only 35% of patients completing all IBSM lessons. A limitation of our study was that physical therapists were not trained in addressing engagement barriers or integrating IBSM program content. The purpose of this pilot study was to describe an integrated PIPT approach that trained physical therapists to support patient engagement with the IBSM program as part of care for chronic pain.

NUMBER OF SUBJECTS: Twenty-five patients (mean $\pm$ SD age, 53.4 $\pm$ 16.3 years; 19 [76%] female, 23 [92%] White) receiving outpatient PT for chronic low back and/or neck pain.

MATERIALS AND METHODS: Enrolled patients completed a baseline survey including validated questionnaires for physical function (PROMIS), pain interference (PROMIS), pain intensity (0-10 numeric rating scale), fear of movement (Tampa Scale of Kinesiophobia), pain catastrophizing (Pain Catastrophizing Scale), and pain self-efficacy (Pain Self-Efficacy Questionnaire). Patients were given access to a 7-session IBSM program to complete at home as part of PT. Physical therapists were trained in IBSM program content and motivational interviewing to assist with integration and engagement. Follow-up assessments in 19 (76%) patients using the same validated questionnaires were completed at 3 months. We assessed mean changes in outcomes from baseline to 3 months. Minimally clinically important difference (MCID) thresholds were used to infer meaningful outcome changes.

RESULTS: Patients attended a mean $\pm$ SD of 8.6 $\pm$ 4.5 PT sessions over a mean $\pm$ SD of 43.6 $\pm$ 22.9 days. Fourteen (60%) patients completed all 7 IBSM lessons, 2 (8%) completed 4 to 6 lessons, 3 (12%) com-

pleted 1 to 3 lessons, and 6 (20%) did not complete any lessons. We observed 3-month improvements in physical function (mean change, 4.8) and pain self-efficacy (mean change, 7.5) and reductions in pain interference (mean change, -2.2), pain intensity (mean change, -1.9), fear of movement (mean change, -3.7), and pain catastrophizing (mean change, -4.7). Twelve (63%) of 19 patients met or exceeded MCID in pain intensity, 11 (58%) in fear of movement, 10 (53%) in pain interference, 9 (47%) in pain self-efficacy, 8 (42%) in physical function, and 7 (37%) in pain catastrophizing.

CONCLUSIONS: Our feasibility pilot of an integrated PIPT approach showed a modest increase in patient engagement compared to our prior study and following physical therapist training. Our preliminary results show potential for patient benefit in pain-related outcomes.

CLINICAL RELEVANCE: Integration of a cognitive-behavioral IBSM program within PT may be a feasible and scalable approach that meets a PIPT model of care for pain management.

OPL8

FOOT OR ANKLE PAIN AS A RISK FACTOR FOR WORSENING KNEE PAIN: THE MOST STUDY

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PURPOSE/HYPOTHESIS: Foot and ankle pain is associated with biomechanical alterations that shift load from the foot and ankle to the knees. Since increased knee joint loading is a well-established risk factor for knee osteoarthritis (KOA), foot and ankle pain may play a key role in the onset and progression of knee pain. Previous work has shown that pain anywhere in the foot or ankle increases the odds of worsening knee pain in those with KOA. However, this work did not account for widespread pain (WSP), which could partially explain the effect of foot and ankle pain on worsening knee pain. We aimed to determine if foot or ankle pain is associated with worsening knee pain while accounting for WSP.

NUMBER OF SUBJECTS: We used data from the 144- and 168-month visits of the Multicenter Osteoarthritis (MOST) Study, a cohort study of persons with or at risk for KOA. For the current study, 2201 participants were included (57% female, 81% white), with a mean $\pm$ SD age of 63.6 $\pm$ 10.1 years and BMI of 29.2 $\pm$ 5.6 kg/m².

MATERIALS AND METHODS: At 144 months, participants were asked, "On most days, do you have pain, aching, or stiffness in any joints?" If the participant answered "yes," painful sites were marked on a homunculus. For the current study, our exposure was foot or ankle pain. For our outcome, worsening knee pain, we calculated the change in the Western Ontario and McMaster Universities Osteoarthritis Index-pain (WOMAC-P) from 144 to 168 months for each knee, then defined "worsening" as an increase of ≥ 2 points. To determine the relation of foot or ankle pain to worsening pain of the ipsilateral and contralateral knees, we used logistic regression models with generalized estimating equations to account for bilateral data. Models were first adjusted for age, sex, BMI, race, depressive symptoms, and baseline WOMAC-P and Kellgren-Lawrence grade of the outcome knee. To account for WSP, analyses were then repeated adding the number of painful sites above the waist as a covariate.

RESULTS: Of the 3892 limbs, 1271 (33%) had foot or ankle pain. Knee pain worsened in 758 knees (19.5%). Compared to limbs without foot or ankle pain, limbs with foot or ankle pain had 1.61 (1.30-1.99) and 1.50 (1.22-1.85) times the odds of worsening ipsilateral and contralateral knee pain, respectively. When accounting for the number of painful sites above the waist, limbs with foot or ankle pain had 1.29 (1.03-1.61) and 1.18 (0.95-1.48) times the odds of worsening ipsilateral and contralateral knee pain, respectively. The mean $\pm$ SD (range) number of painful sites above the waist was 1.68 $\pm$ 1.77 (0-10), and for each additional painful site the odds of worsening ipsilateral and contralateral knee pain were increased by 1.22 (1.16-1.29) and 1.23 (1.16-1.30) times, respectively.

CONCLUSIONS: Foot or ankle pain is associated with increased odds of worsening ipsilateral knee pain, even after accounting for WSP. The odds of worsening contralateral knee pain, on the other hand, seems to be largely explained by WSP.

CLINICAL RELEVANCE: Clinicians should consider foot and ankle pain as well as WSP to optimize outcomes for patients with KOA.

OPL9

MUSCULOSKELETAL IMAGING FOR LOW BACK PAIN IN DIRECT-ACCESS PHYSICAL THERAPY COMPARED TO PRIMARY CARE

Michael Scott Crowell, John Sterling Mason, John Hedrick McGinniss

PURPOSE/HYPOTHESIS: The National Committee for Quality Assurance - Healthcare Effectiveness Data and Information Set (HEDIS) low back pain (LBP) imaging recommendation identifies the percentage of patients who did not have imaging ordered within 28 days of the first encounter with a diagnosis of LBP. The primary purpose of this study was to compare the rates of adherence to HEDIS LBP imaging recommendations in patients aged 18 to 24 years between physical therapists and other primary care providers. A secondary purpose was to compare imaging findings and practice patterns. We hypothesized that physical therapists would have a greater rate of HEDIS adherence, greater rates of significant imaging findings, and demonstrate different practice patterns.

NUMBER OF SUBJECTS: Two thousand three hundred twelve.

MATERIALS AND METHODS: Military Health System Data Repository (MDR) data from January 2019 to May 2020 was reviewed for compliance with the HEDIS LBP imaging recommendation. Separately, AGFA IMPAX digital health care imaging software, searched from 14 June 2014 to 14 June 2020, identified patients with imaging obtained for LBP. Demographics, number of visits, time from initial physical therapy evaluation to imaging order, interventions and medications utilized, abnormal imaging findings, and the clinical significance of abnormal findings were documented. For all analyses, alpha was set at .05. Chi-square tests compared categorical variables. Mann-Whitney *U* tests compared continuous variables due to a nonnormal distribution of data.

RESULTS: From the MDR database, 1845 visits were identified for LBP in the Physical Therapy Clinic (PTC) and 467 visits in the Primary Care Clinic (PCC). In the PTC, 97.9% of encounters were consistent with the LBP imaging HEDIS recommendation compared with 84.1% in the PCC ($P < .001$). From the IMPAX search, 92 PTC and 50 PCC cases with LBP imaging were reviewed. Patients were young (mean $\pm$ SD age, 20.3 $\pm$ 1.3 years) and mostly male (59%). There were no significant differences in any demographics, clinically significant findings (31% PTC, 20% PCC, $P = .180$) or orders leading to specialist referral (31% PTC, 16% PCC, $P = .059$). There were significant differences in mean time from initial evaluation to first diagnostic imaging order (PTC, 26.4 days; PCC, 7.6 days; $P < .001$) and the mean visits from the initial evaluation to the first imaging order (PTC, 3.8 visits; PCC, 1.1 visits; $P < .001$).

CONCLUSIONS: Utilizing data from a national standardized health care performance measure, physical therapists practicing in a direct-access setting were significantly more likely than other primary care providers to appropriately order imaging and had different practice patterns for patients with LBP.

CLINICAL RELEVANCE: Physical therapists possess the knowledge and skills to appropriately order diagnostic imaging. Health policymakers at the state level should continue to advocate for direct-access to physical therapy services, to include referral for diagnostic imaging studies.

OPL10

THE REVISED ITEM RESPONSE THEORY-BASED JAW FUNCTIONAL LIMITATION SCALE WAS RELIABLE, VALID, AND EFFICIENT

Daniel Deutscher, Michael Kallen, Richard Orhbach, Sonia Sharma, Mark William Werneke, Deanna R. Hayes

PURPOSE/HYPOTHESIS: We evaluated items from the Jaw Functional Limitation Scale (JFLS) patient-reported outcome measure (PROM) to optimize its measurement properties for temporomandibular disorder (TMD) assessment; create an item response theory (IRT)-based item bank and associated computerized adaptive test (CAT) and short form (SF) administration modes; and assess its reliability, validity, and efficiency.

NUMBER OF SUBJECTS: Our calibration sample consisted of 2368 adult patients, aged 18 to 68 years (72% female, 44% college degree) with no

TMD, incident TMD, or chronic TMD (TMD type: painful, mechanical, or painful + mechanical) who responded to the JFLS (20 existing + 1 test item) at baseline.

MATERIALS AND METHODS: We tested IRT modeling assumptions of local item independence, unidimensionality, item fit, and absence of differential item functioning (DIF). Of particular importance were bi-factor analyses employed to determine potential multidimensionality impact. We calibrated our PROM using IRT's graded response model and assessed JFLS CAT and SF T scores (mean $\pm$ SD, 50 $\pm$ 10) for reliability, validity, and administration efficiency. We examined potential floor and ceiling effects, and we obtained known-groups validity evidence using baseline scores to discriminate between patient subgroups by expected differing levels of jaw function (target variables: age, gender, education, TMD type). We expected older patients and those who were female, with less education, and had pain + mechanical TMD type would have greater jaw function limitation.

RESULTS: We retained 13 of the 21 JFLS items demonstrating unidimensionality, as confirmed via bifactor analysis (omega-H = 0.90). No items displayed DIF for the factors assessed (gender, age, race/ethnicity, education, pain present). Overall median reliability was 0.91, 0.92, and 0.77 for the full bank, CAT, and SF, respectively. A small but acceptable floor effect (10.4% at lowest possible score) was observed; the ceiling effect (0.1% at highest possible score) was negligible. We created a 6-item SF, selecting items providing the most statistical information at targeted score levels. Reliable (≥ 0.70) *t* scores ranged from 36 to 78+ (SF range, 44-78+), with higher scores representing greater jaw function limitation. Scores discriminated between patient subgroups in clinically expected ways. Simulated CAT scores correlated highly with scores derived from the full bank ($r = 0.98$); they were obtained using an average of 5.6 items (median, 5; range, 4-8).

CONCLUSIONS: The IRT-based JFLS PROM, administered using either CAT or SF, was reliable, valid, and efficient for assessing jaw function limitation for patients with pain and/or mechanical TMD.

CLINICAL RELEVANCE: The IRT-based JFLS PROM provides new measurement advantages including score precision and administration efficiency. It assesses generalized functional limitation of the masticatory system and can be used for research and clinical care in outpatient rehabilitation settings.

OPL11

DO CLINICAL OUTCOMES IMPROVE AFTER TRAINING WITH A CLINICAL PRACTICE GUIDELINE FOR ADHESIVE CAPSULITIS?

Pamela Balla Dibblee, Kate Minick, Amee L. Seitz

PURPOSE/HYPOTHESIS: Evidence-based interventions according to clinical practice guideline (CPG) for adhesive capsulitis (AC): Mobility Deficits are specific to the diagnostic subgroup and guided by the level of tissue irritability. We hypothesize that training tactics (education, NFb; education plus feedback, Fb) will improve the clinician's ability to appropriately subgroup patients based on established clinical history and exam findings, identify impairments of body function and irritability level to apply appropriate rehabilitation interventions that will improve outcomes for patients with AC.

NUMBER OF SUBJECTS: Three hundred thirty-nine.

MATERIALS AND METHODS: Data were extracted from a web-based data collection and quality improvement platform. All patients classified with AC in 2018 and from March 2020 to March 2021 were included. Data included pain, initial and final Quick Disability of the Arm Shoulder and Hand (QDASH) scores, duration of the episode of care or length of stay (LOS; days), number of visits, and failure to progress (FTP), defined as not achieving a minimal clinically important difference (MCID) on the QDASH of 10 points. All therapists within the system were trained using the CPG for shoulder AC, April through August 2019. Clinics were then randomized to receive no feedback or additional feedback including knowledge of performance, 1:1 therapist mentoring and additional articles on the management of the condition. A chi-square test was performed to compare the FTP between pre and post implementation and between the Fb and NFb groups post implementation. *t* tests were used to compare change in QDASH, visit total, and LOS between the groups.

RESULTS: FTP improved from 36.2% pre implementation to 22.6% post implementation of the CPG for shoulder AC, $P = .010$, and was significantly lower for the Fb group (14.8%) compared to NFb (29.9%), $P = .02$. In the year prior to implementation, 171 patients with AC were seen with a FTP of 36.2% and a mean $\pm$ SD of 7.2 $\pm$ 6.1 visits. In the year post implementation 168 patients with AC were treated with FTP rate of 22.6% and 6.7 $\pm$ 4.37 visits. There was no significant effect on number of visits ($P = .39$; mean difference, 0.5; 95% CI: -0.063, 1.63), LOS ($P = .23$; mean difference, 6.5; 95% CI: -4.11, 17.11) or overall outcome change ($P = .16$; mean difference, 2.6; 95% CI: -6.22, 1.02), pre and post implementation. There were 87 patients treated by the group that received NFb, and 81 in the group that received feedback. Therapists who received feedback had greater improvement on the QDASH ($P = .007$; mean difference, -6.0; 95% CI: -10.38, -1.62), and 1.9 more visits ($P = .005$; 95% CI: -3.22, -0.58).

CONCLUSIONS: After implementing a education on the CPG for shoulder AC, all patient outcomes improved without an increase in the number of visits. Therapists that received additional feedback had a lower FTP rate that those who did not receive feedback.

CLINICAL RELEVANCE: Implementing therapist education on a CPG best evidence-based care improved outcomes for all patients. Providing additional feedback and education to therapists after initial training is an important consideration for health systems and clinics implementing guideline-based care.

OPL12

RELATIONSHIP BETWEEN HIP EXTENSION STRENGTH AND SPATIOTEMPORAL GAIT PARAMETERS IN ADULTS WITH LOWER-LIMB LOSS

Taylor Dodenhoff, Lindsay Victoria Case, Jennifer M. Roos, Bhupinder Singh

PURPOSE/HYPOTHESIS: Those with lower limb loss demonstrate atypical spatiotemporal gait parameters including gait speed, cadence, and step length, when compared to able-bodied individuals. There is a link between lower limb muscular strength and gait performance, however, the relationship between hip extensor strength and gait parameters in those with lower limb loss has yet to be thoroughly investigated. The purpose of this study was to investigate the relationship between hip extensor strength on the amputated limb with gait speed, cadence, and step length on the intact limb in adults with unilateral lower limb loss. It was hypothesized that subjects with greater hip extensor strength will have faster gait speed, higher cadence, and greater step length on the intact limb.

NUMBER OF SUBJECTS: Fifteen subjects (4 female, 11 male) with unilateral lower limb loss (9 transtibial and 6 transfemoral) participated in this study. The average $\pm$ SD age of participants was 54.9 $\pm$ 15.3 years (height, 1.8 $\pm$ 0.1 m; weight, 86.3 $\pm$ 17.7 kg).

MATERIALS AND METHODS: University Institutional Review Board approved the study. Hip extensor isometric strength was measured using the MicroFET3 handheld dynamometer. Gait speed, cadence, and step length were measured using the Protokinetic Zeno Walkway with Protokinetic PKMAS software. Pearson correlation coefficient (PCC) and regression analyses were performed to determine the level of relationship between hip extensor strength and the various gait parameters. SPSS Version 25 was used for statistical analysis and *P* value was set at .05 for significance.

RESULTS: Descriptive data are presented as mean values and standard deviations. The PCC and regression analyses determined positive relationships between 2 out of the 3 hypotheses. A mild, positive relationship ($r = 0.61$, $R^2 = 0.37$) was found between hip extensor strength and gait speed. No relationship ($r = 0.14$, $R^2 = 0.02$) was found between hip extensor strength and cadence. A moderate, positive relationship ($r = 0.72$, $R^2 = 0.51$) was found between hip extensor strength of the amputated limb and the step length of the intact limb.

CONCLUSIONS: Hip extension strength has positive correlations between gait speed and step length in patients with unilateral lower limb loss. No significant relationship was found between hip extension strength and cadence.

CLINICAL RELEVANCE: Hip extension strengthening needs to be an important part of the rehabilitation program for individuals with lower limb loss in order to improve their functional gait capacity.

OPL13

EFFECT OF INSPIRATORY MUSCLE TRAINING ON LOW BACK PAIN: A SYSTEMATIC REVIEW WITH META-ANALYSIS*Magno F. Formiga, Barbara D.A. Sousa, Lawrence P. Cahalin*

PURPOSE/HYPOTHESIS: Besides its major ventilatory tasks, the diaphragm plays a key role in postural control strategies as it has a direct anatomical connection to the spine. Isolated diaphragm activity has been shown to contribute to spinal stability even in the absence of abdominal and back muscles work. Current evidence suggests individuals with low back pain (LBP) often present with inspiratory muscle weakness, which can be corrected with specific training. However, the role inspiratory muscle training (IMT) may play in reducing LBP remains unclear. This meta-analysis examined the effectiveness of IMT compared to no-IMT on symptomatology and functional disability outcomes in adults with LBP.

NUMBER OF SUBJECTS: Three hundred two.

MATERIALS AND METHODS: A literature search was performed in PubMed and the Cochrane database through June 2021. The search strategy was conducted in English and included a mix of terms for the key concepts LBP and IMT. A study had to meet the following criteria to be included: (a) the study was conducted in adults with a confirmed diagnosis of LBP, (b) there was random allocation of participants to IMT and control groups, (c) IMT was the sole intervention difference between the groups, (d) the study provided postintervention pain intensity data using visual analog or numeric rating scales, and/or (e) the study provided postintervention LBP-related disability measures. Study quality was assessed using the PEDro scale. Statistical analyses were performed under random-effects models using *R* with the metafor and metagen packages.

RESULTS: Seven trials out of 153 identified records were considered eligible with a total of 302 subjects from both genders (mean $\pm$ SD age, 35.36 ± 18.62 years). Study quality was moderate to high with all studies scoring $\geq 6/10$. POWERbreathe and Expand-A-Lung devices were used for IMT in 5 and 2 trials, respectively. Training protocols lasted for 4 to 8 weeks with IMT intensity ranging from 50% to 90% of maximal inspiratory pressures. Studies used varying numbers of training sets and repetitions. Standard and adapted versions of the Oswestry Disability Index (ODI) were mainly used in the included trials to quantify the degree to which LBP impacted the participants' functional activities. Significant standardized mean differences of -0.81 and -0.29 were found for LBP intensity ($z = -2.14$, $P = .03$; 95% CI: -1.54 , -0.07 ; $I^2 = 98.8\%$) and ODI ($z = -4.73$, $P < .01$; 95% CI: -0.41 , -0.17 ; $I^2 = 40.3\%$), respectively.

CONCLUSIONS: This is the first meta-analysis to report on the effects of IMT on LBP-related outcomes. Our findings suggest that IMT significantly reduced perceived pain intensity and attenuated functional disability in adults with LBP. Further investigation is warranted to determine optimal timing and dosing of IMT in this population.

CLINICAL RELEVANCE: IMT is a promising adjuvant therapeutic tool with potential implications in the management of LBP. IMT is known to decrease diaphragm fatigability which may contribute to better spinal control, thereby reducing LBP intensity and enhancing functional status of affected individuals.

OPL14

HOW COMMON ARE ADJACENT JOINT DISORDERS AFTER SUSTAINING AN ANKLE SPRAIN?*Kaitlyn Sue Foster, Jodi Lynn Young, Tina Greenlee, Daniel I. Rhon*

PURPOSE/HYPOTHESIS: Ankle sprains remain the most common injury sustained in active populations. Despite being commonly referred to as minor injuries, 73% of all athletes have recurrent ankle sprains, 59% report significant disability with residual symptoms, and 40% develop chronic ankle instability. Evidence suggests that a single sprain can lead to kinematic and sensorimotor alterations in the entire lower extremity. These deficits can lead to an increased demand on adjacent joints, increasing risk for additional injury. While these associations are often discussed by clinicians, the incidence of adjacent joint disorders following ankle sprain at the population level is relatively unknown. The purpose of this study

was to investigate the incidence of knee, hip, and lumbar disorders occurring in the year following an ankle sprain.

NUMBER OF SUBJECTS: Thirty-three thousand three hundred sixty-one diagnosed with an acute ankle injury in the Military Health System between 2010 and 2011, with at least 1-year follow-up.

MATERIALS AND METHODS: The incidence of care-seeking injuries of the lumbar spine, hip, and knee that occurred in the year after the initial ankle sprain were calculated. Two-by-two contingency tables were used to determine the incidence within each adjacent joint disorder category (lumbar spine, hip, knee). Demographic information was reported for the full cohort and for adjacent injuries, by region.

RESULTS: Of the total cohort, 73.3% ($n = 24452$) were diagnosed with an ankle sprain. Within a year after ankle sprain, 22.7% ($n = 5549$) of individuals sustained an adjacent joint injury. Of this cohort, 2849 (11.7%) were diagnosed with an injury of the lumbar spine, 809 (3.3%) with a hip injury, and 2696 (11%) a knee injury. More than 1 adjacent injury was uncommon, 127 (0.5%) had both knee and hip disorders, 163 (0.7%) had hip and lumbar disorders, and 56 (0.2%) had all 3 (lumbar, hip, and knee disorders). Less than half of the total cohort received physical rehabilitation after ankle injury, however patients that received exercise therapy as a treatment were less likely to have a subsequent injury of the lumbar spine (OR = 0.63; 95% CI: 0.59, 0.68), hip (OR = 0.59; 95% CI: 0.51, 0.67), and knee (OR = 0.70; 95% CI: 0.65, 0.75).

CONCLUSIONS: Over 1 in every 5 individuals that sought care for an ankle sprain went on to have an adjacent joint injury in the following year. Individuals receiving exercise therapy were less likely to have an adjacent joint injury. This has the potential to help guide treatment and inform decisions related to returning to work and sport. It is unknown if ankle sprains increase the risk for adjacent joint injury as there was no control group without ankle sprains.

CLINICAL RELEVANCE: Adjacent joint injuries are common after ankle sprain. Therefore, clinicians should consider the role of regional interdependence when managing ankle injuries and clearing individuals to return back to activity.

OPL15

A SURVEY OF DIAGNOSTIC IMAGING CURRICULA IN SPORTS PHYSICAL THERAPY RESIDENCY AND FELLOWSHIP PROGRAMS*Dale A. Gerke, Evan Othmer Nelson, Tyler Alan James Amborn, Collin Dean Christensen, Kathleen Orfei*

PURPOSE/HYPOTHESIS: Clinical competency in diagnostic imaging is a foundation of sports physical therapy (PT) practice, yet little is known about how residency and fellowship programs meet the broad, evolving standard for imaging education. The purpose of this study was to assess instructional methods for diagnostic and procedural imaging curricula used in sports PT residency (SPTR) and fellowship (SPTF) programs.

NUMBER OF SUBJECTS: Responses were obtained from 34 programs (45% yield); 29 (85%) represented SPTR and 5 (15%) represented SPTF. Program directors provided 28 responses, faculty or staff provided 6.

MATERIALS AND METHODS: A 46-item electronic survey of program demographics, diagnostic and procedural imaging curricula, curricular outcomes, and imaging scope of practice was distributed to all SPTR and SPTF programs listed on the American Board of Physical Therapy Residency and Fellowship Education directory in May 2021. Data collection and analysis of count-based responses was performed using Qualtrics (Provo, UT).

RESULTS: Direct access to PT was allowed in 32 (94%) programs and 9 (26%) allowed PTs to directly refer for imaging studies. Thirty-one (91%) SPTR and SPTF programs included diagnostic imaging curricula with instruction in radiography (X-ray) (91%), magnetic resonance imaging (MRI) (91%), computed tomography (CT) (74%), ultrasonography (62%), and bone scintigraphy (59%). Educational methods included independent reading (59% of programs; mean $\pm$ SD, 3.7 ± 1.8 hours), lectures (68%; 7.9 ± 16.2 hours), direct observation (65%, 15.5 ± 22.3 hours), online coursework (56%; 11.6 ± 34.8 hours), laboratory sessions (47%; 4.9 ± 5.1 hours), supervised patient experiences (47%; 21.5 ± 38.5 hours), simulated patient experiences (32%; 7.2 ± 11.7 hours), grand rounds (53%; 18.8 ± 28.8 hours), re-

corded lectures (24%; 2.7 ± 1.2 hours), continuing education courses (24%; 9.5 ± 10.7 hours). Up to 8 instructors including PTs (24 programs), nonradiologist physicians (20), radiologists (5), physician assistant or nurse practitioner (5), and athletic trainers (3) taught imaging content. Respondents reported program graduates were proficient at identifying normal anatomy (91% X-ray, 77% MRI, 61% CT) and common pathology (86% X-ray, 73% MRI, 56% CT), recommending imaging (91% X-ray, 82% MRI, 61% CT), integrating results in management decisions (100% X-ray, 91% MRI, 83% CT), communicating results with patients (91% X-ray, 83% MRI, 78% CT) and other providers (82% X-ray, 86% MRI, 78% CT), but less so for signing imaging referrals (27% X-ray, 23% MRI, 28% CT).

CONCLUSIONS: Postprofessional sports PT training programs used multiple educational methods to deliver diagnostic imaging curricula taught by interdisciplinary instructor teams. Programs provided instruction in multiple imaging modalities using clinically-based, interdisciplinary learning strategies that likely model the foundational role of diagnostic imaging in sports PT practice.

CLINICAL RELEVANCE: Imaging curricula and outcomes in SPTR and SPTF programs mirror the description of specialty practice. Graduate proficiency was similar to postprofessional orthopaedic PT education, and superior to entry-level PT education.

OPL16

EDUCATION ALTERED EMOTIONALITY, HARM, CONTROL, AND MEDICATION DOMAINS IN PEOPLE WITH CHRONIC LOW BACK PAIN

Karen E.H. Grossnickle

PURPOSE/HYPOTHESIS: The purpose of the current study was to investigate the impact of an abbreviated therapeutic neuroscience education (TNE) session on 7 domains of pain attitudes and beliefs: solicitude, emotionality, medical cure, control, harm, disability and medication for persons with chronic low back pain (CLBP).

NUMBER OF SUBJECTS: Twenty-eight subjects with CLBP.

MATERIALS AND METHODS: Participants received a 1-hour TNE session delivered by a licensed physical therapist trained in pain education. A Prezi presentation projected on a monitor along with a scripted TNE curriculum was delivered by the physical therapist to each participant. Participants' attitudes and beliefs about their CLBP were assessed using the 30-item Survey of Pain Attitudes-Brief (SOPA-B). The SOPA-B was administered prior to the 1-hour TNE session and following the 1-hour TNE session. The TNE session included curricular content described in *Pain Neuroscience Education: Teaching People About Pain* (Louw et al, second edition). This study was part of a larger study in which subjects were randomized to 1 of 2 groups: in-person delivery or web-based conference platform delivery.

RESULTS: Statistical analysis of the larger study revealed no difference in groups for demographic data nor for impact of delivery mode; therefore, participants were collapsed to 1 group for the present study. Total SOPA-B scores are difficult to analyze due to the operational definitions of the scaled scores for each item (true versus untrue). Further item and domain analysis were warranted. Descriptive analysis for mean, variance, minimum, maximum, standard deviation, and median were analyzed for each item. A significant P value of less than .05 was established for all items analyzed. It was identified that statistically significant changes occurred to the following number of items within the domains for all participants: solicitude 2/5 ($P < .012-.022$), emotionality 4/4 ($P < .001-.005$), medical cure 0/5, control 5/5 ($P < .001-.013$), harm 3/5 ($P < .001-.015$), disability 1/3 ($P < .005$), and medication 3/3 ($P < .003-.025$). All participants improved in their attitudes and beliefs (SOPA-B) regarding their CLBP after the 1-hour TNE. It was identified that the pain attitude and belief domains of emotionality, control, harm, and medication were impacted by TNE the most, while minimal to no significant changes were observed for the pain attitude and belief domains of solicitude, medical cure, and disability.

CONCLUSIONS: TNE content had greater impact on the specific domains of emotionality, control, harm, and medication for participants with CLBP. Future studies should seek to clarify which curricular content impacted the specific domains and further exploration for content that might impact the domains of solicitude, medical cure, and disability should be conducted. Knowledge about which content impacts which domains could

lend to further prescriptive focus of TNE interventions for persons with CLBP lending to potentially greater outcomes.

CLINICAL RELEVANCE: Critical attention to curriculum design and educational delivery of TNE by physical therapists may be vital to outcomes and impact on pain for persons with CLBP.

OPL17

WHAT DOES SYMPTOM DURATION REALLY TELL US ABOUT ACHILLES TENDINOPATHY?

Shawn Hanlon, Brian J. Honick

PURPOSE/HYPOTHESIS: Little is known about the development of Achilles tendinopathy. It is clinically important to understand if there is a natural progression of worsening tendon health associated with experiencing symptoms over a greater period of time. This study was designed to compare tendon health at baseline and treatment outcomes at 4 months between patients with differing lengths of Achilles tendinopathy symptoms.

NUMBER OF SUBJECTS: One hundred three subjects (53 male; mean $\pm$ SD age, 47 ± 12 years) with clinically diagnosed midportion Achilles tendinopathy.

MATERIALS AND METHODS: Subjects were categorized into 4 groups based on self-reported symptom duration, early onset (0-3 months), subacute (3-6 months), typical (6-12 months), and chronic (>12 months). All subjects received standardized exercise therapy including home exercises and were evaluated at baseline and 4-months. Tendon health was measured by the following domains: Symptoms using the Victorian Institute of Sport Assessment-Achilles (VISA-A) and pressure pain threshold; Tendon structure by diagnostic ultrasound (Achilles tendon thickness, thickening, and cross-sectional area (CSA) and continuous shear wave elastography (cSWE); Function by a functional test battery (countermovement jump (CMJ), drop countermovement jump (Drop CMJ), heel-raise endurance test); Patient-related factors by the Foot and Ankle Outcomes Survey-Quality of Life subscale (FAOS-QoL) and patient demographics (age, sex, BMI); Psychological factors by the Tampa Scale of Kinesiophobia (TSK-17). All variables were compared between groups at baseline using 1 way ANOVA and change over time was compared using repeated measures ANOVA.

RESULTS: No significant differences were found at baseline between early onset ($n = 18$), subacute ($n = 20$), typical ($n = 14$), and chronic ($n = 51$) groups for all measures of tendon health. At 4 months, typical and chronic groups showed significantly better outcomes compared the early onset and subacute groups in symptoms (VISA-A: 76 ± 23 , 69 ± 18 , 60 ± 10 , 51 ± 17 ; $P = .003$), quality of life (FAOS-QoL: 70 ± 15 , 76 ± 23 , 53 ± 19 , 52 ± 15 ; $P < .001$), and psychological factors (TSK-17: 35 ± 5 , 32 ± 2 , 35 ± 5 , 38 ± 7 ; $P = .029$), respectively. No differences were found between groups for changes in function or tendon structure measures.

CONCLUSIONS: Symptom duration had no impact on clinical presentation of Achilles tendinopathy at baseline evaluation. Patients with longer duration symptoms experienced greater improvements in symptoms, patient-related factors and psychological factors over 4 months compared to those with shorter symptoms.

CLINICAL RELEVANCE: Duration of symptoms does not seem to relate to injury severity. In addition, the expectation that those with shorter symptom duration will respond quicker to treatment was not supported in this study.

OPL18

WHERE TO START? ESTIMATING INFLUENCE OF INITIAL PROVIDER ON LOW BACK PAIN HEALTH CARE UTILIZATION AND COSTS

Kenneth Joseph Harwood, Jesse Pines, C. Holly A. Andrilla, Bianca Frogner

PURPOSE/HYPOTHESIS: Diagnostic testing and treatment recommendations can vary when health care is sought by individuals for low back pain (LBP), leading to variation in quality and costs of care. The aims of the study were to determine the extent to which the first provider seen for LBP impacts health care costs and utilization, including short- and long-term opioid use, imaging, hospitalizations, out-of-pocket costs, and total costs, using a large national health insurance claims database.

NUMBER OF SUBJECTS: Three million seven hundred ninety-nine thousand five hundred ninety-three.

MATERIALS AND METHODS: Using national private health insurance claims data, individuals aged 18 or older were assigned to cohorts based on the first provider seen at the index date of LBP diagnosis. Exclusion criteria included individuals with a diagnosis of LBP or any serious medical conditions, or an opioid prescription 6 months prior to the index date. Outcome measures included use of imaging, back surgery rates, hospitalization rates, emergency department visits, early- and long-term opioid use, and costs (out-of-pocket and total costs of care) 12 months post index date. We used a common econometric technique, 2-stage residual inclusion (2SRI) estimation to reduce selection bias in the choice of first provider.

RESULTS: For the sample, PCP was most commonly seen first (25.2%), followed by Chiropractor (Chiro) (24.8%), Orthopedist (Ortho) (5.1%), Physical Medicine & Rehabilitation (PM&R) (4.2%), PT (2.9%), Emergency Medicine (2.4%), Advanced Practice Registered Nurse (APRN) (1.6%), Acupuncturist (Acu) (1.0%) and 32.8% saw a mix of "other" providers. Among all individuals, cost and utilization varied considerably based on first provider seen. The frequency of early opioid prescription was significantly lower when care began with an Acu, Chiro or PT and highest for those who began with an EM or APRN. Long-term opioid prescriptions were low across most providers except PM&R and APRN. The frequency and time to serious illness varied little across providers. Total cost of care was lowest when starting with a Chiro (\$5093) or PCP (\$5660), and highest when starting with an Ortho (\$9434) or Acu (\$9205).

CONCLUSIONS: The first provider seen by individuals with LBP was associated with large differences in health care utilization, opioid prescriptions, and cost while there were no differences in delays in diagnosis of serious illness.

CLINICAL RELEVANCE: The first health care provider seen is the entry point into the health care system and affects assessment and intervention strategies that lead to significant variance in health care utilization and cost. Provider care trends may affect understanding of guidelines adherence, care quality and national health care policy development.

OPL19

DOES DECREASED TRUNK FLEXION CONTRIBUTE TO PATELLOFEMORAL JOINT LOADING IN RUNNERS WITH PATELLOFEMORAL PAIN?

Kai-Yu Ho, Tiffany Barrett, Zachary Alexander Clark, Christine DuVall, Tavin Fox, Caitlin Ann Howden

PURPOSE/HYPOTHESIS: Patellofemoral pain (PFP) is the most prevalent type of injury sustained by runners. Reduced trunk flexion during running is theorized to be a contributing factor of elevated patellofemoral joint (PFJ) stress and symptoms in runners with PFP. However, this premise has not yet been examined; thus, the primary purpose of this research study was to determine if runners with PFP would exhibit differences in PFJ stress and trunk flexion angle during running as compared to pain-free runners across various speeds. We hypothesized that runners with PFP would exhibit higher PFJ stress and decreased trunk flexion while running compared to the pain-free runners.

NUMBER OF SUBJECTS: Seven runners with PFP (mean $\pm$ SD age, 28.0 $\pm$ 8.2 years; 5 female, 2 male; weight, 65.2 $\pm$ 13.0 kg; height, 172.7 $\pm$ 12.3 cm) and 5 age-, weight-, and height-similar pain-free control runners (mean $\pm$ SD age, 27.4 $\pm$ 7.8 years; 3 female, 2 male; weight, 75.7 $\pm$ 12.6 kg; height, 175.8 $\pm$ 8.9 cm).

MATERIALS AND METHODS: All participants were tested in 1 session under 3 different running speeds: self-selected, fast (20% faster than self-selected), and slow (20% slower than self-selected) speeds. Trunk and lower extremity kinematics were collected using a 12-camera Vicon motion analysis system at 250 Hz. Ground reaction force (GRF) was collected at 2000 Hz using force plates in the Bertec dual-belt treadmill. PFJ stress, PFJ reaction force, and PFJ contact area were determined using a biomechanical model that utilized subject-specific input variables (ie, knee flexion angle and knee extensor moment). A 2-way ANOVA with repeated measures and post hoc *t* tests were used to compare outcome variables across the 3 speeds and between the 2 groups.

RESULTS: The running speeds were similar between groups (PFP: self-selected, 2.6 m/s; fast, 3.1 m/s; slow, 2.1 m/s; control: self-selected, 2.5 m/s;

fast, 3.0 m/s; slow, 2.1 m/s; $P > .05$). There was no statistically significant difference in peak PFJ stress between the control and PFP groups across the 3 speeds ($P > .05$). Additionally, no significant difference was found in trunk flexion angle, PFJ reaction force, PFJ contact area, knee extensor moment, knee flexion angle, or GRF at peak PFJ stress between the 2 groups across the 3 speeds ($P > .05$). Peak PFJ stress was lowest during slow running compared to fast ($P = .017$) and self-selected ($P = .002$) running conditions across both groups, which was driven by a lower GRF, and resultant knee extensor moment and PFJ reaction force during slow running. There was no significant difference in PFJ contact area, knee flexion angle, or trunk flexion angle between the 3 speed conditions across both groups ($P > .05$).

CONCLUSIONS: Our data suggests that runners with and without PFP exhibited similar peak PFJ stress and trunk flexion angle when running at slow, self-selected, and fast speeds on a treadmill.

CLINICAL RELEVANCE: This preliminary work does not support the theory that reduced trunk flexion during running is a contributing factor leading to increased PFJ stress during running in runners with PFP when compared to pain-free runners.

OPL20

ACHILLES TENDON THICKNESS AND CROSS-SECTIONAL AREA ARE ASSOCIATED WITH NEOVASCULARIZATION AREA

Brian J. Honick, Karin Gravare Silbernagel

PURPOSE/HYPOTHESIS: Diagnostic ultrasound is a useful technique for assessing the structure of the Achilles tendon. Patients with Achilles tendinopathy may have neovascularization, which is the presence of blood vessels within the tendon. A previous study found the severity of Achilles tendinopathy and injury prognosis is influenced by changes in tendon thickness. The impact of neovascularization area on Achilles tendon thickness remains unknown. The purpose of this study was to (1) determine the minimal detectable change for neovascularization area on power Doppler ultrasound and (2) to evaluate associations between neovascularization area and measures of tendon thickness, functional performance, and symptom severity in patients who have midportion Achilles tendinopathy.

NUMBER OF SUBJECTS: Twenty subjects (13 male; mean $\pm$ SD age, 50 $\pm$ 11 years) with both a diagnosis of midportion Achilles tendinopathy and neovascularization on diagnostic ultrasound at the baseline visit of a prospective study.

MATERIALS AND METHODS: The diagnosis of midportion Achilles tendinopathy was confirmed through clinical examination. Tendon structure was assessed using B-mode ultrasound imaging. Images of tendon cross-sectional area (CSA) and longitudinal area were taken at the thickest portion of the free tendon. Longitudinal power Doppler video clips were recorded. The neovascularization area (mm²) was found using GE Quantitative Analysis software (Chicago, IL). Quantitative analysis allows for calculation of maximum blood flow area by analyzing the ultrasound cine loops. Symptom severity was assessed using the Victorian Institute of Sports Assessment-Achilles (VISA-A) questionnaire. Pearson correlations compared the association between neovascularization area, tendon CSA and thickening, functional performance, and symptom severity.

RESULTS: The mean $\pm$ SD neovascularization area was 7.65 $\pm$ 5.84 mm². The minimum and maximum amount of neovascularization detected were 2.18 mm² and 26.40 mm², respectively. The minimal detectable change for neovascularization was 7.65 mm² with a SE of measurement at 1.27 mm². There was a significant positive association between neovascularization area and tendon cross-sectional area, ($r_{20} = 0.605$, $P = .005$; mean $\pm$ SD, 10.30 $\pm$ 3.50 mm²), and tendon thickening, ($r_{30} = 0.550$, $P = .015$; 3.02 $\pm$ 2.29 mm). No significant associations were observed between neovascularization area and single leg hopping plyometric quotient ($r_{19} = 0.149$, $P = .542$; 0.36 $\pm$ 0.18), heel raise work ($r_{18} = -0.214$, $P = .394$; 1735.6 $\pm$ 760.6 J), or score on the VISA-A ($r_{20} = -0.017$, $P = .944$; 53.7 $\pm$ 19.2 points).

CONCLUSIONS: The neovascularization area relates to tendon cross-sectional area and tendon thickening. The size of the area was not related to functional performance or symptom severity. Future longitudinal re-

search is needed to determine how Achilles tendon neovascularization area changes with time and treatment.

CLINICAL RELEVANCE: Neovascularization might partially explain the tendon thickening found in patients with Achilles tendinopathy.

OPL21

WHY DON'T PATIENTS ATTEND ORTHOPAEDIC PHYSICAL THERAPY AFTER PHYSICIAN REFERRAL?

Stephen J. Hunter, Devyn N. Woodfield, Kate Minick, Greg L. Snow, Justin B. Poll

PURPOSE/HYPOTHESIS: Physical therapy (PT) is an effective early treatment option for orthopaedic (ortho) patients. Many patients don't attend PT after referral. The study purpose was to determine the percent of patients who don't attend ortho PT after a physician referral in a large health system and possible reasons why they don't attend.

NUMBER OF SUBJECTS: Patients ranged in age from 12 to 103 years; 25219 individuals that were included were referred by physicians via an Electronic Medical Record (EMR) for ortho PT within a large health system between January 1, 2020 and June 19, 2021. Twenty individuals who did not attend PT within 90 days of the referral were randomly selected and interviewed by an independent experienced assessor.

MATERIALS AND METHODS: Multiple data were collected related to the patient (age, gender, payer), referral (diagnosis, clinic location) and referring provider (age, specialty) to determine any correlation with those who did not attend PT. Logistic regression analysis was performed to determine the probability of patients attending PT. Questions of the 20 interviewed included: (1) what the patient recalled about treatment options at the time of the PT referral; (2) behaviors of care seeking since the PT referral; (3) whether they had engaged in PT since the referral; (4) why they decided not to engage in PT.

RESULTS: Fifty-two percent (13095) of the patients did not attend any PT inside the health system within 90 days of the EMR referral, unchanged from the prior 2 years (51.6%). If a physiatrist referred the patient there was a 63% probability the patient would attend, 48% if referred by a family practice physician. These differences were significant ($P < .001$). The greatest probability of attending was between ages 50 and 80 years. Self-pay patients had the lowest probability of attending, with patients insured by local commercial payer having the highest probability. Payers without copayments (worker compensation and auto) did not seem to impact the probability of attending PT. Of the 20 interviewed, 8 (40%) received PT either after 90 days ($n = 5$) or at a clinic outside the health system ($n = 3$). The primary reasons (more than 1 reason given) from the 12 not attending PT were: (1) the health issues resolved using 1 or more other treatment options (50%); (2) they had other health or life priorities (42%); (3) there was limited appointment availability (30%); (4) their insurance would not cover the cost (25%); (5) confusion in scheduling or missed their appointment (17%). Interestingly, 5/12 (42%) who did not attend PT, indicated they would consider going to PT if their condition does not satisfactorily improve or if their health/life situation changes enabling them to do so.

CONCLUSIONS: Half of the patients referred to orthopaedic PT did not attend within 90 days of the referral, limiting the potential benefit from early PT. Of those interviewed who did not attend PT, 92% indicated the condition had improved or they were waiting for their condition to improve. COVID did not appear to change the percent of patients who did not attend PT.

CLINICAL RELEVANCE: Results from this study indicate opportunities to increase attendance of patients who are referred to orthopaedic PT.

OPL22

B-MODE ULTRASOUND IS EXCEEDINGLY RELIABLE WHEN ASSESSING PATELLAR TENDON MORPHOLOGY AFTER BONE-PATELLAR TENDON-BONE GRAFT HARVEST

Naoaki Ito, Haraldur B. Sigurdsson, Lynn Snyder-Mackler, Karin Gravare Silbernagel

PURPOSE/HYPOTHESIS: Anterior cruciate ligament injuries and subsequent reconstruction surgery (ACLR) are common among young athletes. The

bone-patellar tendon-bone (BPTB) autograft harvested from the central third of the ipsilateral knee's patellar tendon is used frequently for ACLR. Autograft harvest comes with a cost; graft site morbidities such as prolonged quadriceps weakness and anterior knee pain impact rehabilitation after ACLR and long-term knee health. Patellar tendon morphology after BPTB graft harvest may be associated with graft site morbidities and impede rehabilitation. The reliability of morphological measures of the patellar tendon after BPTB graft harvest using ultrasound, however, has not been established. The purpose of this study was to establish the interrater reliability of morphological measures of the patellar tendon after BPTB graft harvest using B-mode ultrasound.

NUMBER OF SUBJECTS: Six women and 4 men (mean $\pm$ SD age, 22.9 ± 5.3 years; height, 1.72 ± 0.12 m; weight, 74.2 ± 19.3 kg) with a history of ACLR using BPTB graft (average months from surgery, 31; range, 2-92).

MATERIALS AND METHODS: B-mode ultrasound images were collected with participants in supine with the knee supported at approximately 30° of flexion with a foam roller. Two physical therapists with 1 year of ultrasound experience collected the images within the same session. All images were processed by a single rater. Variables of interest were patellar tendon length, thickness, and cross-sectional area (CSA). Length and thickness were measured over 3 regions of interest (ROI): over the medial and lateral segments of the tendon that were untouched in surgery, and over the graft site identified as between bony defects on the patella and tibia. Extended field of view was used to measure length. Thickness was measured 1cm distal to the tendon attachment on the patella. CSA was collected over 3 regions: 50% length of the patellar tendon, immediately distal to the patella, and immediately proximal to the tendon attachment at the tibia. Each view was collected 3 times and the averages were used for analysis. Intraclass correlation coefficients (ICCs) using mean-rating, absolute-agreement, 2-way random effects models were performed between measurements from the 2 raters. Minimum detectable change (MDC) for each measure was calculated.

RESULTS: Excellent interrater reliability was found for the length (ICCs from 0.970 to 0.980, MDCs from 2.6 to 3.2 mm), thickness (ICCs from 0.959 to 0.994, MDCs from 0.2 to 0.5 mm), and CSA (ICCs from 0.967 to 0.996, MDCs from 12 to 28 mm²) in all ROI of the patellar tendon after BPTB graft harvest.

CONCLUSIONS: B-mode ultrasound has excellent reliability for assessing patellar tendon morphology and can detect small morphological changes after BPTB graft harvest. Future studies may evaluate the association between patellar tendon morphology and graft site morbidities after ACLR using BPTB graft.

CLINICAL RELEVANCE: B-mode ultrasound is a reliable tool that allows for the detection of small changes in patellar tendon length, thickness, and CSA following BPTB graft harvest.

OPL23

MIDFOOT AND ANKLE COUPLING DURING HEEL RAISE IN PEOPLE WITH AND WITHOUT DIABETES MELLITUS

Hyo Jung Jeong, Baekdong Cha, Jennifer Ann Zellers, Ling Chen, Mary Kent Hastings

PURPOSE/HYPOTHESIS: A heel raise task has been commonly used to assess foot movement dysfunction in people with diabetes mellitus (DM) and peripheral neuropathy (PN). Optimal heel raise performance requires both contributions of midfoot and ankle. Previous studies have used peak values or excursion of midfoot and ankle motion to examine heel raise performance. Coordination (coupling) of intersegmental motion throughout the heel raise task is critical for optimal performance, which remains less understood. The purpose of this study was to characterize and compare the midfoot and ankle cross-correlation during heel raise in people with DM and PN (DMPN) and controls (CON). We hypothesized that the effects of DMPN (DMPN versus CON) would reduce midfoot and ankle coupling, measured with cross-correlation coefficients, during heel raise.

NUMBER OF SUBJECTS: Sixty individuals with type 2 DM and PN (mean $\pm$ SD age, 67 ± 6 years; BMI, 35 ± 7 kg/m²; 43% male) and 22 healthy CON (age, 62 ± 8 years; BMI, 32 ± 6 kg/m²; 36% male).

MATERIALS AND METHODS: Three-dimensional motion analysis (Vicon MX, Los Angeles, CA) was used to acquire kinematic data of midfoot (forefoot

on hindfoot) and ankle (hindfoot on shank) during a unilateral heel raise task. Coupling was assessed using cross-correlation analysis. From 3 repetitions of heel raise, the cross-correlation coefficients (r) were calculated for (1) midfoot sagittal and ankle frontal planes, (2) midfoot sagittal and ankle frontal planes, and (3) ankle sagittal and ankle frontal planes. Fisher's transformation was used to transform the cross-correlation coefficient into z value to normally distribute the data for statistical analysis. Analysis of covariance with age as the covariate was used to compare z scores between DMPN and CON groups.

RESULTS: People with DMPN had significantly less midfoot and ankle kinematic coupling in all of the interactions compared to the CON (midfoot sagittal and ankle frontal planes: r_{DMPN} mean $\pm$ SD, 0.31 ± 0.61 ; r_{CON} mean $\pm$ SD, 0.65 ± 0.52 ; $P = .003$; midfoot sagittal and ankle frontal planes: r_{DMPN} mean $\pm$ SD, -0.24 ± 0.61 ; r_{CON} mean $\pm$ SD, -0.58 ± 0.53 ; $P = .006$; ankle sagittal and ankle frontal planes: r_{DMPN} mean $\pm$ SD, -0.85 ± 0.16 ; r_{CON} mean $\pm$ SD, -0.93 ± 0.04 ; $P = .007$).

CONCLUSIONS: Coordination of midfoot and ankle movement during the heel raise task, in both the sagittal and frontal planes, is difficult for people with DMPN compared to controls without DMPN.

CLINICAL RELEVANCE: Less coupling during heel raise may increase the risk of injury leading to midfoot collapse and skin breakdown in people with DMPN. Identifying and treating midfoot and ankle coupling of heel raise could be important in preventing foot complications in people with DMPN.

OPL24

SELF-EFFICACY AND SYMPTOM DURATION ARE NOT ASSOCIATED IN PATIENTS PRESENTING TO A HIP PRESERVATION CLINIC

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PURPOSE/HYPOTHESIS: Pain self-efficacy is a measure of patients' ability to complete daily tasks despite their pain. Low pain self-efficacy has been associated with worse pain and functional outcomes for a variety of orthopaedic conditions, including hip pathologies such as femoroacetabular impingement syndrome, greater trochanteric pain syndrome, and hip osteoarthritis (OA). Many patients presenting to a hip preservation clinic suffer with chronic hip-related symptoms and low pain self-efficacy; which leads to the possibility that pain chronicity is associated with low pain self-efficacy. However, the relationship between duration of symptoms and pain self-efficacy in patients with hip pathology is not well understood. Gaining a deeper understanding of this relationship may provide clarity in identifying patients at-risk for poor treatment outcomes. Therefore, we aimed to evaluate the relationship between pain self-efficacy and duration of symptoms in individuals presenting to a hip preservation clinic. We hypothesized that higher pain self-efficacy would be associated with a shorter duration of symptoms.

NUMBER OF SUBJECTS: One hundred four participants (61 female, 43 male; mean $\pm$ SD BMI, 28.8 ± 6.5 kg/m²; age, 42.4 ± 16.9 years) presenting to a hip preservation clinic.

MATERIALS AND METHODS: Participants reported their duration of symptoms, completed the Pain Self-Efficacy Questionnaire (PSEQ), and hip diagnosis was recorded. An analysis of variance (ANOVA) was used to evaluate the interaction of hip diagnosis group (nonarthritic intra-articular, extra-articular, or OA) by duration of symptoms group (<3 months, 3-6 months, 6-12 months, 1-2 years, 2-5 years, or >5 years) for baseline PSEQ scores ($P < .05$). If a significant interaction was identified, post hoc t tests were used. If no significant interaction was identified, significant main effects were reported.

RESULTS: Of the 104 participants, 65.4% were diagnosed with a nonarthritic intra-articular hip condition, 19.2% with an extra-articular hip condition, and 15.4% with hip osteoarthritis. In terms of symptoms duration, 4.8% of patients reported symptoms of less than 3 months, 14.4% reported 3 to 6 months, 17.3% reported 6 to 12 months, 26.9% reported 1 to 2 years, 22.1% reported 2 to 5 years, and 14.4% reported more than 5 years. Duration of symptoms did not differ between diagnosis groups ($P = .39$). The average $\pm$ SD PSEQ score was 34.0 ± 14.4 , with 64.4% of patients (67/104) reporting low pain self-efficacy (PSEQ ≤ 40). There was

no interaction for diagnosis and duration of symptoms ($P = .41$), or a main effect for duration of symptoms group ($P = .05$) or diagnosis group ($P = .38$).

CONCLUSIONS: Pain self-efficacy and duration of symptoms were not associated in patients presenting to a hip preservation clinic regardless of diagnosis; however, low pain self-efficacy was common.

CLINICAL RELEVANCE: Clinicians should screen for self-efficacy in all patients, regardless of diagnosis and duration of symptoms. If low self-efficacy is identified, interventions to improve self-efficacy (ie, SMART goal-setting) should be delivered to help improve clinical outcomes.

OPL25

DO YOGA AND PHYSICAL THERAPY IMPROVE PAIN AND DISABILITY THROUGH PSYCHOLOGICAL MECHANISMS? A CAUSAL MEDIATION ANALYSIS

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PURPOSE/HYPOTHESIS: To investigate whether the effects of yoga or physical therapy (PT) on back-related outcomes, versus education, are explained by indirect effects through psychological mechanisms.

NUMBER OF SUBJECTS: Three hundred twenty enrolled; 230 analyzed.

MATERIALS AND METHODS: We performed a mediation analyses using data from a randomized controlled trial comparing yoga, PT, and education interventions for chronic low back pain. Three hundred twenty participants were recruited from a large safety-net hospital and 7 affiliated community health centers in low-income, racially diverse neighborhoods of Boston, MA. Participants were randomly assigned in a 2:2:1 permutation to receive 12 weeks of PT, yoga, or education followed by a 40-week maintenance phase. Primary outcomes were changes in back-related pain on the 11-point numerical rating scale and disability on the Roland Morris Disability Questionnaire score 52 weeks post randomization. Hypothesized mediators were 12-week changes in pain self-efficacy, fear avoidance beliefs, depression, anxiety, perceived stress, and sleep. We used causal mediation analysis to estimate the total effect, direct effect, indirect effect, and proportion mediated.

RESULTS: Participants were predominantly middle aged, (mean age, 46.2 years) female (69.6%) and nonwhite (79.6%). In the PT versus education model, when the mediator was perceived stress, the total effect on disability 2.5 (95% CI: 0.2, 4.8) could be decomposed into a direct effect of 1.6 (95% CI: -0.44, 3.8) and an indirect effect 0.9 (95% CI: 0.1, 1.8; proportion mediated, 33%). Small, indirect effects on disability were observed for stress (indirect effect, 0.7; 95% CI: -0.07, 1.6; proportion mediated, 29%) although these were not statistically significant. No other psychological construct was a statistically significant mediator. In the Yoga versus education model, small, indirect effects on disability were observed for stress (indirect effect, 0.7; 95% CI: -0.07, 1.6; proportion mediated, 29%) although these were not statistically significant. None of the psychological factors appeared to be a strong mediator of the effect of yoga on disability or pain.

CONCLUSIONS: With the exception of stress, psychological factors measured at 12 weeks postrandomization were not significant mediators for the effect of PT and yoga interventions versus education on 1-year improvements in pain and disability outcomes. The temporal relationship between psychological factors, pain, and disability, as well as the importance of targeting psychological patient characteristics warrants further investigation.

CLINICAL RELEVANCE: Our findings suggest that improving disability was generally not predicated on increasing psychological wellbeing. Although pain, disability, and psychological distress overlap, the temporal sequence for treatment is less certain. Improvements in these may happen concurrently as opposed to sequentially. Or, change in pain and disability may lead to improved psychological wellbeing. PT and yoga are multidimensional treatments that may function strongly as a "whole" instead of a "sum of parts" that are designed to target perceived individual psychological or physical dysfunctions.

OPL26

RASCH ANALYSIS OF HIP DISABILITY AND OSTEOARTHRITIS OUTCOME SCORE (JOINT REPLACEMENT) IN ADVANCED HIP OSTEOARTHRITIS

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PURPOSE/HYPOTHESIS: Aging population and higher prevalence of osteoarthritis of the hip (HOA) has led to increasing rates for total hip replacement surgery (THR). Joint replacement short form of the Hip Disability and Osteoarthritis Outcome Score (HOOS-JR) was developed from the full length HOOS to capture recovery in overall hip health in those who undergo THR. It is crucial to understand the measurement properties of HOOS-JR since it is preferred measure under Comprehensive Care for Joint Replacement Model proposed by Center for Medicare and Medicaid Services. Beyond the inception work for HOOS-JR, no study has examined its measurement properties. This study assessed purported single factor structure, internal consistency, differential item functioning (DIF), and ceiling/floor effects of HOOS-JR in individuals with HOA scheduled to undergo THR.

NUMBER OF SUBJECTS: Three hundred twenty-seven patients with advanced HOA (mean $\pm$ SD age, 63.7 ± 10.9 years).

MATERIALS AND METHODS: Data for presurgery assessment for patients with advanced HOA scheduled to undergo THR between January 2018 and May 2020 at a tertiary care hospital were extracted from existing database. Those scheduled for revision of THR or history of lower extremity injury during 6 months prior to the presurgery assessment were excluded. Apart from HOOS-JR scores, demographic and anthropometric variables were extracted for each participant. The assumption of Rasch model tested for pre-THR HOOS-JR scores included the test of fit, fit residuals, ordering of item thresholds, factor structure, DIF, internal consistency and Pearson separation index. Variables included sex (men and women), affected side (left and right), low back pain (yes and no), smoking (yes and no), and osteoporosis (no, osteopenia, and osteoporosis).

RESULTS: The cohort of 327 patients included 129 men and 198 women. The HOOS-JR demonstrated good overall fit to the Rasch model. No items showed concerns with response thresholds. However, the HOOS-JR failed (6.12% over 5%) to meet the assumption of unidimensionality. Item 6 (difficulty in sitting) showed concerns with DIF between men versus women. Person-item threshold distribution (difference between person and item means were equal to 0.92 which was less than 1 logit unit) indicated the score for HOOS-JR was well targeted without substantial floor or ceiling effect. Cronbach's alpha of .91 suggested that 6 items within the HOOS-JR were internally consistent and reliable.

CONCLUSIONS: The HOOS-JR demonstrated adequate fit with the Rasch model. It was also deemed to be reliable and internally consistent. None of the items showed concerns with response thresholds. The data failed to confirm hypothetical unidimensional structure of HOOS-JR in our sample, therefore we recommend exploratory factor analysis to assess dimensionality of HOOS-JR.

CLINICAL RELEVANCE: Clinicians should be confident in using HOOS-JR since it is reliable and does not have floor or ceiling effects. However, clinicians should also be aware that HOOS-JR does not represent a single factor of hip health. Therefore, they may need to consider using an additional validated measure to gain a more comprehensive overview of recovery after THR.

OPL27

PREDICTORS OF PHYSICIAN REFERRAL TO A PHYSICAL THERAPIST FOR A NEW EPISODE OF KNEE OSTEOARTHRITIS

Samannaaz Shamsuddin Khoja, Janet Kues Freburger

PURPOSE/HYPOTHESIS: Physical Therapists (PTs) are uniquely qualified to provide frontline, evidence-based nonpharmacological treatments for knee osteoarthritis (knee OA). Early treatment by PTs is also associated with favorable patient outcomes and a decrease in subsequent health care utilization for knee OA. In the United States, physician referral is still the primary mechanism for patients to see a PT and previous work indicates that physician referral to PTs for knee OA is suboptimal. To improve ac-

cess to PTs for those with knee OA, it is crucial to understand factors that contribute to the variation in physician referral to PT. This study aimed to investigate factors that predict physician referral to PTs for patients seeking physician care for a new episode of knee OA. We hypothesized that factors related to the patient, physician, and practice as well as PT supply would be associated with PT referral.

NUMBER OF SUBJECTS: Ten thousand one hundred one patients 45 years and older (mean $\pm$ SD age, 65 ± 11 years; BMI, 32 ± 7 kg/m²; 62% female) with a physician visit for a new episode of knee OA in 351 ambulatory care clinics of an integrated health system.

MATERIALS AND METHODS: Electronic medical record (EMR) data were examined retrospectively (between October 1, 2016 and September 30, 2017) to identify physician visits for knee OA. Eligible encounters for a new episode of knee-OA (index visit) included a relevant diagnosis for knee OA (ICD10-CM-codes) preceded by a 12-month clean period with no knee OA encounters. PT referrals at the index visit were identified based on revenue codes. We also extracted information related to patient (ie, demographics, BMI, comorbidities), physician (specialty and patient volume), and practice (urban or rural location) characteristics. Supply of PTs by location was assessed by number of practicing PTs within a county for every 10000 county residents. We used generalized mixed effects logistic regression analyses to assess patient, physician, practice, and supply factors that predicted PT referral.

RESULTS: A total of 15% of patients had a PT referral at their index visit. PT referral was higher for patients seen by an orthopaedic specialist (20%) compared to those seen by a primary care specialist (11%) or other medical specialty (15%). Female sex (OR = 1.44, $P < .001$), African American race (OR = 1.28, $P = .027$), seeking care in a county with a supply of ≥ 10 PTs per 10000 persons (OR = 1.34, $P = .045$) and orthopaedic specialty relative to primary care (OR = 1.3, $P = .026$) were associated with higher odds of PT referral. Rural clinic location, (OR = 0.65, $P = .001$) and physicians with knee OA caseload between 16 and 162 cases/year (OR = 0.77, $P = .017$) relative to those with knee OA caseload of less than 16 cases/year were associated with lower odds of PT referral. Insurance and other patient characteristics were not significantly associated with PT referral.

CONCLUSIONS: Patients seen by orthopaedists, by physicians with low knee-OA caseloads, in urban practices, and in areas with higher supply of PTs were more likely to receive an early PT referral.

CLINICAL RELEVANCE: Both local (ie, health system) and state/federal approaches are likely necessary to improve access to PTs for the management of knee OA.

OPL28

A COMPARISON OF MOVEMENT-EVOKED PAIN CALCULATION METHODS IN OLDER ADULTS WITH CHRONIC LOW BACK PAIN

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PURPOSE/HYPOTHESIS: Pain exacerbation during movement, or movement-evoked pain (MeP), is an understudied and poorly understood construct in older adults with chronic low back pain (CLBP). Evidence in younger populations suggests that MeP may be a determinant of disability; given that older adults with CLBP are prone to functional decline and poor health outcomes, it is essential to investigate if MeP contributes to functional decline and disability in this population. Literature suggests that MeP measurement methods should be condition specific, yet no particular method has been established for older adults with CLBP. As origins of CLBP may vary across individuals, we propose to operationalize MeP in this population as pain that is elicited across several different functional contexts. Traditional MeP measurement methods, such as repetition induced summation of pain (RISP), involve the calculation of a change score; however, given that pain behavior is variable in older adults with CLBP, RISP may not adequately characterize MeP in this population. Therefore, we created a novel MeP calculation method by aggregating posttest LBP ratings. The purpose of this study was to compare how cumulative RISP and aggregated posttest MeP differentially contribute to LBP-related disability and physical function in older adults with CLBP.

NUMBER OF SUBJECTS: Two hundred fifty community-dwelling older adults with CLBP from a prospective cohort study.

MATERIALS AND METHODS: At baseline, LBP-related disability was measured with the Quebec Back Pain Disability Scale (QBPDS), while physical function was defined with the Health ABC performance battery (HABC). The HABC includes static and dynamic balance, walking, and chair rise components. LBP ratings were collected before and after the completion of 3 functional tests: Repeated Chair Rise test, 6 Minute Walk Test, and Stair Climbing Test. Cumulative RISP was calculated by summing pain change scores across the tests, while aggregated MeP was calculated by summing posttest LBP ratings. Robust regression with HC3 standard errors was used to examine associations between these MeP variables and both LBP-related disability and physical function. Baseline LBP intensity, as well as best and worst LBP intensities 24 hours prior to evaluation, were averaged to yield composite LBP intensity. Age, sex, BMI, composite LBP intensity, and LBP duration were used as covariates.

RESULTS: After adjusting for covariates, greater aggregated posttest MeP was associated with worse LBP-related disability ($B = 0.593$, $t = 2.913$, $P = .004$) and poorer physical function ($B = -0.017$, $t = -2.007$, $P = .039$). Cumulative RISP was not associated with the QBPDS ($P = .407$) or the HABC ($P = .693$).

CONCLUSIONS: Aggregated posttest MeP, but not cumulative RISP, contributed to disability and decreased physical function among older adults with CLBP beyond the influence of covariates.

CLINICAL RELEVANCE: Aggregated posttest MeP appears to be a unique contributor to disability and poorer function in this population; clinicians should consider including MeP as a component of assessments in this population.

OPL29

RECURRENCE QUANTIFICATION ANALYSIS OF POSTOPERATIVE ANTERIOR CRUCIATE LIGAMENT ISOKINETIC STRENGTH TESTS

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PURPOSE/HYPOTHESIS: Given the high frequency of second anterior cruciate ligament (ACL) tears following reconstructive surgery, a challenge to physical therapists is identifying and addressing motor and functional deficits placing athletes at greater risk of reinjury. There is evidence to suggest isokinetic strength data and other performance criteria have limited utility in predicting second injury. Analyzing entropy (the amount of complexity of patterns within a system) within isokinetic torque curves may reveal differences in neuromuscular control between an ACL reconstructed limb as compared to the uninvolved limb that are not captured by traditional isokinetic analysis. The purpose of this study was to investigate if entropy values obtained from recurrence quantification analysis (RQA) of isokinetic torque curves would differ between ACL reconstructed and uninvolved limbs. We hypothesized that torque curve data of the involved limb would have lesser entropy (complexity) when compared to the uninvolved limb.

NUMBER OF SUBJECTS: Sixteen patients (13 female, 3 male) who had undergone ACL reconstructive surgery at Mayo Clinic Sports Medicine Center in Rochester, MN were included. The mean $\pm$ SD age was 23.6 ± 13.7 years.

MATERIALS AND METHODS: A HumacNorm dynamometer was used to measure isokinetic knee extension and flexion strength. Subjects were seated with their hip and knee at 90° . The uninjured leg was tested first. Subjects performed 5 repetitions of maximum effort knee extension and knee flexion at $60^\circ/\text{s}$, 10 repetitions at $180^\circ/\text{s}$, and 15 repetitions at $300^\circ/\text{s}$. Phase space reconstructions, recurrence plots, and RQA were used to measure temporal organization within the torque signals. Entropy values established the randomness/complexity of patterns in the torque output signals.

RESULTS: Across all 3 testing speeds, entropy values in the isokinetic torque signals were lower in the ACL reconstructed limb (mean $\pm$ SD, 3.482 ± 0.232 bits/bin) when compared to the uninvolved limb (mean $\pm$ SD, 3.646 ± 0.284 bits/bin; $F_{1,15} = 15.255$, $P = .001$).

CONCLUSIONS: Less entropy in knee extension and flexion torque signals in the involved limb may indicate a limitation in neuromuscular system adaptability following ACL reconstruction. Greater dynamic characteristics, the ability to adapt to the environment due to variable responses, and more neuromotor control are associated with higher complexity in a normal limb/normal functioning system. Our results suggest additional analysis of isokinetic strength test data may be useful in assessing an athlete's return to play status.

CLINICAL RELEVANCE: RQA of flexor and extensor isokinetic torque signals may provide additional insight into neuromuscular control following ACL reconstruction.

OPL30

RACIAL DISPARITIES IN PHYSICAL THERAPY UTILIZATION AMONG FULLY INSURED OLDER ADULTS WITH RHEUMATOID ARTHRITIS

Chris Yun Lane, Derrick Lo, Louise Majalap Thoma, Tingting Zhang, Hiren Varma, Deepan Delal, Theresa Shireman

PURPOSE/HYPOTHESIS: Racial/ethnic minorities with rheumatoid arthritis (RA) demonstrate more pain and worse function than whites with RA. Socioeconomic disparities in similar outcomes also exist. Differential utilization of physical therapy (PT), an effective treatment for RA, may contribute to these disparities. The purpose of our study was to examine racial disparities in PT utilization for older adults with RA and to examine the influence of income on these racial disparities.

NUMBER OF SUBJECTS: One hundred ten thousand six hundred seventy-one adults with RA (75% women; mean $\pm$ SD age, 75.7 ± 7.3 years; 80.7% white, 8.5% black, 7% hispanic).

MATERIALS AND METHODS: In these annual cross-sectional analyses of PT utilization between 2012 and 2016, we accessed Medicare enrollment data (Master Beneficiary Summary File) and fee-for-service claims (Parts A, B, and D). The RA cohort included Medicare beneficiaries (aged 65+ years) identified as having RA based on at least 3 diagnosis codes or 2 codes plus a disease modifying medication claim. We defined race (categorized as white, Black, Hispanic, and other), dual Medicare/Medicaid coverage (a proxy for income), and comorbidities using enrollment and Chronic Condition Warehouse data. PT utilization (classified dichotomously as use versus nonuse) was captured through Current Procedural Terminology (CPT) codes in Medicare outpatient claims. Adults who had a CPT code for PT evaluation were classified as utilizing PT. PT-related CPT codes were further classified as active, electrothermal, manual, functional, or other interventions. To assess influence of income on racial disparities in PT utilization, we tested for interaction terms in logistic regression models adjusting for other patient characteristics and comorbidities. Associations between race and dual coverage and PT utilization were calculated as adjusted odds ratios (aOR) with 95% confidence intervals (CIs).

RESULTS: Only 10% to 11% utilized PT services in a given year but 29% utilized PT at any point during the study period. Active interventions were most common (84%-87% of adults who utilized any PT services used an active intervention at any time during their care). There were no interactions between race and dual Medicare/Medicaid coverage on PT utilization. Whites (aOR = 1.28; 95% CI: 1.21, 1.35) and Hispanics (aOR = 1.09; 95% CI: 1.01, 1.17) had greater odds of PT utilization compared to Blacks. Adults with dual Medicare/Medicaid coverage (lower income) had lower odds of PT utilization than adults without dual coverage (aOR = 0.49; 95% CI: 0.47, 0.51).

CONCLUSIONS: Overall PT utilization was low. We found racial disparities in PT utilization that were not dependent on income in a national, racially diverse and fully insured population of older adults with RA.

CLINICAL RELEVANCE: Racial disparities in PT utilization are compounded by low overall PT utilization rates in older adults with RA. As PT improves clinical outcomes for adults with RA, these disparities in PT utilization likely influence disparities in clinical outcomes. Our results suggest that factors outside of income influence racial disparities in PT utilization. Social and institutional barriers need to be addressed to ensure equitable access to PT services.

OPL31

ROTATOR CUFF REPAIR TISSUE ELONGATION MEASURED IN VIVO 3 MONTHS FOLLOWING ARTHROSCOPIC REPAIR

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PURPOSE/HYPOTHESIS: Persistent shoulder weakness is common after rotator cuff repair, even in individuals whose repair remains intact. This disconnect between structural and functional outcomes may be explained by elongation of the repaired tissue, which may alter the length-tension relationship of the supraspinatus muscle-tendon unit. However, previous studies investigating repair tissue elongation have been limited to static conditions where forces on the repair tissues may not reflect those experienced during dynamic activities. Therefore, the objective of this study was to quantify repair tissue elongation under static and dynamic conditions 3 months after rotator cuff repair.

NUMBER OF SUBJECTS: Nine patients following arthroscopic rotator cuff repair (mean $\pm$ SD age, 56 ± 6 years; 2 female).

MATERIALS AND METHODS: During surgery, a 3.1-mm tantalum bead was sutured to the repaired supraspinatus tendon. Glenohumeral kinematics were assessed at 1 week (static) and at 3 months (static and during dynamic scapular plane abduction, SAB) post surgery using a biplanar X-ray system. Repair tissue elongation was assessed by calculating the distance between the bead and the humeral tendon insertion (bead-to-insertion distance, BID). Static retraction was defined as the change in BID between 1-week and 3 months post surgery under static conditions. Maximum dynamic elongation was defined as the maximal positive change in BID during dynamic SAB. The integrity of the repair (ie, intact, recurrent tear) was assessed using MRI. The magnitudes of static retraction and maximum dynamic elongation were assessed with 1-sample *t* tests.

RESULTS: According to MRI, the repair was intact in 8 of 9 patients at 3 months post surgery. Static retraction of the repaired tissue occurred in all patients (10.0 ± 9.1 mm, $P = .01$). During SAB, maximum dynamic elongation averaged 1.4 ± 1.0 mm ($P < .01$). Descriptively, the pattern of dynamic elongation consistently took 1 of 2 forms. In 6 participants, all with intact repairs, the BID underwent an initial increase before decreasing until the end of motion. The remaining 3 patients exhibited an immediate and substantial decrease in the BID at the onset of motion.

CONCLUSIONS: Repair tissue elongation appears to be common in the first 3 months after arthroscopic rotator cuff repair. The distinct patterns of dynamic repair tissue elongation observed may suggest different subgroups of patients based on supraspinatus mechanical and neuromuscular function. For example, the pattern observed in the patient whose rotator cuff reteore is consistent with what would be expected as the BID no longer reflects a tendon under tension. Interestingly, 2 patients with repairs that appeared intact on MRI also exhibited this pattern, which may suggest supraspinatus neuromuscular impairments that may not have been adequately addressed during postoperative rehabilitation. However, this hypothesis remains speculative without measures of muscle function.

CLINICAL RELEVANCE: Repair tissue elongation investigated under static and dynamic conditions may help explain the disconnect between structural and functional outcomes following rotator cuff repair.

OPL32

RESISTANCE TRAINING PREVENTED THE ONSET OF WIDESPREAD, CHRONIC MUSCLE PAIN THROUGH ACTIVATION OF ANDROGEN RECEPTORS

Joseph Lesnak, Lynn Rasmussen, Kathleen Anne Sluka

PURPOSE/HYPOTHESIS: Chronic musculoskeletal pain is more prevalent and widespread in women. Preclinical and clinical work demonstrates the analgesic effects of testosterone. However, treatment with testosterone is not clinically feasible due to difficulty of administration. Resistance training (RT) has been shown to acutely increase testosterone, however, there has been little preclinical work on animal models of RT for pain relief. Therefore, we set out to develop an animal model of RT to study the mechanisms of RT for treatment of chronic pain. We hypothesized that RT would increase testosterone to prevent development of chronic muscle pain through activation of androgen receptors.

NUMBER OF SUBJECTS: A total of 350 C57BL6/J male and female mice were used in this study.

MATERIALS AND METHODS: Mice were grouped into either 8 weeks of RT or sedentary. Muscle pain was induced by 2 pH 5.0 injections into the gastrocnemius muscle combined with fatiguing muscle contractions. To test pain, muscle withdrawal thresholds (MWT) were assessed by applying pressure over the gastrocnemius with force-sensitive tweezers. To test if RT increased strength, front and hind paw grip strength and 1 repetition maximum (1RM) was tested prior to and after 8 weeks of RT. To see if testosterone is elevated following RT, serum samples were collected 5, 15, or 30 minutes after a single RT session and testosterone concentration was quantified by ELISA. As a measure of anaerobic activity, lactate was measured immediately following an exercise bout. To test if androgen receptors mediated the analgesia produced by RT, slow release flutamide (200 mg; androgen receptor antagonist) or control pellets were implanted subcutaneously for the duration of RT. Differences between groups for MWT were assessed with a repeated-measures ANOVA. Differences in strength, testosterone and lactate were analyzed with a 1-way ANOVA.

RESULTS: Sedentary control mice showed a decrease in MWT after induction of the model ($P < .01$), indicating muscle hyperalgesia. Eight weeks of RT prevented development of muscle hyperalgesia in both male and female mice when compared to sedentary controls ($P < .01$). Both male and female mice that performed 8 weeks of RT showed a significantly higher grip strength and 1RM ($P < .01$), and an increase in lactate ($P < .01$). In males, but not females, testosterone was significantly elevated 5 minutes after the RT session when compared with sedentary animals (male, $P = .05$; female, $P = .06$). In mice that received flutamide pellets, the analgesic effects of RT did not occur when compared to mice who received control pellets ($P < .01$).

CONCLUSIONS: Our mouse model of RT results in increased strength, testosterone, and lactate thus validating the model. RT activates androgen receptors to protect against the development of chronic muscle pain in both male and female mice, suggesting the analgesic effects of RT are mediated by testosterone.

CLINICAL RELEVANCE: RT is analgesic in both sexes producing effects through androgen receptors and thus provides a clinical rationale for performing RT in chronic pain populations.

OPL33

INTRODUCING AN ANCHOR-BASED, RISK-ADJUSTED MINIMAL CLINICALLY IMPORTANT DIFFERENCE

Adam D. Lutz, Thomas R. Denninger, Ellen Shanley, Charles Thigpen

PURPOSE/HYPOTHESIS: Value-based reimbursement programs such as CMS' Merit-based Incentive Payment System (MIPS) require a fair assessment of outcome-based quality care measures. Minimal clinically important differences (MCID) are the most commonly used standard to judge quality improvement in patient outcomes. However, values of MCID for an outcome tool can vary widely depending on methodology, follow-up time, and population. Risk-adjustment (RA) of patient-reported outcomes provides a consistent approach to measure patient improvement accounting for initial patient disability and other baseline factors, and is hypothesized to yield a more stable MCID. The purpose of this study was to compare an anchor-based unadjusted (UA) MCID for the Penn Shoulder Score (PSS) to a RA MCID for patients receiving physical therapy for nonsurgical shoulder pain.

NUMBER OF SUBJECTS: A convenience sample of first-time patients that attended a standardized, early physical therapy intervention in South Carolina for shoulder pain; initial PSS score ≤ 80 with no related surgery in the prior 90 days ($n = 91$; 68% female; mean $\pm$ SD age, 50 ± 12 years; BMI, 28 ± 7 kg/m²).

MATERIALS AND METHODS: Patient data, including the PSS and 7-item global rating of change (GROC), were obtained for patients treated for shoulder pain in upstate South Carolina between 2017 and 2019. Patients were considered for inclusion only if all requisite RA variables; initial PSS; and follow-up PSS and GROC were obtained between 2 and 12 weeks of ini-

tial PSS—and within 1 week of each other. The RA residual change was calculated as actual PSS change – RA predicted PSS change. “Success” for MCID included all patients reporting that symptoms were “moderately improved” or better per GROC. The anchor-based MCID measures were calculated using receiver operating curves for the UA and RA values. Agreement between MCID classifications was compared using a kappa statistic. Post hoc testing compared MCID classifications of success for patients in the top and bottom 10% of initial disability to assess ceiling and floor effects.

RESULTS: The mean initial PSS was 57.5 ± 13.3 , while mean PSS change was 21.2 ± 16.0 and mean RA PSS residual was 0.6 ± 15.2 . “Success” per GROC was met in 77% of the sample. Median bootstrapped MCID values were 15.0 (UA; IQR, 13.7-16.2; AUC = 0.91) and -6.3 (RA; IQR, -7.3 to -5.4; AUC = 0.94). The percent that met MCID was similar between groups (UA, 64%; RA, 69%) and the 2 measures demonstrated good agreement ($\kappa = 0.73$). However, substantial differences were identified in the top (UA, 22%; RA, 67%) and bottom 10% (UA, 56%; RA, 68%).

CONCLUSIONS: Our results show that the RA MCID provides a consistent and stable MCID over the full range of values of initial disability yielding a fair approach to judge clinical quality for value-based reimbursement programs.

CLINICAL RELEVANCE: The RA PSS residual MCID method offers a fair assessment of patient improvement in the context of initial disability and provides a framework for equitable quality reporting as required for value-based reimbursement programs. Future analyses should test the measure for robustness in a more heterogeneous patient population before widespread adoption.

OPL34

ARE PHYSICAL THERAPISTS PERFORMING THE REQUISITE SKILLS TO REFER FOR MUSCULOSKELETAL IMAGING?

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PURPOSE/HYPOTHESIS: In 2016, the American Physical Therapy Association's House of Delegates voted in support of pursuing legislation allowing physical therapists (PTs) to refer patients directly to radiology for imaging. Multiple legislative efforts are currently underway to obtain, advance, or protect this referral authority. However, establishing current PT practice patterns is essential in supporting these legislative efforts. As such, the primary aim of this study was to determine if PTs are practicing the skills required to refer patients directly to radiology for musculoskeletal imaging.

NUMBER OF SUBJECTS: For this study, 5894 PTs from all 50 states participated. Physical therapists were invited to participate in this study through direct email, via group email/newsletter from their American Physical Therapy Association (APTA) state chapter, or other physical therapy organizations.

MATERIALS AND METHODS: Participants completed a previously validated survey that assessed 9 requisite skills to refer for musculoskeletal imaging. Five of the skills occurred before imaging referral: triaging the patient; utilizing evidence-based imaging guidelines; considering the cost/benefit of imaging; referring to a provider if imaging is required; and suggesting an imaging modality. Four of the skills were a responsibility of the PT after ordering imaging: reviewing imaging reports; educating patients on imaging findings; integrating imaging findings into the treatment plan; and referring to other providers if the patient is outside the scope of a PT. The possible responses for each of the 9 requisite skills were “not applicable,” “never,” “rarely,” and “routinely.” Descriptive statistics were calculated for survey data as appropriate.

RESULTS: The majority of participants (62.7%) practiced in an orthopaedic clinical setting, 33.2% were board certified and 16.1% had completed residency or fellowship training. For the 5 skills that occur before imaging referral, 94.9% of participants routinely triage the patient, 65.0% routinely utilize evidence-based imaging guidelines, 78.9% routinely consider the cost/benefit of imaging, 83.9% routinely refer to a provider if imaging is required, and 58% routinely suggest an imaging modality. For the 4 skills

that were a responsibility of the PT after ordering imaging, 85.9% of participants routinely review imaging reports, 77.4% routinely educate patients on imaging findings, 84.4% routinely integrate imaging findings into the treatment plan, and 89.8% routinely refer to other providers if the patient is outside the scope of a PT.

CONCLUSIONS: The vast majority of PTs routinely practice the requisite skills required to refer patients directly to a radiologist for musculoskeletal imaging. Areas for improvement may include utilizing evidence-based imaging guidelines and suggesting an imaging modality.

CLINICAL RELEVANCE: These results may have important implications for health policy decisions for pursuing legislation allowing PTs to refer patients directly to a radiologist for imaging.

OPL35

UNCOVERING EXPERT USE OF MUSCULOSKELETAL DIAGNOSTIC ULTRASOUND IMAGING IN PHYSICAL THERAPY PRACTICE

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PURPOSE/HYPOTHESIS: Physical therapists (PTs) are uniquely positioned to incorporate diagnostic musculoskeletal ultrasound imaging (MSK-US) into patient care due to their training in musculoskeletal anatomy and their physical examination skills. Evidence supports that MSK-US can be an extension of a clinical evaluation to visualize underlying trauma, disease, anatomical variations, soft tissue pathology, and dynamic motion. The American Physical Therapy Association research agenda and the Frontiers in Rehabilitation, Science and Technology Council underscore that PTs can use contemporary technology to determine the effects of injury or disease. The diagnostic sensitivity and specificity of MSK-US are comparable to magnetic resonance imaging and computed tomography without the radiation risk. Few PTs incorporate MSK-US as a diagnostic tool into their personal scope of practice, defined as “activities for which a physical therapist is educated and competent to perform.” Early PT adopters, who are Registered in Musculoskeletal Skeletal Sonography (RMSK)-certified, can provide unique perspectives related to clinical application and decision making, critical for introducing new techniques into mainstream practice. The study purpose was to describe the weekly practice-based use and thought processes of MSK-US by PTs, who were RMSK-certified.

NUMBER OF SUBJECTS: Seventeen RMSK-certified PTs who were currently using MSK-US in clinical practice in the United States.

MATERIALS AND METHODS: Longitudinal, observational, case study. Demographic data were collected using the online Research Electronic Data Capture System and for 3 months of weekly reflective journal entries. Demographic data were summarized using descriptive statistics. Case study data were summarized thematically.

RESULTS: Physical therapists estimated an average of 9 MSK-US exams weekly. These examinations accounted for 38% of the PTs' patient caseload. MSK-US examinations contributed significant information very often (65%) and often (26%). Eighty-five weeks of data revealed 823 MSK-US examinations were performed (average, 19 per week). The most common joints scanned (total/weekly averages) were the shoulder (185/7), knee (197/8), ankle (126/5), and wrist (119/7). Case study reflective data revealed the top 3 ways MSK-US was used: to compare patient symptoms and functional limitations with tissue changes, confirm an inconclusive clinical exam, and narrow the potential differential diagnoses.

CONCLUSIONS: Expert clinicians use MSK-US to validate and refine their clinical diagnoses. Ultrasound imaging influenced patient care by identifying the need for medical referral and or support or change a treatment plan.

CLINICAL RELEVANCE: Integration of MSK-US into PTs' evaluation of musculoskeletal disorders provides vital diagnostic data that can guide clinical decision-making, diagnose a patient's presenting complaint, validate the diagnosis of a referring clinician, and refer to appropriate health care providers. The education of novice clinicians should target the most frequently scanned joints: the shoulder, knee, ankle, and wrist.

OPL36

PHYSICAL THERAPY MANAGEMENT OF INDIVIDUALS WITH PROXIMAL BICEPS TENDINOPATHY: A SCOPING REVIEW

Amy Wallace McDevitt, Jodi Lynn Young, Joshua A. Cleland, Paisley Hiefield, Leah Calderon, Suzanne Snodgrass

PURPOSE/HYPOTHESIS: Shoulder pain related to pathology of the long head of the biceps tendon (LHBT) can be debilitating and may interfere with an individual's activity and participation. Chronic tendinopathy of the LHBT is a common condition which is often difficult to treat. Little consensus exists regarding the optimal approach to treating pain and disability due to LHBT tendinopathy. The purpose of this review is to systematically scope the reported physical therapy management of individuals with LHBT tendinopathy.

NUMBER OF SUBJECTS: Not applicable.

MATERIALS AND METHODS: A scoping review of the literature was performed by searching CINAHL, Embase, MEDLINE and SPORTDiscus from inception to June 15, 2020. Quantitative and qualitative research that reported on physical therapy intervention for LHBT tendinopathy were included. A qualitative synthesis that identified themes included in physical therapy intervention was performed. The type of intervention and information on dosing (if provided) were extracted and summarized in tables. Study quality was assessed for the randomized controlled trials.

RESULTS: A total of 3066 potentially relevant records were identified, 12 articles were eligible for inclusion. Of the 12 original studies included, there were 4 randomized controlled trials (RCT), 1 nonrandomized observational intervention study, 1 case series, 2 clinical commentaries and 3 reviews. Themes included therapeutic exercise (including scapular stabilization, rotator cuff strengthening and eccentrics), biophysical agents (including ultrasound, low-level laser and iontophoresis), dry needling, manual therapy interventions (including joint mobilization), activity modification and pain self-management advice and injection. Evidence from 2 moderate quality RCTs showed effectiveness from ultrasound and eccentrics with or without joint mobilization in 1 study and radial extracorporeal shock wave therapy in another. Two low-quality RCTs showed effectiveness from ultrasound with low-level laser in 1 study and iontophoresis in another. A case series (n = 10) suggested utilizing dry needling to the LHBT combined with eccentric exercise.

CONCLUSIONS: Very low level evidence suggested a diversity of physical therapy interventions may be effective for LHBT tendinopathy. Interventions recommended were variable and did not provide sufficient detail or consistency to guide practicing clinicians on ideal physical therapy interventions for treating individuals with LHBT tendinopathy. Further research is needed due to an overall lack of evidence and quality of studies available.

CLINICAL RELEVANCE: There is little high-quality evidence to guide physical therapy interventions utilized to treat individuals with LHBT tendinopathy.

OPL37

IN PURSUIT OF HEALTH EQUITY: IMPACT OF SOCIOECONOMIC FACTORS ON PATIENT-REPORTED OUTCOMES

Kate Minick, Devyn N. Woodfield, Gerard Peter Brennan

PURPOSE/HYPOTHESIS: Patients with lower socioeconomic statuses (SES) have many worse health outcomes compared to patients with higher SES, including worse self-reported health, lower life expectancy, and a higher number of chronic conditions. Lower SES is also associated with limited access to care. However, only a few rehabilitation-specific studies have examined the impact of socioeconomic status on outcomes, and typically in very narrow patient populations. The purpose of this study is to examine the association of factors related to socioeconomic status on failure to progress (FTP) rates in outpatient orthopaedic physical therapy.

NUMBER OF SUBJECTS: Nineteen thousand four hundred twenty-seven patients attending orthopaedic physical therapy in a large health system from January 1, 2020 to June 30, 2021.

MATERIALS AND METHODS: An Equity dashboard was created by combining data sources from the electronic health record, registration, billing, and patient-reported outcomes databases. The data were analyzed for patient-

reported outcome improvement, Area deprivation index (ADI) quintile (1-5, with 1 being least deprived and 5 being most deprived), chronicity, use of interpretation services, ethnicity and race. Logistic regression analysis was performed to determine the impact of race, ethnicity, ADI, chronicity, gender, and use of interpretation services on FTP, defined as not meeting the minimal clinically important difference on the patient-reported outcome measure.

RESULTS: Patients in this data set were 58.4% female with an average age of 53.64 ± 18.87 years and were seen for 7.19 ± 4.83 visits over 48.84 ± 37.80 days; 92.2% of the patients were white, 4.0% did not have a race available in the registration data, and 3.8% were black, indigenous, and other people of color (BIPOC). Nine percent of the patients identified their ethnicity as Hispanic or Latino origin. Interpretation services were utilized for 4.0% of the patients, and 44.2% of patients met the NIH task force definition of chronic pain. Volumes of patients per ADI quintile (and percent BIPOC) are as follows: (1) 5067 (2.5%), (2) 5008 (3.0%), (3) 4025 (3.7%), (4) 2945 (4.7%), and (5) 2382 (6.1%). The logistic regression revealed an overall FTP of 30.6%, $\chi^2_6 = 488.79$, $P < .001$. Significant predictors included ADI (OR = 1.03; 95% CI: 1.00, 1.05), chronicity (OR = 1.97; 95% CI: 1.86, 2.10), and use of interpretation services (OR = 1.24; 95% CI: 1.04, 1.49).

CONCLUSIONS: The success of a physical therapy episode may be impacted by the deprivation of a patient's neighborhood, chronicity of symptoms, and the need for interpretation services. While race and ethnicity were not significant predictors of FTP, because ADI was significant and the neighborhoods with the highest deprivation had a larger proportion of BIPOC, this indicates that minorities may still be disproportionately impacted.

CLINICAL RELEVANCE: Socioeconomic factors should be considered as part of an overall strategy to improve health care equity. Future research should explore other equity-related factors that influence the outcomes of care and measure the impact of interventions to improve equity in health care delivery.

OPL38

EXAMINING THE PREVALENCE OF SLEEP DISTURBANCES IN PATIENTS SEEKING PHYSICAL THERAPY SERVICES

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PURPOSE/HYPOTHESIS: It is estimated that sleep-related problems affect 50 to 70 million adults in the United States with up to 40% reporting poor sleep quality, up to 30% reporting daytime sleepiness, 10% to 30% reporting insomnia or obstructive sleep apnea (OSA), and 5% to 10% reporting restless legs syndrome (RLS). Sleep disturbances have been associated with systemic inflammation and persistent pain levels and have been shown to predict musculoskeletal pain in adults. Pain is a primary driver for people seeking medical services, including physical therapy (PT). Currently, there is limited research on the extent and type of sleep disturbances experienced by patients seeking PT services. The purpose of this study was to assess the prevalence of sleep disturbances and to determine the association between pain severity and sleep disturbances in adults seeking PT services. Hypothesis 1: PT patients will report poor sleep quality, increased daytime sleepiness and insomnia symptoms, and increased risk of OSA and RLS. Hypothesis 2: Higher pain severity will be associated with poorer sleep quality, increased daytime sleepiness, and increased insomnia symptoms.

NUMBER OF SUBJECTS: Eighty-six PT patients 18 years of age and older.

MATERIALS AND METHODS: Participants were issued a link to an electronic survey to provide demographic information (age, sex, ethnicity, educational level, occupation, marital status, type of insurance, medical history, pain severity, pain chronicity, medication list, reason for seeking PT services), and the following questionnaires: Pittsburgh Sleep Quality Index (PSQI), Epworth Sleepiness Scale (ESS), Insomnia Severity Index (ISI), STOP BANG (to assess OSA risk), and RLS risk. Percentages were calculated to describe prevalence of sleep disturbances, and Spearman's correlations were used to identify possible associations between pain level and self-reported sleep questionnaires.

RESULTS: Eighty-six participants (mean $\pm$ SD age, 48 ± 15.88 years; 66 female, 20 male) completed the survey. Seventy-eight percent (n = 67)

scored >5 on the PSQI indicating poor sleep quality, 31% ($n = 27$) scored ≥ 10 on the ESS indicating excessive daytime sleepiness, 50% ($n = 43$) scored ≥ 10 on the ISI indicating insomnia symptoms, 28% ($n = 24$) had intermediate or high risk of OSA, and 40% ($n = 34$) indicated possible RLS. Pain level was significantly associated with PSQI ($r_{84} = 0.29$, $P = .007$), ISI ($r_{84} = 0.269$, $P = .012$), and STOP BANG ($r_{84} = 0.245$, $P = .023$), but was not associated with ESS ($r_{84} = 0.204$, $P = .060$) or RLS ($r_{84} = 0.132$, $P = .226$).

CONCLUSIONS: There was a higher prevalence of poor sleep quality, insomnia symptoms, OSA, and RLS in adults seeking PT services than average in the US population. In addition, pain severity was associated with sleep disturbance scores in PT patients.

CLINICAL RELEVANCE: The high prevalence of sleep disturbances in patients seeking PT services could impact recovery therefore screening for and treatment of sleep disturbances is warranted. Further research is needed to determine best practice for improving sleep in these individuals and if improving sleep maximizes PT outcomes.

OPL39

KINESIOPHOBIA DOES NOT AFFECT SHORT-TERM OUTCOMES FROM MIDPORTION ACHILLES TENDINOPATHY WITH A COMPREHENSIVE TREATMENT PROGRAM

Hayley Powell

PURPOSE/HYPOTHESIS: Kinesiophobia, or fear of movement, has been suggested as an inhibiting factor in the recovery of individuals with Achilles tendinopathy, but the effect on short-term outcome remains unknown. The purpose of this study was to assess short term outcomes in individuals with midportion Achilles tendinopathy with and without kinesiophobia. Secondly, we aim to determine if kinesiophobia changes in the short term with education, exercise treatment and use of pain monitoring model (PMM). We hypothesized that those with kinesiophobia would not recover to the same extent as those without kinesiophobia after 8 weeks of comprehensive rehabilitation.

NUMBER OF SUBJECTS: Sixty-nine subjects with midportion Achilles tendinopathy (mean $\pm$ SD age, 47.6 ± 12.5 years) were recruited for this study.

MATERIALS AND METHODS: Subjects were dichotomized into 2 groups: Those with kinesiophobia (≥ 37) and those without (< 37) based on their Tampa Scale of Kinesiophobia (TSK) score at baseline. TSK, total work for a maximum endurance single heel raise test calculated using a linear encoder affixed to the heel, pain with repetitive single leg hopping assessed via the numeric pain-rating scale (NPRS), and Victorian Institute of Sport Assessment-Achilles (VISA-A) score were assessed at baseline and 8 weeks following initiation of a comprehensive treatment program (Silbernagel protocol). For measurements performed on each limb, the most symptomatic side was used in calculations. A 2-by-2 mixed model ANOVA was performed comparing change in TSK, heel raise work, pain with hopping, and VISA-A from baseline to 8 weeks among the groups.

RESULTS: There were 28 (13 male) patients in the Low TSK group (mean $\pm$ SD age, 49.4 ± 11.6 years) and 41 (21 male) patients in the high TSK group (mean $\pm$ SD age, 46.3 ± 13.1 years; $P = .317$). A significant main effect for time was demonstrated for heel raise work (baseline, 1639.4 ± 749.6 J; 8 weeks, 1791.4 ± 734.8 J; $P = .006$), pain with hopping (baseline, 3.1 ± 2.4 ; 8 weeks, 2.0 ± 2.1 ; $P < .001$), and VISA-A (baseline, 52.8 ± 17.3 ; 8 weeks, 66.0 ± 16.5 ; $P < .001$). There was additionally a main effect for group for VISA-A (with kinesiophobia, 55.7 ± 2.2 ; without kinesiophobia, 64.8 ± 2.7 ; $P = .011$). There was a significant interaction effect for TSK score (with kinesiophobia baseline, 41.5 ± 3.2 ; 8 weeks, 38.0 ± 4.6 and without kinesiophobia baseline, 32.2 ± 3.0 ; 8 weeks, 32.9 ± 4.3 ; $P < .001$).

CONCLUSIONS: Regardless of baseline level of kinesiophobia, individuals with midportion Achilles tendinopathy demonstrated improved heel raise work, pain with hopping, and VISA-A score. Additionally, individuals with clinically high levels of kinesiophobia at baseline demonstrate a significant reduction in TSK score at 8 weeks following the initiation of a comprehensive treatment program.

CLINICAL RELEVANCE: A comprehensive treatment program including education, exercise and pain-monitoring model, results in significant short-term improvement irrespective of presence of kinesiophobia. In addition,

those with kinesiophobia had a significant decrease in kinesiophobia with 8 weeks of treatment.

OPL40

REAL-TIME ULTRASOUND IMAGING OF LOWER LUMBAR INTERSPINOUS SPACES FOLLOWING A PASSIVE INTERVERTEBRAL MOVEMENT TECHNIQUE

Karl C. Rusch, Ayse Ozcan Edeer, Elizabeth Oakley, Emil Euaparadorn

PURPOSE/HYPOTHESIS: There is no study measuring the interspinous space during a passive intervertebral movement (PIVM) technique nor is there any literature demonstrating movement occurs with a passive movement utilizing real-time ultrasound (RTUS). The purpose of this study is to determine if there is movement in the interspinous spaces during a flexion and extension PIVM. We hypothesize that interspinous spacing increases with a flexion PIVM and decreases with an extension PIVM measured by RTUS.

NUMBER OF SUBJECTS: Fifty healthy adults (19 male, 31 female; mean $\pm$ SD age, 25.90 ± 4.54 years).

MATERIALS AND METHODS: In this single-group, pretest-posttest study, participants were excluded if they have any low back injuries in the past 6. The distance in millimeters by digital measurement between the peak of the spinous processes of the fourth lumbar to fifth lumbar vertebra (L4-5) and fifth lumbar vertebra to the sacrum (L5-S1) were measured on images taken via RTUS (Mindray DP-30). Baseline measurements were taken in a side lying position with the hips flexed to 45° (neutral 1), followed by a flexion PIVM, another baseline measurement (neutral 2), and following an extension PIVM. Comparisons of before-after the intervention measurements were made using repeated measures ANOVA by both including and excluding covariates such as gender, height, and age.

RESULTS: The interspinous distances between L4-5 ($P < .001$) and L5-S1 ($P < .001$) were significantly higher following the flexion PIVM than neutral 1. The interspinous distances between L4-5 ($P < .001$) and L5-S1 ($P < .001$) were significantly lower following the extension PIVM than neutral 2. Age was found to be significantly related to L4-5 flexion ($P = .009$). The direction of relation between age and L4-5 flexion ($P = .013$) was positive and linear. After controlling for age, there were still significant changes in L5-S1 flexion ($P = .017$) and extension ($P = .006$).

CONCLUSIONS: Normative data for interspinous spacing between L4-5 and L5-S1 in a neutral spine and during a flexion and extension PIVM technique measured by RTUS can now be confirmed in a healthy population. There was a linear change where flexion PIVMs increased interspinous space from neutral and extension PIVMs decreased interspinous space from neutral therefore we rejected our null hypothesis and accepted our research hypothesis. These findings validate the PIVM technique and provide baseline data for future research to identify if lower spinal dysfunctions will ultimately result in any changes to the resting position of interspinous spaces and during flexion or extension PIVMs.

CLINICAL RELEVANCE: PIVM techniques have been shown to have face validity for agreement of movement between physical therapists. Interspinous space has now been objectively shown to change during a flexion and extension PIVM in a healthy population. PIVMs continue to be a heavily utilized palpation technique for movement assessment at the spine. Given that physical therapists will decide on certain treatment techniques based on their interpretation of opening and closing movements it is important to identify if the perceived movement is truly occurring and by how much.

OPL41

DO INDIVIDUALS WITH FEMOROACETABULAR IMPINGEMENT SYNDROME MEET RECOMMENDED PHYSICAL ACTIVITY GUIDELINES?

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PURPOSE/HYPOTHESIS: Femoroacetabular impingement syndrome (FAIS) is characterized by abnormal femoral and/or acetabular morphology and leads to hip-related pain and functional limitations during ambulation. Little is currently known regarding the effect of FAIS on ambulatory physical activity (PA) engagement, which may be linked with future overall health. In this study, we determined the proportions of persons with

FAIS that met guideline cutoffs for weekly PA using a device-measured approach (ie, waist worn actigraphy) and compared the proportions of those that met cutoffs between persons with FAIS and healthy controls. Secondly, in the FAIS group, we examined differences in demographic and clinical data between those who met and did not meet PA cutoffs.

NUMBER OF SUBJECTS: Twenty-six young adults with FAIS (15 female; mean $\pm$ SD age, 31.0 ± 8.9 years) and 14 young adult healthy control participants (9 female; mean $\pm$ SD age, 28.1 ± 9.1 years).

MATERIALS AND METHODS: To measure PA levels, all participants wore an accelerometer (ActiGraph GT3X+) at the waist during waking hours for 7 days. The primary PA variable was daily minutes spent in moderate-to-vigorous PA (MVPA). Demographic data collected included age, sex, symptom duration (FAIS only), and body mass index (BMI). In the FAIS group, we measured hip pain using the numeric pain-rating scale and patient-reported hip function using the Hip Dysfunction and Osteoarthritis Outcome Score and the International Hip Outcome Tool-12. Last, in the FAIS group, isometric hip and thigh strength was measured bilaterally on an isokinetic dynamometer (Nm/kg). To define PA cutoffs, we adapted the American College of Sports Medicine guidelines to represent a mean daily volume of MVPA (150 min/wk = ≥ 21.4 min/d). We calculated the proportions of those who met the PA cutoff in both groups and compared the proportion between groups using a chi-square test. In the FAIS group, we compared demographic, pain, function, and strength between those who did and did not meet the PA cutoff using independent *t* tests.

RESULTS: The FAIS and healthy control groups did not differ in age, sex distribution, or BMI (all, $P > .33$). A lower proportion of the FAIS group met the PA cutoff (42.3%) compared with the healthy control group (78.6%, $P = .03$). In the FAIS group, those who met the PA cutoff demonstrated lower BMI values (23.7 ± 3.2) compared to those who did not meet the PA cutoff (27.5 ± 5.0 , $P = .04$). FAIS participants who met versus did not meet the PA cutoff did not differ in age, sex distribution, pain/function, or strength measures (all, $P > .15$).

CONCLUSIONS: Persons with FAIS met recommended PA guideline cutoffs at lower proportions than controls, and those who did not meet cutoffs had higher BMI. Future research is needed in larger samples to determine modifiable factors associated with PA levels and healthy weight in persons with FAIS.

CLINICAL RELEVANCE: Interventions should be developed and/or implemented for individuals with FAIS to increase PA engagement and potentially lessen the risk of future health-related comorbidities/diseases associated with decreased PA and increased BMI.

OPL42

THE IMPACT OF PSYCHOSOCIAL FACTORS ON THE BIOMECHANICS OF ADOLESCENTS WITH PATELLOFEMORAL PAIN

Mitchell C. Selhorst, Alicia Fernandez-Fernandez, Jessica Hoehn, Laura C. Schmitt

PURPOSE/HYPOTHESIS: Patellofemoral pain (PFP), one of the most common knee conditions among young individuals, affects up to 10% of the population. The etiology of PFP is multifactorial and a prime contributor is impaired lower extremity mechanics. Pain-related fear is predictive of PFP symptoms and self-reported function. But it is not known if it affects the way an adolescent moves. The purpose of this study was to explore the relationship between pain-related fear and frontal plane biomechanics in adolescents with PFP. We hypothesized that adolescents with elevated pain-related fear would demonstrate greater peak knee abduction moments during a single leg hop task compared with the low pain-related fear and healthy control groups.

NUMBER OF SUBJECTS: Thirty adolescents were recruited into 3 groups ($n = 10$ each): (1) PFP and low pain-related fear (mean $\pm$ SD age, 13.8 ± 1.6 years; 80% female), (2) PFP and high pain-related fear age (15.4 ± 1.6 years; 60% female), and (3) age-matched healthy controls age (15.5 ± 1.8 years; 60% female).

MATERIALS AND METHODS: Demographic information were collected on each participant including pain and self-reported functional ability. Pain-related fear was assessed using the Fear-Avoidance Beliefs Questionnaire-Physical Activity subscale (FABQ-PA) and the Tampa Scale of Kinesio-

phobia-11 (TSK-11). Frontal plane mechanics were quantified using 3-D motion analysis during a single leg hop task. The primary biomechanical variable of interest was peak knee abduction moment. Data analysis: to test the study hypothesis a Kruskal-Wallis test was performed.

RESULTS: Adolescents with PFP in the high pain-related fear group had significantly greater pain-related fear (FABQ-PA, 16.6 ± 3.5 ; TSK-11, 25.1 ± 4.8) than those in the low pain-related fear group (FABQ-PA, 7.7 ± 3.4 ; TSK-11, 18.5 ± 3.4) ($P < .001$). Significant between-group differences were noted for external peak knee abduction moments, both raw and normalized ($P < .001$). Post hoc testing revealed that healthy controls had significantly higher knee abduction moments (raw, 20.5 Nm; normalized, 0.24 Nm/kg) than adolescents with PFP in both the high (raw, 7.5 Nm; normalized, 0.07 Nm/kg) and low (raw, 11.2 Nm; normalized, 0.13 Nm/kg) pain-related fear groups. There was not a significant difference in peak knee abduction moments between adolescents who had elevated maladaptive beliefs and those with low maladaptive beliefs (raw, $P = .17$; normalized, $P = .68$). No other significant between-group differences were noted in the frontal plane. There were no significant differences in single leg hop distance (normalized to height) between groups ($P = .11$).

CONCLUSIONS: Adolescents with PFP who demonstrated high pain-related fear had similar frontal and sagittal plane mechanics compared to adolescents with low pain-related fear during a single leg hop task. Similar to previous research findings, significant differences were observed between adolescents with PFP and healthy controls.

CLINICAL RELEVANCE: Maladaptive beliefs do not appear to significantly affect lower extremity mechanics in adolescents with PFP.

OPL43

VOLUNTARY ACTIVATION OF THE ROTATOR CUFF MUSCLES IN PATIENTS WITH SHOULDER TENDINOPATHY VERSUS HEALTHY CONTROLS

Kshamata Shah, Daniel Wingate Safford, Kathleen C. Madara, Jennifer Cooper, Brett Sweitzer, Andrew Karduna, Philip W. McClure

PURPOSE/HYPOTHESIS: Little is known about the underlying neural mechanisms associated with rotator cuff tendinopathy and associated weakness. Further, no study has determined the differences in central drive ie voluntary activation (VA) in patients as compared to healthy controls. The purpose of this study was to compare the VA and force between patients with shoulder tendinopathy and healthy controls. We hypothesized that VA would be reduced in patients as compared to healthy controls.

NUMBER OF SUBJECTS: Forty-three patients (22 male; mean $\pm$ SD age, 39.2 ± 11.8 years; painful shoulder, 23 right) with positive shoulder impingement tests and 41 age-matched controls (26 male; mean $\pm$ SD age, 36.8 ± 11.8 years).

MATERIALS AND METHODS: Participants were seated on a custom force testing apparatus. Electrodes were placed on the infraspinatus muscle to deliver stimulation and permit collection of VA data. Two isometric maximal voluntary contractions (MVCs) were collected during external rotation. The patient then received the first brief, strong electrical impulse (3-pulse train of 600-microsecond pulses delivered at 50 Hz at an intensity of 150 mV) when they were contracting at 95% of their MVC, and a second impulse at rest. The peak force from the voluntary portion of the isometric contraction, the force augmentation produced by the superimposed electrical stimulus, and the force produced by the stimulus applied to the relaxed muscle are measured and used to determine the VA (VA of 1 indicates full activation of the muscle).

RESULTS: Compared to healthy controls (0.95 ± 0.09), patients (0.74 ± 0.027) had significantly decreased ($P < .01$) VA. External rotation force was decreased in patients (107.2 ± 50.9 N) as compared to controls (136.1 ± 59.9 N) by 21.2% ($P < .05$).

CONCLUSIONS: As expected, VA and external rotation force were reduced in patients with rotator cuff tendinopathy as compared to healthy controls.

CLINICAL RELEVANCE: This suggests that weakness commonly associated with tendinopathy may be at least partially, if not primarily, explained by a lack of central neural drive rather than simply atrophy or loss of tendon integrity. This may suggest that rehabilitation strategies targeted at improvement of neural activation may enhance recovery.

OPL44

VOLUNTARY ACTIVATION OF THE ROTATOR CUFF IN PATIENTS WITH SHOULDER TENDINOPATHY AFTER PAIN RELIEF AND EXERCISE

Kshamata Shah, Daniel Wingate Safford, Kathleen C. Madara, Jennifer Cooper, Brett Sweitzer, Andrew Karduna, Philip W. McClure

PURPOSE/HYPOTHESIS: Rotator cuff tendinopathy is the most common cause of shoulder pain. Shoulder exercise and subacromial injection are the first line of treatment, and have been shown to be effective in about 70% of patients. Weakness is common in these patients although its true source is uncertain. The purpose of this study is to determine the changes in rotator cuff voluntary activation (VA), ie central drive and force, immediately after a pain-relieving subacromial injection, and following a 6-week exercise program, in patients with rotator cuff tendinopathy.

NUMBER OF SUBJECTS: Forty-three patients (21 female; mean $\pm$ SD age, 39.2 $\pm$ 11.8 years; painful shoulder, 23 right) with positive shoulder impingement tests were included.

MATERIALS AND METHODS: Patients were seated on a custom force testing apparatus. Electrodes were placed on the infraspinatus muscle to deliver stimulation and permit collection of VA data. Two isometric maximal voluntary contractions (MVCs) were collected during external rotation. The patient then received the first brief, strong electrical impulse (3-pulse train of 600-microsecond pulses delivered at 50 Hz at an intensity of 150 mV) when they were contracting at 95% of their MVC, and a second impulse at rest. The peak force from the voluntary portion of the isometric contraction, the force augmentation produced by the superimposed electrical stimulus, and the force produced by the stimulus applied to the relaxed muscle are measured and used to determine the VA (VA of 1 indicates full activation of the muscle). VA data were collected at baseline (T1), after the subacromial injection (T2), and after the 6-week exercise program (T3) (n = 36, data missing due to COVID). Exercise included strengthening, stretching and joint mobilization. Pain rating with activity was collected at all 3 time points, and self-report Penn Shoulder Score (PSS) was collected at T1 and T3.

RESULTS: The VA increased ($P < .05$) from T1 (0.74 $\pm$ 0.27) to T2 (0.90 $\pm$ 0.16) and remained unchanged at T3 as compared to T2. External rotation peak force increased ($P < .05$) across all time points and averaged 107.2 $\pm$ 50.9 N at T1 to 127.4 $\pm$ 57.9 N at T3. Pain with activity, measured using numeric pain-rating scale, was significantly reduced ($P < .01$) from baseline (5.3 $\pm$ 2.1) to after injection (2.0 $\pm$ 1.7) and continued to decrease at T3 (1.7 $\pm$ 1.3). The PSS changed from 62.1 $\pm$ 14.3 at baseline to 84.2 $\pm$ 15.1 at discharge.

CONCLUSIONS: As expected, VA was reduced at baseline and improved dramatically after the injection, suggesting that improvements in pain improve muscle activation. At 6 weeks post exercise, pain with activity, and self-reported pain and function measures all improved. The change in the PSS scores, 25 points, exceeded the previously published MCID of 11.4.

CLINICAL RELEVANCE: Understanding neural adaptations with exercise is critical to learning how to best modify the system and optimize current rehabilitation strategies, for example including exercises focused on motor-control training, biofeedback or neuromuscular electric stimulation.

OPL45

INCIPIENT BIOMARKERS OF NEUROPATHIC FOOT DEFORMITY RISK ACROSS STAGES OF CHRONIC KIDNEY DISEASE-MINERAL BONE DISORDER

David R. Sinacore, Michael A. Jones, Mary Kent Hastings, Victor Cheuy, Kevin R. Ford

PURPOSE/HYPOTHESIS: Neuropathic foot deformities are leading contributors to plantar ulceration, infection and ultimately lower extremity amputation (LEA) in individuals with diabetes mellitus (DM), peripheral neuropathy (PN) and chronic kidney disease-mineral bone disorder (CKD-MBD). The highest rates of LEA occur in individuals with DMPN and end-stage (stage 5) CKD. Excessive plantar stresses combined with low pedal bone density may be the incipient biomarkers that dramatically increase the risk for neuropathic foot deformity. The purpose of this study is to determine the prevalence of incipient biomarkers and the risk for neuropathic foot deformities in individuals with DMPN across the stages of CKD-MBD.

NUMBER OF SUBJECTS: Fifty-six (53% female) individuals were studied; 16 young adult controls (YAC) and 40 adults with DMPN and various stages of CKD-MBD. Stages of CKD-MBD were classified based on serum creatinine (Cr) to estimate glomerular filtration rate (GFR) using the CKD-EPI equation.

MATERIALS AND METHODS: All participants had WB X-rays of both feet to determine alignment of the hind foot and midfoot as indicators of foot deformity. All participants had 3 trials of dynamic plantar pressure of walking at their self-selected speed using an emed ST P-2 pressure plate (Novel Inc, St Paul, MN). A plantar map of each step was divided into 5 masks representing the hind foot, medial and lateral midfoot and medial and lateral forefoot. All participants had estimated bone mineral density (BMD) of each calcaneus using quantitative ultrasonometry (QUS-Sahara Clinical Bone Sonometer, Hologic Inc Waltham, MA). Alignment measures which exceeded the lower 99%CL of YAC's in each variable defined the deformity. Multivariate analysis of variance with post hoc pairwise comparisons (Tukey's HSD) were used to compare values of peak plantar pressures (PPP) and calcaneal BMD of participants in each stage of CKD-MBD. Two-by-two frequency tables were calculated to determine the relative risk (RR) of participants in each stage of CKD-MBD having both a PPP > 87 N/cm² in any mask and a low calcaneal BMD (T score less than -0.5 SD) in either foot.

RESULTS: The RR of both biomarkers of neuropathic foot deformity was increased as CKD-MBD progressed. The crude RR was 2.3 (95% CI: 1.1, 4.8; $P = .03$) for stage 2 compared to stage 1 (no disease); RR = 3.5 (95% CI: 1.4, 8.9; $P = .007$) for stage 3 compared to stage 1 and RR = 11.2 (95% CI: 1.6, 77.9; $P = .01$) for stage 4/5 CKD-MBD compared to stage 1.

CONCLUSIONS: As CKD-MBD progresses, PPP increase and pedal BMD decrease which combine to elevate the overall risk for neuropathic foot deformities. Excessive PPP combined with low pedal BMD may be the earliest biomarkers of neuropathic foot deformities ultimately leading to ulceration, arthropathy, infection and LEA.

CLINICAL RELEVANCE: Physical therapists should recognize the incipient biomarkers for neuropathic foot deformity in progressive CKD-MBD. Early recognition of risk factors in the foot may allow interventions to reduce the high rates of acquired deformity, plantar ulceration, infection and ultimately LEA in individuals with DMPN and CKD-MBD.

OPL46

MORE BODILY PAIN IS ASSOCIATED WITH WORSE ADJUSTMENT, GREATER RESTRICTIONS, AND LESS PROSTHESIS SATISFACTION POST AMPUTATION

Jaclyn Megan Sions, Emma Beisheim-Ryan, Ryan T. Pohlig, Mayank Seth

PURPOSE/HYPOTHESIS: The study's primary objective was to determine if the extent of bodily pain is associated with prosthetic outcomes among adults with a unilateral lower-limb amputation (LLA). A secondary objective was to determine between-days, test-retest reliability of pain body diagrams for evaluating the extent of bodily pain among adults with LLA.

NUMBER OF SUBJECTS: One hundred fifty adults underwent telephone screening, of whom 96 individuals with a major unilateral LLA that occurred at least 1 year prior were eligible. Seventy-four adults (43.2% female; 36.5% traumatic etiology; 56.8% transtibial-level) completed all outcomes of interest and were included in this analysis.

MATERIALS AND METHODS: Participants completed an online, cross-sectional research study approved by an Institutional Review Board for Human Subjects Research. Outcome measures included pain body diagrams and the psychometrically-sound Trinity Amputation and Prosthesis Experience Scales-Revised (TAPES-R), which evaluates psychosocial adjustment to LLA (with 3 subscales: General Adjustment, Social Adjustment, and Adjustment to Limitation), activity restrictions, and functional prosthesis satisfaction. Linear regression modeling was used to determine whether the total number of painful body regions identified in the past week helped to explain prosthetic outcomes, after considering potential covariates ($\alpha \leq .010$). A subset of participants (n = 54) recompleted pain body diagrams to evaluate between-days, test-retest reliability, which was evaluated with intraclass correlation coefficients (ICC_{3,1}).

RESULTS: The median number of painful body regions was 3 (25th-75th percentile, 2-7). For the sample, while general and social adjustment were high (ie, 3.8/4.0), adjustment to limitation was lower at 2.8/4.0. Individuals were generally a "little limited" per the Activity Restrictions subscale (where 0 is not limited at all; 2 is limited a lot) and "satisfied" with their prosthesis function. Beyond covariates (ie, age, sex, amputation level), the total number of painful body regions was significantly associated with all TAPES-R subscales ($P < .001-.006$), with the exception of Social Adjustment ($P = .764$). The total number of painful body regions independently explained 14.5%, 11.8%, 11.6%, and 7.4% of the variance in Functional Satisfaction with the Prosthesis, Adjustment to Limitation, General Adjustment, and Activity Restriction, respectively. Test-retest reliability for total number of painful body regions was good ($ICC_{3,1} = 0.84$; 95% CI: 0.73, 0.90).

CONCLUSIONS: Pain body diagrams are reliable for evaluating pain post LLA. A greater number of painful body regions is associated with worse postamputation adjustment, greater activity restrictions, and lower prosthesis satisfaction.

CLINICAL RELEVANCE: Presence of more bodily pain sites is associated with worse postamputation outcomes, highlighting the need for increased clinical and research emphasis on postamputation pain management and secondary pain-site prevention.

OPL47

DOES THE USE OF A CARE PROCESS IMPROVE PATIENT-REPORTED OUTCOMES IN LATERAL ELBOW TENDINOPATHY?

Steven Sorensen, Pamela Balla Dibblee, Kate Minick

PURPOSE/HYPOTHESIS: Lateral Elbow Tendinopathy (LET) has an annual incidence rate of 2.4 per 1000 with an increased proportion of surgically treated cases tripling over a 2-year period from 1.1% to 3.2%. LET is the most treated elbow condition in this not-for-profit health care system, making up 48.8% of all nonsurgical elbow cases. This is a retrospective study of the effectiveness of implementation of a care process (CP) on patient reported outcomes for patients with LET.

NUMBER OF SUBJECTS: Seven hundred thirty-one.

MATERIALS AND METHODS: Data were extracted from a web based data collection platform, the Rehabilitation Outcomes Management System (ROMS). Inclusion criteria were all patients classified as LET with a minimum of 3 visits from January 2019 through May 2021. The outcomes of interest were failure to progress (FTP), defined as not meeting the MCID on the Quick Disabilities of the Arm, Shoulder and Hand Questionnaire (QDASH), change in pain, number of visits and length of stay (LOS). A Welch's t test for unequal variances and chi-square were used to compare these outcomes before and after CP implementation. A CP was created in 2020 by 8 physical and occupational therapists using current evidence through a literature review. The CP included subjective complaints, signs and symptoms, risk factors, differential diagnosis and evaluation data points to classify patients into subgroups of irritability and probable tendon staging. A treatment algorithm was designed to assist the therapist identify the subgroups with matched treatment recommendations. This CP was implemented across the system June to November 2020 using 2 different video recorded 90-minute training sessions, a LET algorithm and a 7-page detailed document including references.

RESULTS: FTP significantly improved from 38.5% pre to 27.9% post implementation: $\chi^2 = 5.81$, $P = .02$. Post implementation, the change in QDASH (mean $\pm$ SD, 19.7 $\pm$ 17.4) was significantly improved compared to preimplementation (mean $\pm$ SD, 14.4 $\pm$ 16.3; $t_{356} = -3.38$, $P < .001$). LOS was slightly longer post implementation (mean $\pm$ SD, 57.2 $\pm$ 35.1) compared to preimplementation (mean $\pm$ SD, 44.9 $\pm$ 32.4; $t_{351} = -3.90$, $P < .001$). However, there was no significant difference in the number of visits (pre: mean $\pm$ SD, 6.0 $\pm$ 3.1; post: mean $\pm$ SD, 6.1 $\pm$ 3.3; $t_{357} = -0.34$, $P = .74$) or for change in pain (pre: mean $\pm$ SD, 1.79 $\pm$ 2.4; post: mean $\pm$ SD, 2.11 $\pm$ 2.2; $t_{396} = -1.53$, $P = .13$).

CONCLUSIONS: In this retrospective study, a CP for LET was developed and implemented in this health care system. The results indicated a significant improvement in FTP and QDASH change without an increase in number of visits. These results are consistent with previous research indicating that continuing education has positive effects on disability scores.

CLINICAL RELEVANCE: The use of a CP based on current evidence influenced patient reported outcomes and FTP rate in patients with LET in this system. Further research is needed to identify the effect of a CP on health care cost utilization, use on various diagnoses and best implementation practices for a care process.

OPL48

QUADRICEPS STRENGTH SYMMETRY PREDICTS VERTICAL GROUND REACTION FORCE RUNNING SYMMETRY 6 MONTHS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Rachel K. Straub, Leana Mosesian, Christopher M. Powers

PURPOSE/HYPOTHESIS: Running asymmetry following ACL reconstruction (ACLR) has been reported to persist up to 5 years post surgery. This is problematic as vertical ground reaction force (vGRF) asymmetry has been implicated as a risk factor for knee osteoarthritis and ACL reinjury. Although quadriceps strength asymmetry has been proposed as being contributory to running asymmetry in this population, evidence to support this premise is lacking. Furthermore, there remains insufficient evidence for a "minimum threshold" for quadriceps strength symmetry to minimize running asymmetry following ACLR. The primary purpose of this study was to determine whether quadriceps strength symmetry can predict peak vGRF running force symmetry in persons who have undergone ACLR. As a secondary aim, we sought to determine the optimal clinical cutoff for quadriceps strength symmetry to identify patients at risk for vGRF running asymmetry.

NUMBER OF SUBJECTS: Seventy-nine patients (age, 12-58 years; 55 female, 24 male) who had previously undergone ACLR (53 autografts and 26 allografts).

MATERIALS AND METHODS: We retrospectively reviewed data from patients who completed bilateral quadriceps strength testing (isometric, 60° of knee flexion) and a running evaluation at a self-selected running speed (7.3 $\pm$ 1.3 mph) on an instrumented treadmill (Zebris FDM-THQ-S-3i). All patients were tested 6 months post ACLR (28.1 $\pm$ 1.3 weeks). Limb symmetry indices were computed for quadriceps strength and the peak vGRF during running. Linear regression analysis was used to determine if quadriceps strength symmetry predicted peak vGRF running force symmetry. A receiver operating characteristic (ROC) curve was used to determine the clinical cutoff value for quadriceps strength symmetry to differentiate between high vGRF running symmetry (vGRF running symmetry ≥ 0.95) and low vGRF running symmetry (vGRF running symmetry < 0.95). The quadriceps strength symmetry cutoff was selected by extrapolating the point on the ROC curve that maximized the sum of sensitivity and specificity.

RESULTS: Increased quadriceps strength symmetry was found to predict increased vGRF running symmetry ($P < .001$, $R^2 = 0.20$). ROC curve analysis indicated that quadriceps strength symmetry distinguished patients with high versus low vGRF running symmetry with 78% accuracy (AUC = 0.78; 95% CI: 0.68, 0.88; $P < .001$). To define high-risk for low vGRF running symmetry (positive test), the identified quadriceps strength symmetry cutoff was < 0.88 . This cutoff produced a sensitivity of 77% and specificity of 70%.

CONCLUSIONS: Greater quadriceps strength symmetry predicted greater running force symmetry 6 months post ACLR. Quadriceps strength asymmetry can be used to screen patients who may be at risk for vGRF running asymmetry.

CLINICAL RELEVANCE: Patients who have quadriceps strength symmetry less than 0.88 may be at risk for vGRF running asymmetry. This threshold should be considered when clearing patient to return to running post ACLR.

OPL49

EVIDENCE-INFORMED REHABILITATION FOLLOWING HIP ARTHROSCOPY AND FEMOROACETABULOPLASTY, WITH OR WITHOUT LABRAL REPAIR

Hiral Tailor, Mary Richel Kimbrough, Christine Chansamone, Chris Anne Sebelksi

PURPOSE/HYPOTHESIS: In 2018, it was reported that hip arthroscopic surgeries cost an average of \$23120. Postsurgical rehabilitation to resolve

limitations in participation and recreation can last up to 6 months. Communication between the surgeon and the physical therapist (PT) may include a postoperative guideline. Due to the high level of financial burden on patients and the scarcity of an evidence-informed guideline, the purpose of this review was to examine the current literature for hip arthroscopy, femoroacetabuloplasty with or without labral repair timelines, and interventions to develop evidence-informed rehab guidelines for this patient population.

NUMBER OF SUBJECTS: Not applicable.

MATERIALS AND METHODS: Standardized search terms were used to search within the gray literature including Google Scholar for “consensus statements” or “guidelines,” *US News* Ranking Top 10 medical schools (2020), and physician-based guidelines through Google. Findings within the gray literature were analyzed with a priori decision to examine the first 100 results in Google Scholar and Google. Inclusion criteria: with or without labral repair, traumatic or atraumatic, pincer, cam, combined impingement, and acetabuloplasty, femoroplasty, and/or labral repair. Exclusion criteria: articles greater than 10 years, presence of systematic disease or pediatric hip disorders, presence of another joint condition, previous hip surgery, and microfracture, iliotibial band release, and/or iliopsoas release.

RESULTS: Thirty-three sources in the gray literature met the inclusion/exclusion criteria. Sources were Level 4 or Level 5 evidence. Within the first 100 results of Google Scholar, 7 sources met the criteria after removal of duplicates. The first 100 results of the Google standardized search resulted in 24 sources. Only 2 of the top 10 US medical schools had guidelines available online. No sources agreed on consistent recommendations for utilization of postoperative bracing. Greater than 50% of sources agreed upon avoiding early activation of the iliopsoas during the protective/inflammatory phase and avoiding isotonic hip flexion until 8 weeks post-op. The sources generally agreed on utilizing specific patient outcome measures (Modified Harris Hip Score, Hip Outcome Score-Sports Specific Subscale, International Hip Outcome Tool, and Coping Mechanism Evaluation).

CONCLUSIONS: There is a paucity of evidence informed postsurgical rehabilitation guidelines following hip arthroscopy publicly available. There is a lack of consensus and evidence to support the use of bracing postoperatively. Agreement exists to avoid early activation of the iliopsoas to prevent the development of postop psoas tendinopathy.

CLINICAL RELEVANCE: This review aids in the analysis of the available literature on hip arthroscopy, femoroacetabuloplasty with or without labral repair for the production of evidence-informed guidelines. Collaborative opportunities are available for PTs to develop and produce effective and efficient guidelines for patient care regarding this postoperative condition.

OPL50

SYSTEM-WIDE APPROPRIATENESS OF PHYSICAL THERAPIST-REFERRED RADIOGRAPH IMAGING IN HOSPITAL-BASED OUTPATIENT CLINICS

Scott P. Taufferner, Evan Othmer Nelson, Marcus Kip Schick

PURPOSE/HYPOTHESIS: The purpose of this study was to assess the appropriateness of radiography studies referred directly from physical therapists (PTs) during routine care.

NUMBER OF SUBJECTS: Eighty-eight PTs working in 6 ambulatory musculoskeletal physical therapy (PT) clinics in the UW Health system were authorized to refer patients for radiography studies.

MATERIALS AND METHODS: Physical therapist-signed radiology department referrals between October 2017 and September 2020 were retrospectively identified in the electronic medical record. The radiology referral was created at the physical therapy evaluation or follow-up visit for patients seen by referral or direct access. An experienced physical therapist responsible for training staff to implement imaging in PT practice manually reviewed all encounters associated with the referral. Data extraction included (1) confirmation a PT signed the referral (2) clinical judgment in the visit documentation justified imaging (3) referral met the category of “usually appropriate” in the American College of Radiology (ACR) appropriateness criteria (4) imaging views/projections ordered (5) documenta-

tion within the order included rationale/question to be answered by the radiologist (6) radiologist impression and (7) documentation the PT disseminated the imaging results to the patient. A second PT reviewed radiology referrals when the primary reviewer determined the clinical judgement did not justify imaging or the referral was not “usually appropriate” per ACR appropriateness criteria.

RESULTS: Twenty-six PTs working in 5 clinics made 100 direct referrals for radiography studies. All PTs worked at clinics with onsite imaging. Eighty-one referrals were appropriate according to clinical judgement and ACR appropriateness criteria. Individually, 87 imaging referrals included documentation to support clinical judgement, 86 referrals met ACR appropriateness criteria, and only 7 referrals did not meet either measure of appropriateness. All referrals included the rationale or question to be answered by the radiologist. Sixty-eight referrals had clear documentation the patient was informed of the imaging result. New clinical findings were identified in 30% of the imaging studies. Twice, adjacent body regions were imaged when it was not appropriate.

CONCLUSIONS: Authorization for PTs in a large hospital-based organization to directly refer patients for radiograph imaging resulted in a small number of referrals by a few providers. Similar to reports from single practice locations, the system consistently generated appropriate referrals for radiograph imaging. A meaningful number of imaging studies identified novel findings that may have altered the clinical course. Evidence the imaging results were communicated to the patient was inconsistent; this disparate finding may result from communication workflows that were disconnected from the point of care.

CLINICAL RELEVANCE: The appropriateness of imaging referrals was maintained during system-wide implementation of physical therapy authority to refer directly for diagnostic imaging in a large hospital based organization with multiple clinic locations.

OPL51

PAIN SELF-EFFICACY AT 3 MONTHS PREDICTS PAIN OUTCOMES 24 MONTHS AFTER LOWER EXTREMITY FRACTURE

Joshua J. Van Wyngaarden, Kristin Archer, Lucy Bowers, Brian W. Noehren, Paul Matuszewski

PURPOSE/HYPOTHESIS: Psychosocial factors have been shown to carry important associations with chronic pain and pain-related disability after lower extremity fracture (LEF). However, no study to date has evaluated multiple psychosocial variables simultaneously to assess which construct carries the most consistent association with pain-related outcomes. The purpose of this study was to assess pain catastrophizing, pain self-efficacy, and depression 3 months after surgery and determine which construct was consistently predictive of the development of chronic pain and pain-related disability at 24 months. We hypothesized that pain self-efficacy would be consistently associated with the development of chronic pain and pain-related disability in operative patients with LEF.

NUMBER OF SUBJECTS: One hundred twenty-two patients (mean $\pm$ SD age, 41.7 $\pm$ 14.7 years) with a LEF requiring surgical fixation and no history of chronic pain were recruited from a Level I Trauma Center for participation in this prospective cohort study.

MATERIALS AND METHODS: Three months after surgical fixation, patients completed the Pain Catastrophizing Scale, Pain Self-Efficacy Questionnaire, and PROMIS Depression computer adaptive test. Demographic and injury characteristics were extracted from the patient's medical record. Chronic pain development was assessed 24 months after surgery, and was defined using the National Institutes of Health recommendation of pain present greater than 3 months and bothersome at least half the days over the last 6 months. Patients also completed the Brief Pain Inventory Pain Severity Subscale and the PROMIS Pain Interference, with higher scores on each indicating worse pain outcomes. Separate multivariable regression analyses were conducted for each outcome, controlling for the outcome at baseline, injury severity score, age, smoking status, BMI, education level, and depression, pain catastrophizing, and self-efficacy at 3 months.

RESULTS: Ninety-nine patients (81%) completed this study. Of these patients, 28 (28.3%) reported chronic pain at 24 months. Pain self-efficacy

at 3 months was associated with chronic pain development (OR = 0.93; 95% CI: 0.88, 0.98; $P = .007$), pain severity ($\beta = -0.06$; 95% CI: -0.1 , -0.02 ; $P = .008$), and pain interference ($\beta = -0.28$; 95% CI: -0.47 , -0.08 ; $P = .006$) at 24 months. Pain catastrophizing and depression were not found to be related to any outcomes ($P > .05$).

CONCLUSIONS: Low pain self-efficacy at 3 months was consistently predictive of all pain outcomes at 24 months after surgery for LEF even when accounting for important potential confounding variables.

CLINICAL RELEVANCE: The results of this study indicate that the patient's early confidence and beliefs regarding their recovery potential strongly influence their actual outcome. Clinicians can utilize the simple 10-item Pain Self-Efficacy Questionnaire early in recovery to identify patients at risk for poor outcomes and identify meaningful interventions to improve recovery trajectory.

OPL52

CENTRAL SENSITIZATION MEDIATES CORTICAL EXCITABILITY RESPONSES TO A BRAIN STIMULATION INTERVENTION FOR CHRONIC LOW BACK PAIN

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PURPOSE/HYPOTHESIS: Central sensitization (CS), or increased cortical excitability to sensory stimuli, has been hypothesized to be an underlying mechanism for the development of chronic pain. Noninvasive brain stimulation, such as repetitive transcranial magnetic stimulation (rTMS), has a potential for chronic pain reduction. The available evidence for the effects of rTMS on cortical excitability in patients with chronic pain is conflicting, possibly in part due to the heterogeneity of study populations, for example, the extent of CS. Therefore, the purpose of this study was to examine the effects of a single session of rTMS on cortical excitability of the 2 groups: patients with chronic low back pain (CLBP) who exhibited high and low CSI scores, as compared to the effects on their matched controls who did not have LBP.

NUMBER OF SUBJECTS: Sixteen patients with CLBP and 16 age- and gender-matched controls.

MATERIALS AND METHODS: Participants with CLBP were dichotomized into high CS ($n = 8$) and low CS ($n = 8$) groups using the Central Sensitization Inventory (CSI) cutoff score of 33.5 that was established previously. Both the cortical excitability assessment and rTMS intervention were directed to the hot spot on the primary motor cortex (M1) corresponding to the first dorsalis interosseus (FDI) muscle. The hot spot was defined as the location yielding the largest peak-to-peak motor evoked potential (MEP) amplitude in the muscle at the lowest TMS stimulation intensity. Next, the resting motor threshold (RMT) was established for each participant. A RMT was the TMS intensity that yields MEPs larger than 50 μV in 5 out of 10 consecutive trials when the targeted muscle was at rest. The average amplitude of MEPs of 10 stimulations at 120% of the RMT intensity was used to quantify cortical excitability, and was measured before and immediately after the rTMS intervention. All participants received a single session of 10 Hz rTMS at 90% of RMT for 20 minutes, a total of 2000 pulses.

RESULTS: Both the low CSI group (pre, 1238 μV ; post, 1285 μV ; $P = .779$) and its matched controls (pre, 1672 μV ; post, 2395 μV ; $P = .123$) had an increase of MEPs after 1 session of rTMS, but the increase in the low CSI group was less. However, the high CS group had a decrease of MEPs after rTMS (pre, 2322 μV ; post, 1620 μV ; $P = .093$), whereas its matched controls had an increase of MEPs after rTMS (pre, 1906 μV ; post, 2137 μV ; $P = .263$).

CONCLUSIONS: In contrast to the participants with low CSI scores and asymptomatic controls, CLBP participants with high CSI scores demonstrated a different neurophysiological response to rTMS. The difference in the extent of CS between the 2 groups could have contributed to their cortical excitability difference in response to the rTMS intervention.

CLINICAL RELEVANCE: This study identifies a potential mediator, the extent of CS, which could account for the different neurophysiological responses to rTMS in patients with CLBP. These results will serve as pilot data for future studies to explore the role of CS in mediating the clinical responses to rTMS.

OPL53

HIP, KNEE, AND ANKLE JOINT CONTACT FORCE SYMMETRY DURING WALKING AND RUNNING FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Altered joint contact force (JCF) may play a central role in the increased incidence of posttraumatic osteoarthritis following ACL reconstruction (ACLR). Relative to the nonsurgical limb, decreased knee JCF has been observed following ACLR, particularly during activities with greater task demands. Whether this knee joint unloading promotes compensatory hip or ankle JCF asymmetry is unknown. We aimed to compare interlimb hip, knee, and ankle JCF symmetry during walking and running between people with and without a history of ACLR.

NUMBER OF SUBJECTS: Thirty recreational athletes (19 female; age, 22.3 years) with a unilateral ACLR in the previous 2 to 7 years (47 ± 15 months) and 30 participants with no previous lower extremity surgery matched on sex, mass, and activity level.

MATERIALS AND METHODS: Bilateral 3-D lower extremity kinematics (200 Hz) and ground reaction forces (1000 Hz) were collected during walking (1.25 m/s) and running (2.70 m/s) on an instrumented treadmill. Resultant hip, axial knee (tibiofemoral joint), and axial ankle JCF were calculated using a validated musculoskeletal model with an inverse dynamics-based static optimization routine. Hip, knee, and ankle peak JCF and JCF impulse interlimb symmetry indices (LSI) were compared between ACLR and control participants using separate 2-factor (group by task) analyses of variance ($\alpha = .05$). Effect sizes were estimated using partial eta square to define small ($\eta^2 > 0.01$), medium ($\eta^2 > 0.06$), and large ($\eta^2 > 0.14$) effects.

RESULTS: Compared to the control group, lower peak knee JCF was observed in the surgical limb of the ACLR group relative to nonsurgical limb during both walking (ACLR LSI = 98.4%, control LSI = 100.1%) and running (ACLR LSI = 96.6%, control LSI = 98.8%) conditions ($P = .04$, $\eta^2 = 0.07$). Similarly, lower knee JCF impulse LSI was observed in the ACLR group during both walking (ACLR LSI = 98.5%, control LSI = 100.7%) and running (ACLR LSI = 97.1%, control LSI = 100.2%; $P = .04$, $\eta^2 = 0.06$). An interaction of group and task was identified for peak hip JCF LSI, with increased JCF in the ACLR limb compared to the nonsurgical side, but only during the running condition (ACLR LSI = 113.3%, control LSI = 101.3%; $P = .01$, $\eta^2 = 0.10$). Hip JCF impulse LSI was also larger in the ACLR limb during running, but the asymmetry was not statistically greater than the control group (ACLR LSI = 110.8%, control LSI = 102.5%; $P = .17$, $\eta^2 = 0.03$). Peak ankle JCF LSI and ankle JCF impulse LSI were not different between groups during the walking or running conditions.

CONCLUSIONS: Individuals with a history of ACLR experience decreased surgical limb knee JCF across activities with varied task demands. Increased ipsilateral peak hip JCF during running suggests a proximal redistribution of knee joint loads following ACLR during activities with increased task demands.

CLINICAL RELEVANCE: Hip and knee JCF asymmetry following ACLR may contribute to increased risk for joint pathologies such as premature osteoarthritis. Consideration of both hip and knee mechanics appears necessary for rehabilitation efforts intended to restore a more symmetrical lower extremity kinetic profile following ACLR, particularly during activities with greater task demands.

OPL54

PATIENT-REPORTED OUTCOMES AND TIMED UP-AND-GO FOLLOWING OSSEOINTEGRATION IN PEOPLE WITH LOWER-LIMB AMPUTATION

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PURPOSE/HYPOTHESIS: People with lower-limb amputation (LLA) are routinely prescribed a socket prosthesis; however, approximately 30% of socket prosthesis users experience complications with the fit of their prosthesis including skin irritation, pain, and compromised fit due to residual limb volume fluctuations. Osseointegration is a procedure that creates a direct connection between the bone and prosthetic limb through a bone-anchored prosthesis, eliminating the need for a sock-

et interface, and is offered as a secondary procedure to people with LLA who experience significant complications with socket prostheses. The purpose of the study was to evaluate change in patient-reported outcomes on mobility, balance, and disability and Timed Up-and-Go (TUG) performance 1 year post osseointegration compared to preosseointegration in individuals with LLA. We hypothesized patient-reported outcomes and TUG times would improve 1 year post osseointegration compared to preosseointegration.

NUMBER OF SUBJECTS: Nine people (mean $\pm$ SD age, 46 $\pm$ 11 years; BMI, 27.6 $\pm$ 4.2 kg/m²; 56% female [n = 5], 13 $\pm$ 12 years since amputation) with LLA underwent osseointegration with press-fit implants. Seven participants had transfemoral amputations and 2 patients had transtibial amputations.

MATERIALS AND METHODS: Patient-reported outcomes and the TUG were administered pre and 1 year post osseointegration. Patient-reported outcomes included the Prosthetic Limb Users Survey of Mobility (PLUS-M), an instrument for measuring mobility of adults with LLA, the Activities-Specific Balance Confidence (ABC) Scale, a measure of balance confidence in performing activities without experiencing unsteadiness, and the World Health Organization Disability Assessment Schedule (WHODAS) 2.0, an assessment of disability for adults. Paired t tests were used to assess change in outcomes 1 year post osseointegration compared to preosseointegration.

RESULTS: One participant did not complete the TUG, as they were unable to attend the clinical portion of the data collection session. Post osseointegration, participants demonstrated improvements in PLUS-M (pre, 40 $\pm$ 24; post, 72 $\pm$ 24; P = .003), improvements in ABC (pre, 74 $\pm$ 14; post, 86 $\pm$ 11; P = .034), and reductions in WHODAS 2.0 (pre, 24% $\pm$ 12%; post, 10% $\pm$ 14%; P = .018). Participants demonstrated no change in the TUG post osseointegration compared to preosseointegration (pre, 9.8 $\pm$ 1.8 seconds; post, 9.8 $\pm$ 2.4 seconds; P = .98).

CONCLUSIONS: Participants report greater mobility in their prosthesis, greater confidence with their balance, and less disability post osseointegration. Participants demonstrated no change in the TUG; however, preosseointegration TUG times were less than 10 seconds (interpreted as normal function), indicating a potential ceiling effect for the TUG in this population. Future studies should include more demanding tasks to evaluate change in functional capacity, including fast-walking speed and stair climbing.

CLINICAL RELEVANCE: Osseointegration is a novel procedure for people experiencing complications with their socket prosthesis, and recent findings suggest osseointegration improves patient-reported outcomes.

OPL55

VALIDITY AND RELIABILITY OF THE FEAR-AVOIDANCE BELIEFS QUESTIONNAIRE IN ADOLESCENTS WITH PATELLOFEMORAL PAIN

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PURPOSE/HYPOTHESIS: Patellofemoral pain (PFP) is one of the most common musculoskeletal diagnoses in adolescent patients, leading to decreased participation in sports and recreational activities. Maladaptive psychosocial beliefs, including fear avoidance, are correlated with pain and dysfunction among adults with PFP. The Fear-Avoidance Beliefs Questionnaire (FABQ) is a self-report measure identifying the impact of fear avoidance beliefs on physical capabilities. The physical activity subscale of the FABQ (FABQ-PA) is adversely correlated with pain and function in adults with PFP; however, it is unknown whether the FABQ-PA is valid and reliable in adolescents with PFP. The purpose of this research study was to determine the validity and reliability of the FABQ-PA in adolescents with PFP. We hypothesized that the FABQ-PA would demonstrate validity and good reliability in determining fear avoidance beliefs among adolescents with PFP.

NUMBER OF SUBJECTS: One hundred twenty-four adolescents with PFP (mean $\pm$ SD age, 14.7 $\pm$ 1.7 years; 62% female).

MATERIALS AND METHODS: This was an observational study. Participants completed self-report outcome measures, including the FABQ-PA. The FABQ-PA is a 5-item self-report measure categorizing fear avoidance behaviors, with each item graded on a 0 to 6 scale and higher scores indi-

cating high fear-avoidance beliefs. Outcome measures used to determine convergent validity in the FABQ-PA are as follows: kinesiophobia (Tampa Scale for Kinesiophobia-11), function (Anterior Knee Pain Scale), pain (numeric pain scale), pain catastrophizing (Pain Catastrophizing Scale-Child) and fear of pain (Fear of Pain-Child, Avoidance subscale). Data analysis: Cronbach's alpha was used to determine internal consistency of the FABQ-PA, and Spearman rho was used to assess convergent validity with other measures.

RESULTS: Participants completed the FABQ-PA with a mean $\pm$ SD score of 12.4 $\pm$ 5.2. The internal consistency was good with a Cronbach's alpha of .77. Moderate convergent validity was observed between fear of pain (n = 24) (r_s = 0.65, P < .01), kinesiophobia (n = 124) (r_s = 0.62, P < .01), and function (n = 124) (r_s = -0.56, P < .01), while weak convergent validity was observed between pain (n = 124) (r_s = 0.38, P < .01), and pain catastrophizing (n = 124) (r_s = 0.37, P < .01).

CONCLUSIONS: The FABQ-PA demonstrated good reliability and acceptable convergent validity in adolescent patients with PFP. The FABQ-PA exhibited moderate convergent validity to measures of fear of pain, kinesiophobia and function, and weak convergent validity to measures of pain and pain catastrophizing. The FABQ-PA demonstrates validity and reliability as a measure of fear avoidance among adults with PFP, and now demonstrates similar characteristics in the adolescent population.

CLINICAL RELEVANCE: As PFP is a common diagnoses in adolescents, the FABQ-PA can be a useful tool to identify fear avoidance, which has been shown to negatively impact patient outcomes in patients with PFP.

OPL56

CASE SERIES: EMERGENCY DEPARTMENT PHYSICAL THERAPY CONSULT AND FOLLOW-UP OUTPATIENT PHYSICAL THERAPY FOR ACUTE LOW BACK PAIN

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PURPOSE/HYPOTHESIS: Low back pain (LBP) accounts for nearly 4 million annual Emergency Department (ED) visits, and 3-month outcomes following an ED visit for LBP are poor; nearly half have moderate-severe pain and functional loss. Only 10% of ED visits for LBP receive outpatient physical therapy (PT) within 3 months, despite established benefits (reduced imaging, downstream costs, opioid use) of early compared to delayed PT. Integrating PT directly into ED patient care may facilitate evidence-based guideline concordant care and improve outcomes. This case series presents pilot data of patients evaluated by an ED PT program and follow-up with an outpatient PT.

NUMBER OF SUBJECTS: Three patients with an acute episode of LBP enrolled in an ongoing clinical trial evaluating an integrated model of ED PT were subsequently evaluated in outpatient PT.

MATERIALS AND METHODS: Patients were evaluated and managed by the ED PT using a treatment-based classification modified for use in the ED (ED-TBC). Two outpatient PTs blinded to the ED PT classification and outcomes evaluated the patients in outpatient PT within 1 week from the ED visit. Pain severity (0-10/10), ED-TBC or TBC treatment classification, and Keele STarT-Back Score risk stratification for developing persistent LBP and disability (low risk, $\leq 3/9$ total score; medium, $\leq 3/5$ distress subscore; high, $\geq 4/5$ subscore) were compared between visits.

RESULTS: Three patients (3 female; mean age, 59.0 years; range, 53-58 years) with an acute episode of LBP seen in the ED by PT were referred to outpatient PT. Patients classified with the ED-TBC and TBC were placed in the same treatment classification in both the ED and outpatient PT (stabilization; directional preference). Pain decreased in 2 patients by a mean $\pm$ SD of 5.5 $\pm$ 1.8 from the ED visit. STarT-Back score reduced in these 2 patients (7/9 to 6/9; 7/9 to 4/9) and risk stratification for prognosis improved in one. The third patient's pain was unchanged (8/10), STarT-Back had worsened (3/9 to 7/9), and risk stratification increased from low to high for persistent pain and disability. With a medical history of osteopenia, she had radiographs in the ED and was provided with a diagnosis (known L5-S1 spondylolisthesis grade II) prior to seeing the ED PT. Prior to outpatient PT, she saw urgent care, consulted an orthopaedic surgeon, and had an MRI.

COMBINED SECTIONS MEETING

CONCLUSIONS: These 3 cases illustrate consistency in TBC classification, but changes in patient presentation between PT consult embedded in an ED visit and outpatient PT 1-week later for patients with acute LBP. Patient risk stratification for persistent pain and disability can change (worsen/improve) after an ED visit and may be related to imaging results or other unknown factors.

CLINICAL RELEVANCE: Early PT management for patients with LBP shows

reduced health care utilization and improved guideline concordant care, but the efficacy of early PT management for patients with acute LBP seen in the ED is lacking. Preliminary results from a case series illustrates consistency in ED PT evidence-based treatment classification using a modified TBC compared to outpatient PT classification and changes in prognosis after ED PT for risk of persistent pain and disability.

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SPL1

CHOOSING TO DECREASE ACTIVITY LEVEL AFTER ANTERIOR CRUCIATE LIGAMENT INJURY MAY PROTECT THE KNEE FROM CLINICAL OSTEOARTHRITIS

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PURPOSE/HYPOTHESIS: Approximately 50% of individuals develop post traumatic knee osteoarthritis (PTOA) within a decade after ACL rupture. PTOA has been associated with reduced sports and recreational participation and lower self-reported quality of life. The role of activity level in the development of PTOA is not understood. The purpose of this study was to assess self-described knee function and clinical knee OA based on activity level and reason for reducing activity level after ACL rupture.

NUMBER OF SUBJECTS: Two hundred eleven athletes 5 years after ACL rupture or reconstruction (mean $\pm$ SD age, 32.1 ± 9.3 years; BMI, 25.4 ± 3.9 kg/m²).

MATERIALS AND METHODS: This is a cross-sectional analysis of a prospective cohort study at the 5-year time point. Participants were enrolled if they were Level I (eg, soccer) or level II (eg, racket sports) athletes at the time of ACL rupture, and excluded if they had grade III ligamentous injury, articular cartilage lesions >1 cm², or history of ACL injury. Individuals were categorized into 3 groups: high activity (HA; level 1 and 2), reduced activity due to knee related reasons (KR; level 3 and 4), and reduced activity due to lifestyle changes (LS; level 3 and 4; eg, motivation, aged out of sport). An ANOVA was used to quantify mean differences in the Global Rating Score (GRS), and each KOOS subscale in the 3 groups. A chi-square test evaluated differences among classifications of clinical knee OA. Clinical knee OA was defined using Luyten et al criteria, requiring 2 out of 4 KOOS subscales (pain, symptoms, function, quality of life) are $\leq 85\%$. Our sample includes athletes, so we found it clinically relevant to include the sports and rec subscale in the clinical OA definition.

RESULTS: A significant difference was found between the HA and KR groups ($P < .006$) and between the KR and LS groups ($P < .031$) in GRS and each KOOS subscale: GRS (HA, 93.3 ± 10.9 ; KR, 86.0 ± 11.5 ; LS, 95.7 ± 5.0); KOOS pain (HA, 95.5 ± 7.5 ; KR, 89.7 ± 9.6 ; LS, 97.9 ± 3.4); KOOS symptom (HA, 91.5 ± 10.6 ; KR, 84.0 ± 14.7 ; LS, 95.4 ± 3.7); KOOS ADL (HA, 98.3 ± 4.2 ; KR, 96.0 ± 6.6 ; LS, 99.2 ± 1.8); KOOS Sports and Recreation (HA, 91.4 ± 13.1 ; KR, 76.8 ± 23.5 ; LS, 95.0 ± 9.0); KOOS Quality of Life (HA, 84.7 ± 16.8 ; KR, 63.7 ± 21.2 ; LS, 84.9 ± 14.3). No difference was found between the HA and LS group ($P > .476$). The percent of each activity group classified as having clinical knee OA was 24.6% in the HA group, 68.4% in the KR group and 5.0% in the lifestyle reasons group ($P < .01$).

CONCLUSIONS: Those who reduce their activity level due to knee related reasons have poor self-reported outcomes 5 years after ACL rupture, with

68% being classified with clinical knee OA. Conversely, those who choose to reduce their activity level due to lifestyle reasons have the best clinical knee OA outcomes and have GRS and KOOS scores equal to or higher than the HA group.

CLINICAL RELEVANCE: Selecting to reduce activity levels due to changes in lifestyle after ACL injury may be protective against developing clinical knee OA. Individuals who reduce activity levels due to knee related reasons are a target group for OA prevention in rehabilitation.

SPL2

SEASONAL INTERNAL AND EXTERNAL ROTATION AND SELF-REPORTED FUNCTION IN DIVISION I UPPER EXTREMITY ATHLETES

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PURPOSE/HYPOTHESIS: Changes in glenohumeral (GH) range of motion (ROM) and self-reported pain and function are common in overhead athletes with shoulder injuries. The primary purpose was to compare preseason and postseason differences in side-to-side GH external rotation (ER) and internal rotation (IR) ROM between athletes who received in-season treatment for an upper extremity (UE) injury and those who did not receive treatment. We hypothesized a difference would exist in side-to-side ROM between treatment groups and across the season. The secondary purpose was to compare self-reported UE pain and function throughout the season. We hypothesized a difference would exist in self-reported pain and function scores between treatment groups and throughout the season.

NUMBER OF SUBJECTS: Twenty-six Division I collegiate athletes (9 gymnasts, 17 swimmers; 15 female, 11 male; mean $\pm$ SD age, 20.0 ± 1.2 years).

MATERIALS AND METHODS: Preseason passive GH ER and IR were collected by the teams' athletic trainer (AT). Postseason measurements were taken by the team AT and 2 physical therapists. Self-reported pain and function was recorded biweekly with a modified Kerlan-Jobe Orthopedic Clinic questionnaire (m-KJOC). Any in-season treatments for UE injuries were reported by the ATs. The side-to-side differences in ROM between shoulders were determined by subtracting the right from left sided values for IR and ER. Two-factor ANOVAs with factors of collection period (preseason/postseason) and group (received treatment or not) were used to compare the side-to-side differences in IR and ER. A 2-factor ANOVA with collection period (early/mid/late season) and group was used to compare m-KJOC scores. For each comparison, in the instance of no significant interaction, the main effects of time and treatment status were evaluated. Alpha was set at .05.

RESULTS: There were no significant interactions between collection period and group for the athletes' side-to-side difference in ER ($P = .814$), IR ($P = .988$), or the m-KJOC scores ($P = .572$). There was no main effect of group on side-to-side differences in ER (3.2° , $P = .431$), IR (-3.4° , $P = .598$), or m-KJOC (11.2% , $P = .295$). There was no main effect of the collection period for ER (-5.8° , $P = .322$), IR (4.7° , $P = .540$), or m-KJOC (-0.8% , $P = .792$). A post hoc power analysis indicated a range of 70% to 90% power to detect a 10° difference in side-to-side ROM differences for the comparative analyses.

CONCLUSIONS: Across the competitive season, no significant differences in side-to-side ER and IR ROM were observed between those receiving treatment for an UE injury and those not receiving treatment. No significant differences in m-KJOC scores were identified between those receiving in-season treatment for an UE injury versus those not receiving treatment.

CLINICAL RELEVANCE: Asymmetries in ROM for bilateral UE athletes may not be as clinically informative compared to unilateral UE sports. It may be more beneficial to compare ROM to healthy normative data instead of side-to-side comparisons.

SPL3

QUADRICEPS PERFORMANCE AT 3 MONTHS IS PREDICTIVE OF JUMPING BIOMECHANICS 1 YEAR POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN COLLEGIATE ATHLETES

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PURPOSE/HYPOTHESIS: Impaired quadriceps function early after anterior cruciate ligament reconstruction (ACLR) is weakly to moderately associated with abnormal knee biomechanics near the time of return to sport (RTS). Quadriceps performance is typically quantified via knee extensor peak torque (PT), but recent research suggests that a more comprehensive characterization of quadriceps function, including rate of torque development (RTD) and torque steadiness (TS), may improve prediction of knee function after injury or surgery. The purpose of this study was to determine if early recovery of PT, RTD, and TS post ACLR is associated with improved movement mechanics at RTS in collegiate athletes. We hypothesized that early quadriceps performance symmetry would be associated with knee biomechanics symmetry during the countermovement jump (CMJ) 1 year post ACLR.

NUMBER OF SUBJECTS: Sixteen Division I collegiate athletes (9 male; mean $\pm$ SD age, 20 ± 1.2 years; BMI, 25.7 ± 3.7 kg/m²) who underwent unilateral ACLR.

MATERIALS AND METHODS: Quadriceps performance was assessed at 3.4 $\pm$ 0.7 months (3 months) post ACLR using both ramp-and-hold maximal volitional isometric contractions (MVIC) and rapid maximal effort isometric trials at 90° flexion. PT and TS were calculated from each MVIC trial. TS was calculated as the mean difference between the raw torque output and a low-pass filtered signal (2 Hz cutoff), expressed as a percentage of PT. RTD was calculated as the slope from 20% to 80% of PT during the rapid effort trials. CMJ trials were performed at 11.2 ± 1.6 months (1 year) post ACLR while 3-D kinematics and ground reaction forces were recorded. Variables calculated during takeoff (TO) and landing (LAND) included total knee excursion, peak knee extensor moment (PKEM_{TO} and PKEM_{LAND}), rate of knee extensor moment (RKEM_{TO} and RKEM_{LAND}), and knee positive and negative work (PW_{TO} and NW_{LAND}). Limb Symmetry Indices (LSI) were calculated for quadriceps performance variables and CMJ variables. A multivariable regression model was used to assess 3-month LSIs of PT, RTD, and TS as predictors of 1-year CMJ knee kinetic and kinematic LSIs.

RESULTS: RTD was not associated with any of the CMJ variables and was removed from the model. PT and TS LSIs at 3 months were significantly associated with PKEM_{TO} ($P = .02$, $R^2 = 0.46$), PW_{TO} ($P = .04$, $R^2 = 0.40$), PKEM_{LAND} ($P = .02$, $R^2 = 0.48$), RKEM_{LAND} ($P = .01$, $R^2 = 0.49$), and NW_{LAND} ($P = .04$, $R^2 = 0.40$) at 1 year. TS partial correlations were significantly associated with RKEM_{LAND} ($P = .03$, $R^2 = 0.31$) and NW_{LAND} ($P < .05$, $R^2 = 0.27$).

CONCLUSIONS: Quadriceps performance symmetry at 3 months post ACLR explained 40% to 50% of the variance in CMJ biomechanics 1 year post ACLR in Division I collegiate athletes. TS was individually associated with

RKEM_{LAND} and NW_{LAND} when accounting for PT, but PT was not independently associated with any CMJ biomechanics when accounting for TS.

CLINICAL RELEVANCE: In collegiate athletes, maximizing quadriceps neuromuscular performance in the initial 3 months post ACLR may improve CMJ knee kinetic symmetry at 1 year. TS symmetry should be further explored as it was most strongly associated with CMJ landing mechanics.

SPL4

ISOKINETIC RATE OF TORQUE DEVELOPMENT PREDICTS PEAK TORQUE FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Knee extension rate of torque development (RTD) deficits measured via isometric testing are documented at various time points following anterior cruciate ligament reconstruction (ACLR). Studies have shown strong, positive relationships between isometric measures of RTD and maximum strength. Isokinetic dynamometry is the gold standard for return to sport testing but it is unclear if similar relationships exist between isokinetic RTD and peak torque. The purpose of this study was to examine the influence of isokinetic RTD on peak torque following ACLR. It was hypothesized that isokinetic RTD would predict peak torque at faster testing velocities in ACLR patients. Further, we hypothesized interlimb RTD asymmetries would be present throughout the velocity spectrum at 6 months postop ACLR.

NUMBER OF SUBJECTS: Participants were 13 young individuals (mean $\pm$ SD age, 18.3 ± 6.2 years; 9 male) approximately 6 months (5.45 ± 0.68) post primary, unilateral ACLR.

MATERIALS AND METHODS: Participants performed isokinetic testing consisting of 5 repetitions across a velocity spectrum including $60^\circ/\text{s}$, $120^\circ/\text{s}$, $240^\circ/\text{s}$, and $400^\circ/\text{s}$ on each limb. RTD (ft-lb-s⁻¹-lb⁻¹) was calculated from repetition onset (15% of the target velocity) to the time of peak torque. All torque values were normalized to body weight. Time to achieve the target velocity (milliseconds) was also identified. Variables of interest from the middle 3 repetitions were averaged at each velocity for each limb for each participant. Multiple linear regressions evaluated the association of RTD and time to target velocity with peak torque at each velocity and paired t tests compared between limb differences for variables of interest ($P \leq .05$).

RESULTS: On the involved limb, RTD predicted peak torque at $60^\circ/\text{s}$ ($\beta = 0.521$, $P = .007$) and $240^\circ/\text{s}$ ($\beta = 0.159$, $P = .009$) but not at $400^\circ/\text{s}$ ($\beta = 0.011$, $P = .577$). Time to the target velocity predicted peak torque at $400^\circ/\text{s}$ ($\beta = -0.003$, $P = .031$) but did not at $60^\circ/\text{s}$ ($\beta = 0.003$, $P = .257$) or $240^\circ/\text{s}$ ($\beta = 0.002$, $P = .219$). Paired limb comparisons showed greater RTD at $60^\circ/\text{s}$ ($P < .001$) and $240^\circ/\text{s}$ ($P = .016$) and decreased time to target velocity at $400^\circ/\text{s}$ ($P < .001$) for uninjured compared to involved limb.

CONCLUSIONS: The hypothesis was partially supported as RTD, but not time to target velocity, predicted peak torque at $60^\circ/\text{s}$ and $240^\circ/\text{s}$. At $400^\circ/\text{s}$, time to target velocity predicted peak torque but not RTD. This may be related to force-velocity relationships. At $400^\circ/\text{s}$ the repetition onset velocity is $60^\circ/\text{s}$ where subjects can produce larger torques. In contrast, peak torque at $400^\circ/\text{s}$ is much lower which may artificially influence the RTD. Time to target velocity may provide a better measure of force development at higher velocities as subjects accelerate freely similar to an isotonic condition.

CLINICAL RELEVANCE: Isokinetic testing at higher velocities is advocated as it is believed to have greater association with sport specific function, but ideal testing velocities and interpretations have not been established. These metrics may be considered for future studies to evaluate correlation with athletic performance to increase the value of current return to sport testing.

SPL5

EARLY QUADRICEPS STRENGTH AND ITS IMPACT ON YOUNG ATHLETES FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Quadriceps (QF) strength is a key factor in return to sport (RTS) decision making after ACL reconstruction (ACLR).

However, the clinical significance of QF strength in early postoperative care lacks a criterion value that is predictive of subsequent clinical outcomes. The purpose of this study was to test the hypothesis that early QF strength (EQ) was associated with kinematics during a single leg landing task (SLL) and current discharge criteria at the time RTS in young athletes after ACLR.

NUMBER OF SUBJECTS: Fifty-seven patients after unilateral ACLR (mean $\pm$ SD age, 15.8 ± 2.2 years; 37 female).

MATERIALS AND METHODS: All patients completed an isokinetic EQ strength test ($180^\circ/\text{s}$) at a mean time of 13.6 ± 2.1 weeks post ACLR. Within 4 weeks of medical clearance for RTS, the same patients completed a RTS testing battery: isokinetic strength, hop tests (single hop, triple hop, crossover hop, 6 m timed hop), and the International Knee Documentation Committee subjective knee form. A score of ≥ 90 was identified as "meeting" RTS criteria. At the RTS testing session, 3-D motion analysis was performed during SLL task from a 31-cm height. Variables of interest included sagittal plane trunk, hip, and knee kinematics during the landing phase of SLL. Based on EQ data, the cohort was split into high EQ (HEQ; Limb Symmetry Index (LSI) $\geq 80\%$) and low EQ (LEQ; LSI $< 80\%$) groups. The interaction between landing mechanics and both EQ groups was evaluated using 2-by-2 repeated-measures ANOVA. A chi-square test was utilized to determine the association between each EQ group and the likelihood of meeting all RTS criteria.

RESULTS: There was no difference in age, sex, or graft type distributions between EQ groups. Analysis of the SLL task showed an interaction with the LEQ group having increased peak trunk excursion ($17.0^\circ \pm 4.5^\circ$) landing on the involved limb compared to the uninvolved limb ($14.7^\circ \pm 4.8^\circ$) and both the involved limb ($14.4^\circ \pm 7.1^\circ$) and uninvolved limb ($15.2^\circ \pm 9.9^\circ$) of the HEQ group ($P = .02$). Conversely, the LEQ group displayed increased uninvolved limb hip flexion excursion ($31.7^\circ \pm 7.2^\circ$), compared to the involved limb ($28.9^\circ \pm 7.5^\circ$) and both the involved ($26.0^\circ \pm 10.0^\circ$) and uninvolved limb ($24.7^\circ \pm 7.9^\circ$) of the HEQ group ($P = .01$). There was a main effect of side with sagittal plane knee excursion ($P = .04$), as all patients demonstrated reduced knee flexion on the involved limb ($57.6^\circ \pm 11.1^\circ$) compared to the uninvolved limb ($60.6^\circ \pm 10.7^\circ$). Finally, the LEQ group was 4 times more likely to fail to meet all RTS criteria at the time of medical clearance (OR = 4.0; 95% CI: 1.3, 12.1; $P = .01$) compared to the HEQ group.

CONCLUSIONS: Patients categorized as LEQ at 3 months post ACLR displayed high-risk biomechanics during a SLL task and were less likely to meet current discharge criteria at the time of medical clearance for RTS.

CLINICAL RELEVANCE: EQ strength may help identify the potential for more normal movement patterns and ability to meet current discharge criteria at the time of RTS in young athletes following ACLR. Further, it may help guide the selection of clinical interventions during the early postoperative stage of rehabilitation following ACLR to optimize outcomes.

SPL6

DEFINING ADAPTIVE SPORTS EXPERIENCES: A NATIONAL SURVEY OF PHYSICAL THERAPY AND PHYSICAL THERAPY ASSISTANT PROGRAMS

Kayla Dawn Black, Marissa Credle, Roxana Garcia Escalante, Sebastian M.I. Hicks, Amy Jo Morse, Deanne R. Fay

PURPOSE/HYPOTHESIS: Adaptive sports have shown to enhance quality of life in individuals with disabilities. Participation in adaptive sports experiences (ASE) may help future physical therapists (PTs) and physical therapist assistants (PTAs) understand the role of sport in rehabilitation and the importance of skills including communication, empathy, and accessibility. The purpose of this study was to determine how ASE are integrated into PT/PTA education and the facilitators, barriers, and perceived benefits of such experiences.

NUMBER OF SUBJECTS: Survey respondents included 72 programs (39 PT, 33 PTA).

MATERIALS AND METHODS: A Qualtrics survey was developed and validated through a 3-step process. The final survey used logic to guide question advancement and contained 6 to 34 multiple choice and free response questions. A link to the survey was emailed to the directors of all US-accredited PT and PTA programs. Quantitative data were analyzed using

descriptive, Mann-Whitney, and chi-square statistics to compare frequencies related to program demographics of program type, institution type, urban/nonurban designation, geographic region, and cohort size ($P < .05$). Open-ended responses were analyzed for themes using a constant comparison method.

RESULTS: A majority of survey respondents were from public (58%), urban (78%) programs with cohort sizes of less than 50 students (81%). Half of the respondents (50%) provide specific adaptive sports educational content in their curricula and slightly over half (58%) offer ASE (volunteer experience, 50%; extra credit, 30%; required, 20%). Adaptive sports inclusion in curricula and opportunity for ASE was more common in PT versus PTA programs and in smaller cohorts (program type, $P < .001$; cohort size, $P < .05$). Regardless of whether a program offered ASE, student time/schedules was the most common barrier. A program faculty relationship with an organization was the most common facilitator to ASE. Faculty perceived the benefits to include awareness of abilities in those with a disability, value of adaptive sports, and opportunities to engage with one's community through service.

CONCLUSIONS: Physical therapy programs and programs with smaller cohorts (< 50 students) are more likely to offer ASE and include adaptive sports content in their curricula. The greatest barrier to offering ASE is lack of student time, which is likely why most ASE are voluntary and PTA students have fewer opportunities. Faculty engaging with organizations that offer ASE are crucial in bringing these opportunities to students during their education.

CLINICAL RELEVANCE: The academic programs that participated in this study are reflective of the demographics of accredited PT and PTA programs in the United States. Since cohort size and program length cannot be altered to accommodate for ASE, information related to ASE should be emphasized in the course content and faculty should be encouraged to develop relationships in the community to offer these experiences to students.

SPL7

DO PSYCHOLOGICAL FACTORS CONTRIBUTE TO NEUROMUSCULAR ASYMMETRIES FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION?

Joanna Borawski, John Sterling Mason, Erin Marie Miller, William J. Pitt, Michael Scott Crowell, Richard A. Brindle

PURPOSE/HYPOTHESIS: After an anterior cruciate ligament reconstruction (ACLR), only 47% of military members return to full duty (RTD), possibly due to persistent neuromuscular asymmetries. Psychological factors, such as fear of reinjury, may also contribute to the reduced return to duty rate in military members. The purpose of this study was to determine the relationship of psychological factors and time since surgery to neuromuscular asymmetries in United States Military Academy (USMA) Cadets with a history of recent ACLR. We hypothesized that psychological factors and time since surgery would predict asymmetries in jump landing ground reaction forces (GRF), quadriceps peak torque (PT) and joint position sense (JPS).

NUMBER OF SUBJECTS: Twenty-nine.

MATERIALS AND METHODS: Participants had a history of unilateral ACLR 10 to 38 months prior to data collection. We assessed psychological factors using the Tampa Scale of Kinesiophobia (TSK-11) and Anterior Cruciate Ligament-Return to Sport after Injury scale (ACL-RSI). To assess jump landing GRF, participants jumped off a 31-cm box placed a distance of 50% of their height onto 2 AMTI (AMTI, Watertown, MA) force plates embedded in the floor, recording at 1200 Hz. JPS was measured while seated via a digital inclinometer strapped to the tibia; participants were asked to replicate an angle of 15° of knee flexion with their eyes closed. Quadriceps PT was measured with isometric knee extensor muscle strength on a Humac isokinetic dynamometer (CSM, Stoughton, MA) with the knee and hip flexed to 90° . Limb symmetry indices (LSI) were calculated for PT and GRF. A multiple regression model was used with backward selection to enter predictor variables.

RESULTS: Twenty-nine cadets (14 female, 15 male; mean $\pm$ SD age, 20 ± 1.8 years; 20 ± 9 months from surgery) participated in the study. The mean ACL-RSI score was 58.5 ± 19.9 , TSK-11 score was 19.8 ± 4.6 , quadriceps

PT LSI $80.6\% \pm 20.9\%$, landing GRF $94.0\% \pm 26.7\%$, and JPS deviation $2.1^\circ \pm 2.0^\circ$. The ACL-RSI score statistically significantly predicted quadriceps PT ($R^2 = 0.40$, $P < .001$). There were small, statistically significant correlations between days post ACLR ($r = 0.42$, $P = .013$), TSK-11 ($r = -0.42$, $P = .012$) scores on LSI of peak force in quadriceps strength. The TSK-11, ACL-RSI, and time since surgery were not able to predict either landing GRF or JPS deviation.

CONCLUSIONS: Larger ACL-RSI scores accounted for 40.4% of the variance of LSI of peak knee extensor torque indicating that a greater positive psychological outlook may be correlated with improved LSIs of quadriceps strength from 10 to 38 months post ACLR.

CLINICAL RELEVANCE: Even at 1 to 3 years following an ACLR, individuals with greater psychological scores on the ACL-RSI exhibit superior quadriceps strength limb symmetry. Therefore, a multidisciplinary model may be beneficial to a service member's rehabilitation following ACLR to address psychological factors, which may decrease their ability to RTD.

SPL8

GLENOHUMERAL JOINT ROTATIONAL RANGE-OF-MOTION CHARACTERISTICS AND INJURY PATTERNS IN A DIVISION I MEN'S GYMNASTICS TEAM

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PURPOSE/HYPOTHESIS: Sufficient glenohumeral (GH) range of motion (ROM) is critical to overhead performance. Changes in GH external (ER) and internal rotation (IR) across competition periods have been reported in overhead athletes. There is relatively little literature reporting on the ROM characteristics and injury patterns of male gymnasts. Our purpose was to describe the GH rotational ROM and injury patterns in a team of Division I Men's Gymnasts throughout a competitive season. We hypothesize there will be a significant difference in GH ER and IR between pre and postseason measurements.

NUMBER OF SUBJECTS: Nine NCAA Division I men's gymnasts.

MATERIALS AND METHODS: Passive GH ER and IR was collected before and after the competition season with a standard goniometer by the team's athletic trainer (AT). The total arc of motion was also calculated (ER+IR). To account for the bilateral nature of gymnastics, measurements for dominant and nondominant shoulders were treated independently ($n = 18$). Injury history and in-season injuries requiring medical evaluation were documented by the AT. Descriptive statistics were used to summarize injury incidences. Paired t tests were used to compare the average ER, IR, and total arc of motion between pre- and post-season time points ($P < .05$).

RESULTS: Eight of 9 gymnasts sustained an injury requiring medical evaluation over the 16-week competition season. Of those injured, 5 athletes sustained an upper extremity injury, while 5 sustained a lower extremity injury. The most commonly injured upper extremity region was the shoulder complex. Four of the 5 athletes who reported a prior upper extremity injury sustained an upper extremity injury during the season. There was not a significant difference in ER (pre, $87.3^\circ \pm 11.8^\circ$; post, $90.2^\circ \pm 10.2^\circ$; $P = .15$), IR (pre, $66.9^\circ \pm 10.4^\circ$; post, $65.9^\circ \pm 7.7^\circ$; $P = .48$), or total arc of motion (pre, $154.0^\circ \pm 13.0^\circ$; post, $156.0^\circ \pm 12.2^\circ$; $P = .35$) between time points.

CONCLUSIONS: Across the 16-week competition season, we observed a high seasonal injury incidence of both upper and lower extremity injuries on this Division I male gymnastics team. The shoulder and knee were the most commonly injured body regions. Of those who sustained an in-season injury, the majority reported a previous injury to that body region. Similar to the few studies that exist of male gymnastics injury patterns, reinjury incidence is high in competitive gymnastics. The gymnasts in our sample possessed less IR than ER, a common finding in overhead athletes. However, there was not a significant change in rotational ROM across the competition season. Future prospective studies are needed to determine if GH ROM limitations are a factor in upper extremity injury development in male gymnasts.

CLINICAL RELEVANCE: There is relatively little literature reporting on the injury incidence and ROM characteristics of competitive male gymnasts. As suggested for other overhead athletes where associations between ROM

deficiencies and injury have been demonstrated, such as baseball pitchers, clinicians should also consider assessing and addressing ROM deficiencies in male gymnasts.

SPL9

QUADRICEPS PERFORMANCE AT 3 MONTHS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IS ASSOCIATED WITH RUNNING BIOMECHANICS AT 1 YEAR IN COLLEGIATE ATHLETES

Andrew Michael Broderick, Daniel Garrett Cobian, Keith Alan Knurr, Bryan C. Heiderscheit

PURPOSE/HYPOTHESIS: Quadriceps neuromuscular impairments are universal following anterior cruciate ligament reconstruction (ACLR) and are associated with abnormal movement mechanics, worse patient-reported outcomes, and increased reinjury risk. Early postoperative quadriceps function is associated with better patient-reported outcomes up to 2 years post ACLR; however, the relationship between early quadriceps performance and running biomechanics remains unknown. The purpose of this study was to determine how quadriceps performance symmetry at 3 months post ACLR relates to knee biomechanics symmetry during running at 1 year post surgery.

NUMBER OF SUBJECTS: Sixteen Division I athletes (7 female; mean $\pm$ SD age, 20.3 ± 1.2 years; BMI, 25.7 ± 3.7 kg/m²) who underwent unilateral ACLR.

MATERIALS AND METHODS: At 3.4 ± 0.7 months (3 months) post ACLR, quadriceps performance was assessed using ramp maximal voluntary isometric contractions (MVIC) and rapid voluntary isometric rate of torque development (RTD) trials with the knee in 90° flexion. Peak knee extensor torque (PT) and torque steadiness (TS) were obtained from MVIC trials. TS was calculated as the mean difference between the raw torque signal and low pass filtered torque signal (2-Hz cutoff) within a 4s window and expressed as a percentage of PT. RTD was calculated as the slope from 20% to 80% of peak torque during the rapid effort trials. At 11.2 ± 1.6 months (1 year) post ACLR, knee biomechanics during running at 4.08 ± 0.5 m/s were obtained. Peak knee extensor moment (PKEM), rate of knee extensor moment (RKEM), and peak knee flexion angle (PKF) of each limb were computed. Limb symmetry indices (LSI) were calculated for all variables. Multivariable regression models were constructed using 3-month PT, RTD, and TS symmetry as predictors of 1-year knee symmetry during running and reported as R^2 with associated P values.

RESULTS: Quadriceps performance symmetry at 3 months was significantly associated with running PKF ($P = .04$, $R^2 = 0.39$), PKEM ($P = .04$, $R^2 = 0.39$), and RKEM ($P = .03$, $R^2 = 0.43$) symmetry 1 year post ACLR. Including RTD in the model did not alter the observed associations. PT and TS symmetry explained approximately 40% of the variance in knee symmetry during running.

CONCLUSIONS: A weak to moderate association was observed between 3-month quadriceps performance symmetry at 3 months and knee biomechanics symmetry during running at 1 year in Division I collegiate athletes post ACLR.

CLINICAL RELEVANCE: Earlier resolution of quadriceps performance symmetry post ACLR may improve knee symmetry during running near the time of return to sport in competitive athletes. Rehabilitation interventions should aim to prioritize quadriceps performance within 3 months post surgery.

SPL10

ROTATOR CUFF STRENGTH IS NOT AUGMENTED BY BLOOD FLOW RESTRICTION TRAINING

Jason Brumitt, Marcey Keefer Hutchison, Daniel Chang Yun Kang

PURPOSE/HYPOTHESIS: Blood flow restriction (BFR) training utilizes a tourniquet applied to the upper or lower extremities (UE or LE) to occlude blood flow while exercising. BFR allows one to train at a lower load while achieving the benefits (eg, increased strength and size) that are observed when training at a higher load. Increases in strength and size have been observed in muscles distal to tourniquet application; in addition, gains have also been observed in muscles proximal to the occlusion cuff. Three studies have evaluated the ability of BFR to augment strength of the ro-

tator cuff with mixed results. Common features of these prior studies included a randomized controlled trial design, proximal UE tourniquet application, training frequency 2 times per week for 8 weeks, training loads 20% to 30% 1RM, and similar training volumes. All 3 studies have reported no between group differences in shoulder ER strength and 2 studies reported no between group differences in scaption (ie, supraspinatus) strength. One study reported a significantly greater increase in shoulder internal rotation strength. Strength gains in muscles proximal to tourniquet application appears possible; however, the best approach to augment strength gains in the rotator cuff is currently unknown. Prior research has demonstrated systemic effects, including a greater growth hormone response, when BFR is applied to the LE. The purpose of this study was to evaluate the ability of BFR, when applied to a LE, to augment strength gains in the rotator cuff.

NUMBER OF SUBJECTS: Thirty-five healthy untrained subjects (mean $\pm$ SD age, 23.5 $\pm$ 2.9 years).

MATERIALS AND METHODS: This trial was registered with ClinicalTrials.gov (NCT04596020). Subjects were randomized to the BFR or non-BFR groups. Pretests/posttests included the collection of sonographic images of the rectus femoris and strength measurements using a handheld dynamometer (MicroFET 2; Hoggan Scientific, Salt Lake City, UT) by coinvestigators blinded to group allocation. The test-retest reliability for MMT was established a priori and excellent (>0.9). 1RM testing was performed during the pretest period for each exercise with training loads set at 30% 1RM. The training program was performed twice a week for 8 weeks with LE exercises (single-leg knee extension and standing single leg curl; 4 sets each [reps 30, 15, 15, 15]) performed first, with or without BFR (LOP, 80%). Next the scaption and sidelying ER exercises (3 sets by 15 reps) were performed without BFR.

RESULTS: Subjects in both groups achieved statistically significant gains in supraspinatus, shoulder ER, quadriceps, and hamstrings strength ($P < .001$). There were no between group differences for strength. There was no within group or between group differences in rectus femoris CSA.

CONCLUSIONS: Rotator cuff strength was not augmented in this randomized controlled trial utilizing a LE BFR protocol. Future studies should manipulate 1 or more of the following variables: LOP, number of exercises performed under occlusion, and the number of training sessions.

CLINICAL RELEVANCE: This study, as well as prior studies, demonstrate a clinical challenge associated with using BFR to augment rotator cuff strength.

SPL11

THE IMPACT OF SEX DIFFERENCES AND PSYCHOLOGICAL RESPONSE ON PHYSICAL ACTIVITY FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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

PURPOSE/HYPOTHESIS: Research indicates that physical activity (PA) progressively decreases in the years after anterior cruciate ligament reconstruction (ACLR), particularly among young female athletes. The contribution of psychological factors to this decline in PA is unknown. The purpose of this study was to test the hypotheses that (1) athletes with a higher psychological response years after ACLR would demonstrate higher PA, and that (2) females would demonstrate lower psychological response and PA levels compared to males.

NUMBER OF SUBJECTS: Forty-seven participants (68% female; mean $\pm$ SD age, 23.3 $\pm$ 4.5 years; 16.1 $\pm$ 2.6 years old at the time of RTS) initially enrolled in a large cross-sectional cohort study were recruited for this follow-up analysis at 8.5 $\pm$ 3.1 years post ACLR.

MATERIALS AND METHODS: Participants completed a series of online questionnaires for the measurement of PA and psychological impact of ACLR (8.5 $\pm$ 3.1 years post ACLR). Moderate-to-vigorous physical activity (MVPA; MET-minutes/week) was quantified through the International Physical Activity Questionnaire (IPAQ) Short Form. Psychological impact of ACLR was measured using the Anterior Cruciate Ligament Return to Sport After Injury (ACL-RSI) scale, Self-Perception Profile (SPP) Athletic Competence subscale, Brief Resilience Scale (BRS), and the Knee Activity Self-Efficacy Questionnaire (KASE). Hypotheses were

evaluated with linear regression modeling and independent-samples t tests ($P \leq .05$).

RESULTS: There were no differences in age or time from ACLR to testing between males and females ($P > .05$). Females reported significantly less MVPA compared to males ($P = .036$; mean $\pm$ SD male, 6840.0 $\pm$ 6039.8 MET-min/wk; female, 3702.5 $\pm$ 3857.2 MET-min/wk) and lower ACL-RSI scores ($P = .007$; mean $\pm$ SD male, 89.1 $\pm$ 11.3; female, 67.9 $\pm$ 27.8). The SPP, BRS, and KASE scores were not different between sexes ($P = .355$, $P = .964$, and $P = .142$, respectively). ACL-RSI was the only psychological response predictor of MVPA ($\beta = 63.68$, $P = .020$). A 1-point increase in ACL-RSI score was associated with 63.68 additional MET-minutes/week of MVPA. ACL-RSI subscales were compared between sexes, with females reporting lower values on the Emotions ($P = .03$; mean $\pm$ SD male, 90.0 $\pm$ 13.2; female, 65.1 $\pm$ 306), Confidence ($P = .03$; mean $\pm$ SD male, 89.6 $\pm$ 11.0; female, 70.5 $\pm$ 27.1), and Risk appraisal ($P = .03$; mean $\pm$ SD male, 85.3 $\pm$ 14.1; female, 68.8 $\pm$ 29.9) subscales.

CONCLUSIONS: In accordance with our hypothesis, a more positive psychological response in the years after ACLR was associated with higher MVPA. However, ACL-RSI was the only psychological response measure associated with PA. Further, females demonstrated significantly lower ACL-RSI scores and less MVPA compared to males.

CLINICAL RELEVANCE: Female athletes may benefit from rehabilitation interventions that address psychological response and the importance of PA engagement in order to optimize PA behavior following the completion of formalized clinical care. While investigation with larger sample sizes is needed, this work highlights the impact of psychological responses on PA after ACLR, which may have significant impact on long term health outcomes.

SPL12

INITIAL LOWER EXTREMITY AND TRUNK INJURIES INCREASE RISK OF SUBSEQUENT ARM INJURIES IN BASEBALL PITCHERS

Garrett Scott Bullock, Charles Thigpen, Thomas Noonan, Michael Kissenberth, Ellen Shanley

PURPOSE/HYPOTHESIS: (1) To investigate the relationship between initial trunk or lower extremity injury and subsequent arm injury; and (2) to investigate the relationship between initial shoulder or elbow injury and subsequent arm injury.

NUMBER OF SUBJECTS: Two hundred ninety-seven Minor League Baseball (MiLB) pitchers.

MATERIALS AND METHODS: A 7-year prospective injury risk study was conducted with MiLB pitchers. Pitches, athlete exposures (AE), and arm injuries (1-day time loss) were collected. An injury was considered initial when it was the first injury, and until the pitcher had fully recovered and been cleared by the sports medicine team to return to competition for at least 1 game. A subsequent injury was defined as an injury to a body part following initial injury. At a $\beta = 0.80$, $\alpha = .05$, a follow-up time of 7 months, and an injury rate of 30% from preliminary data from 2012, a total of 290 pitchers were required to perform a Cox Survival analysis. Cox survival analyses with 95% confidence intervals (95% CIs), risk ratio (RR), and risk difference (RD) were performed. Confounders controlled for included: Age, body mass index, arm dominance, seasonal pitch load, number of pitching appearances, and previous arm injury. Sensitivity Cox analyses included only moderate or severe lower extremity or trunk injuries and only moderate or severe initial arm injuries.

RESULTS: Two hundred ninety-seven pitchers participated (total player days, 85270). Arm injury incidence was 11.4 arm injuries/10 000 AEs and lower extremity and trunk injury incidence was 5.2 injuries/10 000 AEs. Pitchers that sustained a lower extremity or trunk injury demonstrated a greater hazard (2.6; 95% CI: 1.2, 5.6; $P = .019$) of sustaining an arm injury. Pitchers that sustained an initial shoulder injury demonstrated greater hazard (9.3; 95% CI: 1.1, 83; $P = .047$) of sustaining a subsequent shoulder or elbow injury compared to pitchers that sustained an initial elbow injury. Pitchers that sustained a lower extremity or trunk injury demonstrated no difference in subsequent arm injury risk (RR = 1.1; 95% CI: 0.9, 1.2; RD, 3.0; 95% CI: -9.7, 15.6). Pitchers that sustained an initial shoulder injury demonstrated increased risk

(RR = 4.3; 95% CI: 1.1, 17.4; RD, 19.7; 95% CI: 6.1, 33.3). Sensitivity analyses demonstrated similar results.

CONCLUSIONS: The incorporation of time and exposure demonstrated an increased subsequent arm injury risk in pitchers that sustained an initial lower extremity or trunk injury. Pitchers that sustained an initial shoulder injury demonstrated a greater risk and hazard of sustaining a subsequent arm injury, compared to pitchers that sustained an initial elbow injury. However, this secondary analysis should be interpreted with caution.

CLINICAL RELEVANCE: While absolute subsequent arm injury risk is similar following a lower extremity or trunk injury, clinicians should monitor risk with workload accumulation, which may be related to pitching compensatory strategies in a fatigued state. Pitchers that sustain a shoulder injury should be evaluated and perform both shoulder and elbow rehabilitation strategies prior to return to sport.

SPL13

USES OF HEALTH CARE SYSTEM MEDICAL SERVICES BY ATHLETES AFTER INJURY AT THE HIGH SCHOOL LEVEL

Garrett Scott Bullock, John M. Mobley, John M. Brooks, Gil Gilliland, Michael Kissenberth, Ellen Shanley

PURPOSE/HYPOTHESIS: Prior studies have shown decreased health care utilization and an increased likelihood of seeking emergency room services rather than primary care consultations for health concerns among lower socioeconomic (SES) populations. However, these studies are largely reported on adult populations for a variety of medical conditions. Access, utilization, and timeliness of referred health care services in schools with full-time athletic trainers and physicians has yet to be explored within public health. Additionally, there is little understanding how athletes from different SES schools utilize outside health care services when provided with similar sports medicine care and hours. The purpose of this study was to describe and compare injuries and health care service utilization by school SES over 1 full academic year. It is hypothesized that athletes at lower SES high schools will use a lower ratio of health care services compared to athletes from higher SES high schools.

NUMBER OF SUBJECTS: Seven thousand three hundred ninety-three high school athletes.

MATERIALS AND METHODS: A previously validated injury and health care service process prospectively collected data from 1 large school district. The school district provides full-time sports medicine care for each high school. Per federal guidelines, percentage of free and reduced lunch (FRPL) for each school was calculated to stratify schools into high (<50% FRPL) and low ($\geq 50.1\%$ FRPL) SES groups. Missing data were <1%, complete case analyses were performed. Healthcare services performed outside the school district were <1%. Incidence proportion with 95% confidence intervals for injury and health care service utilization were calculated. Incidence proportion ratios and hierarchical relative risk models were performed to assess potential differences in injuries and health care service utilization between athletes from high and low SES schools. Confounders included school, age, sex, and sport.

RESULTS: One thousand seven hundred fifty-six injuries were reported among in 7393 participating athletes from 14 high schools. Similar injury incidence proportions were reported between high and low SES schools (1.1; 95% CI: 1.0, 1.2). Athletes from low SES schools were 2.0 (95% CI: 1.2, 3.4) and 3.4 (95% CI: 1.8, 6.6) more likely to receive emergency and physical therapy care compared to athletes from high SES schools. School SES status was not associated with the use of physician 1.0 (0.9, 95% CI: 1.2), imaging 1.2; 95% CI: 0.8, 1.9), or surgery services (1.5; 95% CI: 0.9, 2.4).

CONCLUSIONS: Students at lower SES schools were more likely to utilize emergency department and physical therapy services compared to athletes at higher SES schools. Understanding factors influencing health care services choice and usage by student athletes from different SES backgrounds may assist sport medicine clinicians in identifying and ultimately dismantling barriers in improving time to health restoration, athlete outcomes, and health care monetary burden.

CLINICAL RELEVANCE: At the initial injury and health care referral, sports medicine clinicians should enquire about the athlete's potential physician and physical therapy choices, and how they can affect their return to sport.

SPL14

QUALITY OF MOVEMENT MAY BE AN IMPORTANT RISK FACTOR IN ADOLESCENTS FOR SECOND ANTERIOR CRUCIATE LIGAMENT INJURY

Lauren Schlacht Butler, Alexa Rae Martinez, Apeksha Gupta, Kristin Hayden

PURPOSE/HYPOTHESIS: Young active patients have a high risk of anterior cruciate ligament (ACL) reinjury. Return to sport tests are commonly performed in physical therapy to aid with return to sport decision making, but often lack qualitative assessments and validation. The purpose of this study was to explore the association between return to sport test battery characteristics as risk factors for second ACL injury in adolescents.

NUMBER OF SUBJECTS: Seventy-seven adolescent patients who underwent primary ACL reconstruction between 2014 and 2018 (55 male; mean $\pm$ SD age at surgery, 16 ± 2 years; BMI, 25 ± 5 kg/m²).

MATERIALS AND METHODS: A retrospective chart review was conducted. Demographics, sport history, surgery, and outcomes documented during the physical therapy ACL return to sport test were extracted from medical records. All variables were analyzed descriptively. For categorical variables, frequency and proportion were reported and chi-square or Fisher's exact test was used to assess differences between "no second ACL injury" and "second ACL injury" groups. For continuous variables, median and interquartile range were reported and Wilcoxon rank sum test was used to assess differences between "no second ACL injury" and "second ACL injury" groups.

RESULTS: Of the patients, 14.2% (n = 11) suffered a second ACL injury, with 81.8% males compared to 18.2% females (n = 9 and n = 2, respectively). Median Tegner score in both groups was 7 (IQR, 7-9). Median time to RTS clearance was significantly different between the no second ACL injury and second ACL injury groups (10; IQR, 8-12 versus 8; IQR, 8-9 months; $P = .017$). Overall, 66.2% of patients passed the return to sport test (no second ACL, 66.7% [n = 44] versus second ACL injury, 63.6% [n = 7]). The second injury group performed the 6 inch lateral step down test on the involved limb with significantly less limb unsteadiness compared to the no second injury group (n = 0 versus n = 21, $P = .030$). The second injury group demonstrated greater loss of pelvic plane control during the triple hop for distance (THD) on the involved limb compared to the no second injury group (n = 21 versus n = 1, $P = .052$). There was a significant difference in performance of the 45° sidestep cut between groups on the uninvolved limb with a mean of 1 error in the no second ACL injury group compared to a mean of 2 errors in the second ACL injury group ($P = .041$).

CONCLUSIONS: Patients who suffered a second ACL injury performed the 6-inch lateral step-down with less unsteadiness, demonstrated poorer pelvic plane control during the THD, and poorer performance on the 45° sidestep cut on the involved limb.

CLINICAL RELEVANCE: This study suggests that quality of movement may be an important component to evaluate when making return to sport decisions after ACLR.

SPL15

DEVELOPMENT AND RELIABILITY OF A GAZE-CONTROLLED VISUAL COGNITIVE REACTIVE TRIPLE HOP TEST

Meredith Chaput, Byrnadeen T. Farrage, Janet E. Simon, HoWon Kim, Scott M. Monfort, Dustin Robert Grooms

PURPOSE/HYPOTHESIS: Evidence suggests visual-cognitive function is associated with lower extremity injury risk biomechanics. Traditional return to sport assessments emphasize physical performance and lack ecological validity to assay visual-cognitive demands of sport. Previously developed neurocognitive hop tests challenge isolated constructs of visual processing. However, multidomain visual (visual attention and memory) and cognitive processing (response inhibition) is needed to navigate sport environments. Therefore, the purpose was to develop and determine the reliability of a new gaze controlled triple hop test that better simulates on-line visual-cognitive processing in sports participation.

NUMBER OF SUBJECTS: Twenty-one healthy participants (11 female; mean $\pm$ SD age, 23.5 ± 3.7 years; height, 172.9 ± 11.9 cm; weight, 73.0 ± 16.8 kg; Tegner, 5.5 ± 1.1) were recruited. Leg dominance was determined as preferred leg to kick a ball.

MATERIALS AND METHODS: The Visual-Cognitive Reactive Triple Hop (VCR) was developed to challenge peripheral visual attention with response inhibition to a go-no/go stimulus for hop initiation. Gaze was controlled via a central visual memory task to minimize using vision to compensate for stability while hopping. The VCR is a functional assessment measuring physical performance (hop distance), cognitive performance (reaction time), and visual-memory (3 colors appear on the central stimulus while hopping) during a linear triple hop. Participants completed 2 practice trials on their dominant leg followed by 3 trials of the traditional triple hop and the VCR. The maximum of the 3 trials for each task was used for analyses. Testing sessions were separated by 10 to 14 days to determine reliability. Reliability was assessed by calculating intraclass correlation coefficients (ICC) with 95% confidence intervals and standard error of the measurement (SEM). Additionally, a paired sample *t* test was used to determine if there were differences between testing conditions (traditional versus VCR); alpha was set at .05.

RESULTS: Excellent reliability was exhibited for the traditional triple hop distance (ICC_{2,1} = 0.96; 95% CI: 0.91, 0.99; SEM, 16.99 cm) and VCR (ICC_{2,1} = 0.92; 95% CI: 0.82, 0.97; SEM, 24.10 cm), and moderate reliability for the VCR reaction time (ICC_{2,1} = 0.62; 95% CI: 0.09, 0.84; SEM, 0.09 seconds) outcomes. On average, the VCR resulted in a deficit of -8.17% for the distance hopped (36.4 ± 5.1 cm, *P* < .05, *d* = 0.55).

CONCLUSIONS: The test-retest reliability of the VCR is moderate to excellent and results in a significant physical performance deficit when compared to performance on a traditional triple hop.

CLINICAL RELEVANCE: After anterior cruciate ligament reconstruction (ACLR), patients demonstrate increased brain connectivity in regions responsible for visual-cognitive processing and might uniquely engage in visual-attention neural resources to preserve functional performance. Our current data provide evidence to support that peripheral visual attention, response inhibition, and central gaze visual memory can be reliably challenged in a single performance assessment. Development of such assessments is warranted to simulate the visual-cognitive demands of sport in clinic-based tests.

SPL16

WHAT ARE THE RISK FACTORS ASSOCIATED WITH PAIN IN POSTPARTUM RUNNERS?

Shefali Mathur Christopher, Suzanne Snodgrass, Chad Edward Cook

PURPOSE/HYPOTHESIS: The purpose of this study was to identify risk factors associated with running-related pain in postpartum runners with and without pain. This study also aimed to understand the compounding effects of multiple associative risk factors by developing a clinical decision tool to identify postpartum runners at higher risk for pain.

NUMBER OF SUBJECTS: Five hundred thirty-eight postpartum runners.

MATERIALS AND METHODS: Postpartum runners who ran once a week with at least 1 child ≤36 months and postpartum runners unable to run because of pain, but identified as runners, were surveyed. Running variables (mileage, time to first postpartum run), postpartum variables (delivery type, breastfeeding, incontinence, sleep, fatigue, depression), and demographic information were collected. Risk factors for running-related pain were analyzed in bivariate regression models. Variables meeting criteria (*P* < .15) were entered into a multivariate logistic regression model to create a clinical decision tool. The tool identified compounding factors that increased the probability of having running-related pain after childbirth.

RESULTS: Eleven variables were included in the multivariate model with 6 retained in the clinical decision tool: runner type-novice (OR = 3.51; 95% CI: 1.65, 7.48), postpartum accumulated fatigue score of >19 (OR = 2.48; 95% CI: 1.44, 4.28), previous running injury (OR = 1.95; 95% CI: 1.31, 2.91), vaginal delivery (OR = 1.63; 95% CI: 1.06, 2.50), incontinence (OR = 1.95; 95% CI: 1.31, 2.84), and <6.8 hours of sleep on average per night (OR = 1.89; 95% CI: 1.28, 2.78). Having ≥4 risk factors increased the probability of having running-related pain to 61.2%.

CONCLUSIONS: Postpartum runners are reporting pain when running; however, there are no studies exploring this pain. This study provides a deeper understanding of the risk factors for running-related pain in postpartum

runners. Future longitudinal studies that follow asymptomatic postpartum women returning to running after childbirth over time should be performed to validate these findings.

CLINICAL RELEVANCE: Studies have reported that women are initiating or returning to running after childbirth with up to 80% reporting pain. There are no studies exploring running-related pain or risk factors for this pain after childbirth in runners. Postpartum runners have a variety of biomechanical, musculoskeletal, and physiologic impairments from which to recover from when returning to high-impact sports like running, which could influence initiating or returning to running. With this information, clinicians can monitor and educate postpartum runners initiating or returning to running. Education could include details of risk factors, combinations of factors for pain and strategies to mitigate risks. Coaches can adapt running workload accounting for fatigue and sleep fluctuations to optimize recovery and performance.

SPL17

PREINJURY COUNTERMOVEMENT JUMP KINETICS ARE NOT RESTORED 2 YEARS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN COLLEGIATE ATHLETES

Daniel Garrett Cobian, Kurtis Rayfield, Jennifer L. Sanfilippo, Mikel Renee Joachim, Bryan C. Heiderscheit

PURPOSE/HYPOTHESIS: Abnormal lower extremity (LE) biomechanics are common following anterior cruciate ligament reconstruction (ACLR). The uninjured (UN) limb is typically used as a reference for involved (INV) limb assessments but may overestimate recovery as bilateral deficits occur after ACL injury. Preinjury (PRE) data from individuals who later undergo ACLR is rare, but may provide unique insight into post surgical changes of both limbs. The purpose of this study was to assess changes in countermovement jump (CMJ) performance from PRE through 2 years post ACLR in collegiate athletes.

NUMBER OF SUBJECTS: Twenty-five NCAA Division I athletes (10 female; mean ± SD age, 20.4 ± 1.3 years; BMI, 26.7 ± 4.0 kg/m²).

MATERIALS AND METHODS: Athletes performed maximal CMJs on a force plate PRE and 4, 6, 8, 12, 18, and 24 months (4M, 6M, 8M, 12M, 18M, 24M) post ACLR. PRE assessments were part of a standard preseason evaluation. Force signals were sampled at 800 Hz. Jump height, eccentric (ECC_{PF}), concentric (CON_{PF}), and landing phase (LAND_{PF}) peak force and ECC rate of force development (ECC_{RFD}) were computed from the force time-series. Linear mixed models assessed changes in CMJ kinetics from PRE by limb and limb-by-time interactions. Least-square mean differences ± standard errors are reported.

RESULTS: All athletes completed PRE assessments at 2.1 ± 1.3 months prior to injury. Post ACLR, 20, 15, 20, 14, 9, and 7 athletes completed testing at 4M, 6M, 8M, 12M, 18M, and 24M, respectively. Compared to PRE, CMJ height was significantly decreased at 4M (PRE, 38.7 cm; 4M, 30.8 cm; *P* < .01). INV limb performance was significantly reduced (*P* < .04) from PRE for ECC_{PF} (PRE, 11.1 ± 0.3 N/kg; 4M, 8.2 ± 0.4 N/kg; 6M, 9.3 ± 0.4 N/kg; 8M, 9.7 ± 0.4 N/kg; 12M, 10.1 ± 0.4 N/kg), CON_{PF} (PRE, 12.2 ± 0.3 N/kg; 4M, 9.8 ± 0.3 N/kg; 6M, 10.4 ± 0.3 N/kg; 8M, 10.7 ± 0.3 N/kg; 12M, 11.2 ± 0.3 N/kg; 18M, 11.4 ± 0.4 N/kg), LAND_{PF} (PRE, 26.1 ± 1.6 N/kg; 4M, 15.4 ± 1.7 N/kg; 6M, 18.8 ± 1.8 N/kg; 8M, 21.6 ± 1.7 N/kg; 12M, 23.0 ± 1.8 N/kg; 18M, 20.3 ± 2.0 N/kg; 24M, 21.8 ± 2.1 N/kg), and ECC_{RFD} (PRE, 37.5 ± 3.3 N/s/kg; 4M, 17.7 ± 3.5 N/s/kg; 6M, 22.2 ± 3.8 N/s/kg; 8M, 25.5 ± 3.5 N/s/kg; 12M, 27.4 ± 3.8 N/s/kg; 18M, 28.7 ± 4.4 N/s/kg). Compared to PRE, decreased (*P* < .05) UN limb ECC_{RFD} (PRE, 37.3 ± 3.3 N/s/kg; 4M, 26.4 ± 3.5 N/s/kg; 6M, 30.3 ± 3.8 N/s/kg) and LAND_{PF} (PRE, 26.4 ± 1.6 N/kg; 12M, 23.4 ± 1.8 N/kg; 18M, 22.0 ± 2.0 N/kg; 24M, 22.1 ± 2.1 N/kg) were observed. Significantly increased UN limb CON_{PF} was found at 4M (12.6 ± 0.3 N/kg) and 6M (12.5 ± 0.3 N/kg) compared to PRE (12.2 ± 0.3 N/kg).

CONCLUSIONS: CMJ height is restored by 6 months post ACLR, but kinetic abnormalities of both limbs are detected up to 2 years post ACLR. CMJ ECC and CON phase INV limb performance reach PRE levels by 2 years post ACLR, but interestingly, a persistent reduction in LAND_{PF} of both limbs is observed.

CLINICAL RELEVANCE: Characterizing CMJ performance only by height ignores CMJ biomechanic abnormalities that persist beyond the typical

time frame for return to sport. Collegiate athletes post ACLR may develop adaptive CMJ landing strategies to reduce impact forces bilaterally. It is unclear if this represents a training effect to mitigate reinjury risk or a biopsychological response to ACLR.

SPL18

DOES HANDHELD DYNAMOMETRY CORRELATE WITH BIODEx AND NORDBORD WHEN MEASURING ECCENTRIC HAMSTRING STRENGTH?

William Purifoy Cooner, Mary C. Hannah, Srikanti Vallabhajosula, Shefali Mathur Christopher

PURPOSE/HYPOTHESIS: Multiple devices are currently used to objectively measure hamstring strength including isokinetic dynamometry (IKD), the NordBord (NB), and handheld dynamometry (HHD) which, due to cost and ease of use, is the most clinician friendly. Previous studies have compared hamstring strength between the HHD and either NB or IKD, but comparisons were made between isometric HHD versus isometric IKD and NB in 1 study and between eccentric HHD versus concentric IKD in other study. Comparing hamstring muscle strength in the same contraction type (eccentric) with all 3 devices may bring more clarity to the correlation between these assessment methods. Therefore, the aim of this study was to investigate the correlation between eccentric hamstring strength measured using HHD compared to IKD and NB. We hypothesize that the HHD will have moderate correlation with IKD and NB.

NUMBER OF SUBJECTS: Thirty-two first-year collegiate athletes participated in the study during the first 2 weeks of preseason training.

MATERIALS AND METHODS: Each subject completed eccentric hamstring muscle strength testing on a single day in a random order using an HHD, IKD (30°/s), and the NB. Average or peak torque was calculated for each measurement. Comparison was made between the torque of same limb using each measurement device. Data were analyzed using intraclass correlation coefficients to determine agreement.

RESULTS: The measurement of eccentric hamstring strength using HHD compared with NB eccentric strength had moderate agreement (left ICC = 0.735, right ICC = 0.658). Agreement between the HHD and IKD was poor to moderate (left ICC = 0.495, right ICC = 0.741). Finally, the level of agreement for the NB compared to IKD eccentric strength was moderate (left ICC = 0.655, right ICC = 0.611).

CONCLUSIONS: Assessing hamstring strength across all 3 devices eccentrically shows moderate correlation which was similar to results of previous studies comparing strength with different devices using different types of contractions.

CLINICAL RELEVANCE: Hamstring strength is commonly measured when rehabilitating an athlete from a hamstring strain. Measuring eccentric strength may be valuable in the return to play decision-making process and for predicting risk of hamstring injury. Isokinetic dynamometry is considered the gold standard for muscle strength assessment, and recently the NordBord has become a more common method to test eccentric hamstrings strength. While less expensive and more clinic-friendly, the torque measured by HHD only has moderate correlation with NB and IKD.

SPL19

EARLY QUADRICEPS STRENGTH AND SINGLE-LEG HOP KINEMATICS AT RETURN TO SPORT AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Nicholas Duke, Staci Thomas, Matthew P. Ithurburn, Laura C. Schmitt, Mark Vincent Paterno

PURPOSE/HYPOTHESIS: The importance of early return of quadriceps femoris (QF) strength after anterior cruciate ligament reconstruction (ACLR) is well documented. However, the relationship between early return of QF strength and movement quality at RTS, a potential risk factor for future injury, is unknown. The purpose of this study was to examine the relationship between early return of QF strength after ACLR and single leg hop biomechanics at the time of RTS. The tested hypothesis was that patients with higher early QF strength would demonstrate more optimal landing patterns at RTS.

NUMBER OF SUBJECTS: Twenty-nine patients post ACLR (19 female; mean $\pm$ SD age, 17.8 $\pm$ 3.8 years).

MATERIALS AND METHODS: Isokinetic QF strength was tested 3 months post ACLR at 180°/s. The quadriceps index (QI) was calculated by dividing the involved limb value by the uninvolved limb $\times$ 100. Patients were then divided into 2 groups: low quadriceps (LEQ <90%) and high quadriceps (HEQ $\geq$ 90%). When patients received medical release to RTS, 3-D motion analysis was conducted during the landing phase of a single-leg hop (SLH) for distance. Demographic data and sagittal-plane trunk, hip, and knee landing kinematic data during the SLH for distance were compared between groups using independent-samples *t* tests. Paired-samples *t* tests were used to compare limb asymmetries in landing kinematics.

RESULTS: LEQ and HEQ groups included 23 and 6 patients, respectively. No significant differences were found in age, weight, or time to RTS between groups ($P > .05$). The LEQ group was significantly taller (172.0 $\pm$ 8.0 cm) than the HEQ group (163.6 $\pm$ 2.0 cm) ($P = .02$). Peak trunk flexion was significantly greater for the LEQ group (LEQ, 39.5 $\pm$ 11.1) compared to the HEQ group (HEQ, 25.6 $\pm$ 9; $P = .009$). Peak hip flexion was also found to be greater for the LEQ group (LEQ, 51.9 $\pm$ 10.5; HEQ, 42.2 $\pm$ 4.0; $P = .038$). No significant differences were found for peak knee flexion (LEQ, 54.1 $\pm$ 12.7; HEQ, 53.7 $\pm$ 12.4; $P = .80$) or distance hopped normalized to height (LEQ, 0.97 $\pm$ 0.12; HEQ, 0.88 $\pm$ 0.07; $P = .08$) between groups. There were no side-to-side differences noted in sagittal plane trunk ($P = .10$), hip ($P = .80$), or knee ($P = .15$) kinematics, regardless of group.

CONCLUSIONS: Patients at RTS after ACLR demonstrate different sagittal-plane landing mechanics related to the timing of QF strength return early in rehabilitation. Patients with high QF strength return at 3 months had less movement at their trunk and hip in the sagittal plane when landing from a SLH for distance, despite no difference in hop performance.

CLINICAL RELEVANCE: Examining the continuum of care after ACLR is important. This study found a relationship between early QF strength return and landing kinematics at RTS. Previous research has found a link between high-risk kinematics at RTS and second ACL injury. Developing treatments that bridge the gap between early QF strength and high-risk movement at RTS may help clinicians address risk factors during rehabilitation rather than only at the time of RTS.

SPL20

QUALITATIVE MOVEMENT ASSESSMENT DURING A SINGLE-LEG TRIPLE HOP: RELIABILITY AND LIMB PERFORMANCE

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BACKGROUND: Single-leg hop tests are commonly used to determine readiness for return to sport following anterior cruciate ligament reconstruction (ACLR). A common criticism of hop tests is their inability to account for quality of movement errors, which may be associated with increased risk of reinjury. The Qualitative Analysis of Single Leg Stance (QASLS) tool was originally developed to assess movement abnormalities during a single leg squat. QASLS scores can range from 0 to 10 with lower scores indicating better neuromuscular control. The utility of this tool for identifying quality of movement errors during single leg hopping has not been explored.

PURPOSE/HYPOTHESIS: To determine the inter and intrarater reliability of the QASLS tool for a single leg triple hop and explore if differences in reliability exist between novice and experienced clinicians. Secondary purpose was to determine if performance differences existed between limbs, or over time from 6 to 9 months postoperative.

NUMBER OF SUBJECTS: Twenty subjects (mean age, 16.5 years; 60% female).

MATERIALS AND METHODS: Subjects 10 to 24 years old and $\geq$ 6 months post ACLR were eligible for this study. Subjects were recorded performing a maximal effort single leg triple hop at 6 and 9 months postoperatively. Recordings were viewed individually by 2 board-certified sports clinical specialists, and 3 doctor of physical therapy students in their second year of education. All raters were trained in the use of the QASLS tool during a single online training session. Raters were blinded to surgical limb

and utilized the QASLS to rate the final landing of the triple hop task. Intraclass correlation coefficient (ICC) was calculated to measure reliability. Wilcoxon signed-rank test was utilized to assess QASLS scores between limbs at both time points, as well as intralimb change between time points.

RESULTS: The cumulative interrater reliability of the surgical limb was moderate (ICC = 0.703). Little difference was seen between experienced and novice raters with ICCs of 0.703 and 0.603, respectively. Intrarater reliability was better, with a cumulative ICC of 0.857. Experienced raters demonstrated slightly higher reliability (ICC = 0.891) than novice (ICC = 0.831). There were no differences between surgical and nonsurgical limb performance at 6 months (4.3 versus 4.7, $P = .48$) or 9 months (4.3 versus 3.2, $P = .155$). There were no differences in QASLS scores from 6 to 9 months in either the involved (4.30 versus 4.35, $P = .94$) nor uninvolved limbs (4.7 versus 3.2, $P = .11$).

CONCLUSIONS: Regardless of rater experience, the QASLS offers moderate to good interrater and intrarater reliability. Moderate QASLS scores indicate quality of movement errors existed within both limbs. No differences in QASLS score were observed between surgical or nonsurgical limbs, and scores did not improve over time.

CLINICAL RELEVANCE: Clinicians of all experience levels can reliably use the QASLS to assess quality of movement during a single leg triple hop. The lack of difference between limbs suggests movement errors may be present bilaterally and remain unchanged even in the later phases of rehabilitation.

SPL21

RELIABILITY OF A VISUAL-COGNITIVE MEDIAL HOP-FOR-DISTANCE TEST FOR RETURN-TO-SPORT TESTING

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PURPOSE/HYPOTHESIS: Sport participation requires athletes to engage in rapid visual-motor processing of their environment while simultaneously making movement decisions (run, cut, jump, etc). However, traditional return to sport (RTS) assessments primarily measure functional performance through a series of hopping tests (forward, side, crossover, etc). Recently, visual-cognitive tasks have been added to hop tests to better simulate the athletic setting, however there is limited focus on frontal plane movement. Therefore, the purpose of this study was to develop and evaluate the reliability of a new visual-cognitive medial side hop (VCMH) test that challenges physical and cognitive performance.

NUMBER OF SUBJECTS: Twenty-two healthy college students participated (11 female; mean $\pm$ SD age, 23.5 $\pm$ 3.64 years; height, 172.9 $\pm$ 11.58 cm; weight, 74.1 $\pm$ 17.25 kg; Tegner score, 5.6 $\pm$ 1.1). Leg dominance was determined as preferred leg to kick a ball.

MATERIALS AND METHODS: A medial side hop for distance was performed with and without a visual-cognitive task (VCMH). The visual-cognitive component was a modified space task challenging rapid visual encoding and spatial memory involving letters (D, F, K, J) being presented (100 milliseconds) in a circular array. Upon removal, an indicator would appear for the participant to recite the letter at the corresponding location for delayed recall (1.9 seconds). Both physical performance (medial hop distance, physical errors) and cognitive performance (cognitive errors) were measured. Participants completed 2 practice trials and 3 trials of traditional medial side hop and VCMH on the dominant limb. Maximum hop distance of the 3 trials of each task was analyzed. To determine test-retest reliability, subjects completed 2 identical testing sessions separated by 10 to 14 days. Intraclass correlation coefficients (ICC) with 95% confidence intervals and standard error of the measurement (SEM) were calculated to assess reliability of the tasks. A paired t test was conducted to evaluate performance differences between the traditional and VCMH. Alpha level was set at .05.

RESULTS: There was high reliability for the traditional medial side hop (ICC_{2,1} = 0.88; 95% CI: 0.72, 0.95; SEM, 7.16 cm) and VCMH distances (ICC_{2,1} = 0.86; 95% CI: 0.66, 0.94; SEM, 6.82 cm). Maximum hop distance was significantly lower during the VCMH (86.92 $\pm$ 18.24 cm) com-

pared to the traditional medial side hop (96.25 $\pm$ 20.67 cm, $P < .05$, $d = 0.74$), with a performance deficit of -9.69%.

CONCLUSIONS: The VCMH has high test-retest reliability and resulted in a significant reduction in physical performance when compared to the traditional medial side hop.

CLINICAL RELEVANCE: Medial hopping has been shown to elicit greater limb asymmetry in healthy and injured athletes relative to forward hop tasks. Additionally, rapid visual encoding and short-term visual memory are essential for information processing and decision making in sport. This study provides evidence that a rapid visual-cognitive challenge can be added to the medial side hop, is reliable and can increase performance difficulty, potentially supporting utility of the VCMH as a novel tool for RTS assessment.

SPL22

PARTICIPATION IN ADAPTIVE SPORTS PROGRAMS: PERCEPTIONS OF THE PARENT AND CHILD

Deanne R. Fay, Elena Marie D'Angelo, Danielle Hernandez, Russell Nettlow, Carly Roberts, Ianelly Sanchez, Hayden Sutton

PURPOSE/HYPOTHESIS: Children with a physical disability often have limited access to participation in community and school-based sports. An understanding of the role of community-based adaptive sports programs in enhancing participation may help society address this limitation. The purpose of this study was to describe and interpret the experience of participating in an adaptive sports program from the perspectives of children with a physical disability and their parents.

NUMBER OF SUBJECTS: A total of 18 participants were interviewed, including 9 children with a physical disability between the ages of 7 and 12 who participated in adaptive sports and one of their parents.

MATERIALS AND METHODS: Using a phenomenological research design, data were collected through in-person semi-structured interviews with guiding questions. Each child and parent was interviewed separately about his or her experience with the adaptive sports program. Interviews were audio-recorded and researchers took field notes to document specific observations including body language, tone, or expressions during the interview. After interviews were professionally transcribed, they were analyzed using a constant comparison coding method with the use of NVivo software. Trustworthiness was established through reflexive journaling, triangulation of sources, peer debriefing, and quotation exemplars.

RESULTS: Throughout the interviews, all parents and children discussed how their participation in adaptive sports was driven by the actual experience. Three main themes with additional subthemes emerged from the data. When Seeking the Experience, the parents and children were looking for Sport, Fitness and Team participation as well as Opportunity, Inclusion and Fun. Parents also discussed challenges Discovering the Right program. Creating the Experience included Awareness Enhancing participation as well as components that helped with Fitting it In, program design that included Addressing Worries, and Coaches Making a Difference. In the end, Reaping the Benefits included Health and Growth, a Sense of Belonging, and Having Fun.

CONCLUSIONS: These findings suggest that parents view their child's participation in adaptive sports as important and positive. The parents discussed a strong desire for their child to feel included and feel as though they were a part of a team. The children revealed that their main desire was to have fun and be with friends while participating in their respective sports. Parents and children spoke of how the program's efforts to recruit more children and to be flexible in meeting their needs and addressing their concerns were crucial to a good experience.

CLINICAL RELEVANCE: This project adds to the under-researched topic of participation in adaptive sports for children with a disability. The perspectives of the parents and children involved, specifically the desire for inclusion, the need for fun, and role of the adaptive sports community in making it feasible, will help inform adaptive sports organizations on the important aspects of a successful program. Physical therapists working with community-based adaptive sports programs could be instrumental in assisting with many of these areas.

SPL23

EXPERT CLINICAL DECISION MAKING IN PHYSICAL THERAPY
MANAGEMENT OF CONCUSSION: A QUALITATIVE STUDY

Anne K. Galgon, Rebecca Ann Bliss

PURPOSE/HYPOTHESIS: Recent publication of the concussion clinical practice guideline (CPG) is intended to assist clinicians in their decision making specific to evaluation and intervention. Clinical practice guidelines are supported by best current evidence, though it is unknown what other factors drive clinical decision making in the realm of concussion management. The purpose of this study is to explore factors related to the process of clinical decision making of expert physical therapists who treat individuals with concussion injury.

NUMBER OF SUBJECTS: Ten.

MATERIALS AND METHODS: This qualitative study involved one-on-one, 45-minute semi-structured interviews with physical therapists involved in routine concussion management. Therapists were included if they have over 3 years of experience in concussion practice and have treated ≥ 15 individuals for postconcussion symptoms in the last year. Interviews were audio recorded, with data transcribed verbatim before being thematically analyzed. Constant comparative analysis process of open, axial, and selective coding leading to theme development was utilized and discussed by all investigators to ensure consensus of interpretation. Member checking during the interview and during postcoding phone calls confirmed researchers' interpretations and was used to ensure trustworthiness.

RESULTS: The therapists' experience in treating concussion ranged from 5 to 20 years. Three overarching categories of themes were identified that contribute to clinical decision making. (1) Patient-centered care which included subthemes of listening and observing, patient education, therapeutic alliance, what the patient brings to the table, adaptive approach, and multidisciplinary resources. (2) Clinical expertise that included subthemes of evidence-based care, hypothetical deductive reasoning, pattern recognition, reflection in action, clinical experience and training, and clinical environment. (3) Patient-related factors which included subthemes of concussion specific issues (concussion related impairments, external-management, and self-management activities) and contributing factors (preexisting conditions, personal factors, social/environmental factors and maladaptive behaviors).

CONCLUSIONS: Experienced physical therapist provide a consistent approach utilizing patient centered care, clinical expertise and patient related factors when making decisions specific to individuals with concussion injury. These factors can assist more novice clinicians to develop their management strategies and improve care models for optimal outcomes.

CLINICAL RELEVANCE: Identified themes may broaden frameworks and guidelines for the management of individuals post concussion specific to the field of physical therapy.

SPL24

THE RELATIONSHIP BETWEEN BONE BRUISE VOLUME AND OBJECTIVE
FUNCTION FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTIONConnor Gregory Galloway, Mary Halloran Ward,
Jacquelyn Lee Kleihege, Steven Richard Higbie,
Walter R. Lowe, Manickam Kumaravel, Lane Brooks Bailey

PURPOSE/HYPOTHESIS: Subchondral bone bruises are commonly observed on magnetic resonance imaging (MRI) following anterior cruciate ligament (ACL) injury due to the high-impact forces resulting from the subsequent loss of joint stability. Studies suggest an increasing rate and severity of posttraumatic arthritis in individuals following ACL reconstruction (ACL-R), however, the relationship between bone bruise severity and posttraumatic arthritis remains poorly understood. There is conflicting evidence regarding the relationship between volume of bone bruise and patient-reported and functional outcomes following ACL-R, which may potentially impact postoperative management. The purpose of this study was to examine the influence of bone bruise volume following ACL-R on subjective and functional outcomes at the time of medical release and 2 years.

NUMBER OF SUBJECTS: Sixty patients undergoing primary ACL-R.

MATERIALS AND METHODS: Clinical and demographic data were gathered via a single surgeon ACL database. Bone bruise volumes were calculated using coronal images of preoperative MRIs. Outcome variables obtained at the time of medical release included; International Knee Documentation Committee (IKDC-2000) score, ACL Return to Sport after Injury (ACL-RSI) psychological readiness, range of motion (ROM), single-leg balance, single-leg hop tests, and change-of-direction task. At 2 years, reinjury rate and self-reported knee function using the single assessment numeric evaluation (SANE) were obtained. Interrater and intrarater reliability for bone bruise volume measures were assessed using intraclass correlation coefficients (ICCs). A forward stepwise linear regression was used to determine the relationship between bone bruise volume and patient function. An a priori alpha level of .01 was used to determine inclusion into the model.

RESULTS: There were no differences in baseline patient or surgical demographics ($P > .05$). Both intrarater ($ICC_{2,1} = 0.94-0.99$, $P < .01$) and interrater ($ICC_{1,2} = 0.88-0.99$, $P < .01$) reliability were acceptable for estimating bone bruise volume. The distribution of bone bruise injuries were as follows; lateral femoral condyle (76.7%), lateral tibial plateau (88.3%), medial femoral condyle (21.7%), and medial tibial plateau (26.7%). The mean total bone bruise volume was 7065.7 ± 6226.6 . There were no relationships between total bone bruise volume and time of medical clearance ($P = .832$), IKDC-2000 at time of medical clearance ($P = .200$), ACL-RSI at time of medical release ($P = .370$), and SANE score at 2-year follow-up ($P = .179$).

CONCLUSIONS: Preoperative bone bruise volume is not associated with delayed time to return to sport, psychological readiness, and self-reported knee function at time of medical release and 2 years following ACL-R. The lateral femoral condyle sustains the highest frequency of bone bruise injuries.

CLINICAL RELEVANCE: Clinicians should consider the lack of influence that bone bruise volume has on intermediate and 2-year functional outcomes. In light of these results, we do not recommend postoperative protocols be adapted based on severity of subchondral bone bruising, however, further investigation is warranted.

SPL25

EXAMINING THE USE OF UPPER EXTREMITY PHYSICAL
PERFORMANCE TESTS IN SPORTS PHYSICAL THERAPY PRACTICE

Matthew L. Gauthier, Casey Adam Unverzagt, Amee L. Seitz

PURPOSE/HYPOTHESIS: Many athletes are unable to successfully return-to-sport (RTS) following upper extremity injury, with even fewer returning-to-sport at their previous level of performance. Research shows passing physical performance tests (PPTs) reduces reinjury rates following lower extremity injury. However, outcomes regarding the use of PPTs to reduce upper extremity injury is lacking, which may be attributed to a lack of clinical use. The study purpose was to explore reported use and potential barriers of PPTs by physical therapists treating athletes with upper extremity injuries.

NUMBER OF SUBJECTS: Five hundred fifteen.

MATERIALS AND METHODS: Physical therapists who currently treat athletic patients with upper extremity injuries were eligible to participate in the study. An electronic survey was distributed to sports physical therapists nationally and internationally through social media and email to membership of professional organizations. Respondents were asked demographic information and questions related to (1) which upper extremity PPTs respondents use; (2) barriers to using PPTs; (3) perceived proportion of athletes that pass predetermined RTS criteria before discharge from care; and (4) factors that contribute to patients being discharged prior to meeting predetermined RTS criteria.

RESULTS: Five hundred fifteen participants (84.6% from the United States, 27.4% with specialist certification, mean 16.3 years clinical experience) completed the survey. Using the International Classification of Functioning, Disability, and Health (ICF) as a framework to interpret the results, the most common reported factors used by physical therapists to make RTS decisions were time from injury (97.8%), impairments (range

of motion, manual muscle tests, handheld dynamometry, isokinetic testing, and proprioceptive testing) (19.8%-98.6%), and contextual factors such as subjective report and patient-reported outcome measures (80.5%-93.0%). Fewer than half of respondents (8.7%-45.2%) reported using activity limitations, such as upper extremity PPTs, when making RTS decisions. Reported barriers to the use of PPTs included a lack of time (55.0%) and equipment (65.0%), a perceived lack of evidence supporting the use of upper extremity PPTs (46.8%), and a clinician's lack of understanding of this evidence (62.8%). Only 25% of therapists report the majority of their patients (>75%) pass all predetermined PPT goals. The most common reasons for patients being discharged prior to passing PPT goals were insurance visit limitations (68.2%), patient self-discharge (67.8%), financial reasons (53.6%), and clearance from another health care provider (51.8%).

CONCLUSIONS: Over 50% of clinicians are not using PPTs when determining RTS readiness, underappreciating activity limitations within the ICF classification to evaluate an athlete's progress.

CLINICAL RELEVANCE: Less than optimal RTS and reinjury rates in upper extremity athletes may be attributed, in part, to patient discharge prior to full physical performance. Identified barriers to the use of PPTs highlight the need for research on more efficient, valid testing protocols in making RTS decisions. Strategies to overcome barriers to using PPT for RTS decisions are needed.

SPL26

EFFECTS OF BLOOD FLOW RESTRICTION ON STRENGTH DURING EARLY ANTERIOR CRUCIATE LIGAMENT REHABILITATION IN ADOLESCENTS

Nicholas Gary Giampetruzzi, Arthur Fredericks, Dylan P. Roman, Jennifer Prue, Adel Lolice, James Lee Pace, Allison Crepeau

PURPOSE/HYPOTHESIS: Blood flow restriction training (BFRT) has gained popularity due to reported benefits in reducing muscle atrophy and mitigating strength deficits following anterior cruciate ligament reconstruction (ACLR). While there are a number of studies that have reported on the use of BFRT in the adult population, there is limited information about the use of BFRT in the adolescent population and its effect on muscle strength and function. Therefore, the purpose of this study was to determine the effect of adding BFRT to traditional rehabilitation in the adolescent population after ACLR. This study's primary aim was to investigate the impact BFRT has on isometric strength testing and patient reported function at 3 months postoperatively.

NUMBER OF SUBJECTS: BFRT group (BFRTG): 11 patients (6 female; mean $\pm$ SD age, 14.9 $\pm$ 1.8 years) and control group (CG): 47 patients (24 female; mean $\pm$ SD age, 15.2 $\pm$ 0.6 years).

MATERIALS AND METHODS: A prospective intervention group was compared to an age matched retrospective control group as part of an ongoing clinical trial. This included patients between 12 and 18 years of age, who underwent primary ACLR at Connecticut Children's from January 2020 to present. In addition to a standardized rehabilitation protocol these patients utilized a personalized tourniquet system for BFRT with limb occlusion pressure of 80%. The intervention group completed a standardized BFRT protocol that included completion of 3 BFRT exercises twice a week for 12 weeks. Load progression was based on the patient's perceived level of exertion. A 3-month strength assessment was completed by patients in both groups. The test included isometric knee extension and flexion strength at 60° of knee flexion. Peak torque was normalized to body weight and used to calculate limb symmetry index (LSI). IKDC scores were recorded. Two-sample *t* tests were used to determine differences between the BFRTG and CG.

RESULTS: No differences were seen between groups for age ($P = .58$), height ($P = .54$), and weight ($P = .22$). Median days from surgery to test was 89 days for the BFRTG and 95 for the CG. Significant differences were seen between the BFRTG and CG for peak knee extensor torque when normalized to body weight in both the surgical (1.8 $\pm$ 0.4 versus 1.4 $\pm$ 0.6 Nm/kg, $P = .02$) and nonsurgical limbs (2.7 $\pm$ 0.6 versus 2.1 $\pm$ 0.5 Nm/kg, $P = .03$). No significant differences were seen between groups for knee extensor LSI (67.6 $\pm$ 10.0 versus 68.6 $\pm$ 21.5, $P = .83$), knee flexor LSI (81.9

$\pm$ 19.7 versus 78.6 $\pm$ 35.0, $P = .67$) or IKDC scores (65.1 $\pm$ 6.8 versus 70.9 $\pm$ 13.6, $P = .06$).

CONCLUSIONS: The BFRTG had increased quadriceps peak torque per body mass compared to the CG for both the surgical and nonsurgical limbs. Though the BFRTG presented with greater normalized peak torque, there were no differences between groups for knee extensor and flexor LSIs. Additionally, there were no differences between groups for patient reported outcomes.

CLINICAL RELEVANCE: In adolescents, BFRT may impact bilateral knee extensor force production during early postoperative ACLR rehabilitation. Continued investigation is needed to further evaluate the impact of BFRT in this population.

SPL27

TWELVE-WEEK POSTOPERATIVE JOINT LOADING BETWEEN INDIVIDUALS WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION VERSUS REPAIR

Shiho Goto, Joseph Patrick Hannon, Steve B. Singleton, Lindsey Dietrich, Craig Craig Garrison

PURPOSE/HYPOTHESIS: Anterior cruciate ligament repair (ACL-Rp) is a potentially more joint "friendly" alternative to the traditional ACL reconstruction (ACL-Rc) procedure secondary to less surgical trauma with the preservation of the native ACL ligament. Recent research suggests that the ACL-Rp procedure provides good short-term clinical outcomes comparable to the ACL-Rc procedure. However, no studies have examined biomechanical differences between these 2 procedures. The purpose of this study was to examine knee joint loading differences at 12-week postoperative time point (12W) between individuals who underwent ACL-Rc and ACL-Rp procedures during a walking task. We hypothesized that individuals with ACL-Rp would have greater knee joint loading compared to those with ACL-Rc.

NUMBER OF SUBJECTS: A total of 39 active individuals participated (19 ACL-Rp: mean $\pm$ SD age, 37.32 $\pm$ 13.57 years; height, 170.79 $\pm$ 8.73 cm; mass, 75.21 $\pm$ 17.83 kg; 20 ACL-Rc: mean $\pm$ SD age, 27.35 $\pm$ 11.65 years; height, 172.54 $\pm$ 9.32 cm; mass, 73.56 $\pm$ 14.02 kg). Participants were included if they were between the ages of 12 and 60 years, had no previous history of ACL injury, and were active at time of injury.

MATERIALS AND METHODS: Participants walked an approximately 10-m-long runway at their preferred speed at RTS while a 3-D motion capture system and 2 force plates collected kinematics and ground reaction force data. Knee extension moment impulse (iKEXTmm) and peak KEXTmm were calculated during phase 1 (P1: initial contact to 50% of the stance phase) and phase 2 (P2: 50% of the stance phase to toe-off) from surgical (SURG) and nonsurgical (N-SURG) limbs and were averaged across 3 trials. Independent *t* tests were performed between the groups (ACL-Rp versus ACL-Rc) for age, height, and mass. Variables with significant difference were used as covariate for following analyses. Separate ANCOVAs were performed on each biomechanical variable for each limb (SURG and N-SURG) to examine differences between groups. A priori alpha was set at $\leq .05$.

RESULTS: A significant difference was observed in age ($P = .018$) which was used as covariate. For biomechanical variables, the ACL-Rp group demonstrated significantly greater iKEXTmm during P1 compared to the ACL-Rc group (ACL-Rp, -0.0035 ± 0.0029 ; ACL-Rc, -0.0013 ± 0.0019 ; $P = .011$). No other significant differences were observed in any of the biomechanical variables ($P > .05$).

CONCLUSIONS: The ACL-Rp group consistently demonstrated greater knee joint loading throughout the first half of the stance phase of gait compared to the ACL-Rc group. Decreased peak KEXTmm has been identified as a potential precursor to the development of tibiofemoral osteoarthritis (TFOA). These findings suggest that the ACL-Rp procedure may have the potential to reduce the risk of developing TFOA in this population. Investigating other biomechanical variables across tasks is warranted to better understand the biomechanical outcomes between these 2 different surgical procedures.

CLINICAL RELEVANCE: Individuals with ACL-Rp have greater ability to load at their knee joint during gait at 12W which may reduce the risk of development of TFOA.

SPL28

IMPACT OF AGE- AND ACTIVITY-RELEVANT QUADRICEPS FEMORIS STRENGTH TARGET VALUES ON LANDING MECHANICS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Gina Marie Gugliotta, Christin Marie Zwolski, Staci Thomas, Mark Vincent Paterno, Laura C. Schmitt

PURPOSE/HYPOTHESIS: Between-limb quadriceps femoris (QF) strength symmetry is recommended to inform return-to-sport (RTS) decisions post ACL reconstruction (ACLR). Identifying target strength values may overcome potential limitations of limb symmetry. This study sought to identify age- and activity-relevant QF strength target values at RTS post ACLR and test the hypothesis that adolescents after ACLR who meet QF strength target values would demonstrate landing mechanics more consistent with uninjured athletes compared to those who did not meet target values.

NUMBER OF SUBJECTS: One hundred forty-eight young athletes within 4 weeks of medical clearance to RTS after primary, unilateral ACLR (mean $\pm$ SD age, 16.9 $\pm$ 3.3 years; 67% female; ACLR group) and 57 uninjured athletes (mean $\pm$ SD age, 17.2 $\pm$ 2.5 years; 74% female; CTRL group).

MATERIALS AND METHODS: All participants completed an isokinetic thigh strength assessment (180°/s). Peak torque values for each limb were normalized to body weight (Nm/kg). The lower bound of the 95% confidence interval for normalized QF peak torque in the CTRL group defined the QF strength target value. Lower extremity kinematic and kinetic data of the landing phase of a bilateral drop vertical jump were also collected. Variables of interest included peak vertical ground reaction force (GRF; N/kg), peak knee flexion excursion (degrees), and peak internal knee extension moment (Nm/kg) of each limb. One-way analysis of variance and Bonferroni post hoc testing compared variables of interest among participants with ACLR who met the QF target value (QF-yes), those who did not meet the QF target value (QF-no), and controls.

RESULTS: The ACLR and CTRL groups didn't differ in age, sex distribution, or preinjury activity level ($P > .05$). Based on CTRL data, the QF strength target value was 1.649 Nm/kg. In the ACLR group, 61% of subjects were classified in the QF-yes group and 39% were classified in the QF-no group, with no between-group demographic differences ($P > .05$). During landing, GRF on the involved limb was greater in the CTRL group compared to both QF groups ($P < .001$). On the uninvolved limb GRF was greater in QF-no group compared to QF-yes group ($P = .001$). Knee flexion excursion was greater in the involved limb of QF-yes group compared to CTRL group ($P = .013$), with no differences between QF groups ($P = .068$) or among groups on the uninvolved limb ($P = .097$). Involved limb peak internal knee extension moment was lowest in QF-no group compared to QF-yes ($P = .055$) and CTRL ($P < .001$) groups, and highest in CTRL group compared to QF groups ($P = .001$) with no differences on the uninvolved limb ($P = .217$).

CONCLUSIONS: After ACLR, nearly 40% of adolescents at RTS do not achieve age- and activity-relevant QF strength targets on the involved limb. Those who did not meet the target value demonstrated altered involved limb landing mechanics compared to those who did and uninjured controls.

CLINICAL RELEVANCE: For young athletes with ACLR, considerations of QF strength target values may better inform RTS decision making and facilitate normal landing mechanics. More research is needed to evaluate the impact of age- and activity-relevant QF strength values on outcomes after adolescent ACLR.

SPL29

CAN A FORCE-PLATE SYSTEM IDENTIFY TACTICAL ATHLETES AT RISK FOR MUSCULOSKELETAL INJURY?

Ben Hando, W. Casan Scott, Jacob Bryant, Juste Tchandja, Siddhartha Angadi

PURPOSE/HYPOTHESIS: The purpose was to determine if scores from a proprietary force plate system were associated with the likelihood of sustaining a musculoskeletal injury (MSKI) during an Air Force Special Warfare (AFSW) training course. We hypothesized that trainees who sustained an MSKI during the 8-week surveillance period would, on average, demonstrate lower musculoskeletal health scores at baseline testing.

NUMBER OF SUBJECTS: Eight hundred twenty-three.

MATERIALS AND METHODS: AFSW trainees were screened using Sparta Science force plate scans immediately prior to an 8-week AFSW training course. Scans included countermovement jumps (CMJ) that were processed through proprietary software to produce MSK Health scores, which were used to quantify a trainees risk for subsequent MSKI, as is recommended by the company. There were 2 primary outcomes, any MSKI and lower extremity (LE) MSKI. Medical encounter data were extracted for each subject for the 8-week period during the course and the 14-week period preceding the course start date. Diagnosis codes were characterized as MSKI (yes/no) and further categorized as LE MSKI (yes/no). We compared demographic (age, BMI), fitness scores (1.5-mi run, 1500-m fin, sit-ups), prior MSKI rates, and Sparta MSK Health scores in each group (yes/no) for both primary outcomes (Any MSKI and LE MSKI). Independent t tests were used to compare continuous measures and chi-square analyses were used for comparing frequency counts (prior MSKIs). We conducted unadjusted univariate logistic regression analyses to test for associations between MSK Health scores and the likelihood of each MSKI outcome during the surveillance period. To test the associations between MSK Health scores and the 2 MSKI outcomes while controlling for the effects of demographic, fitness, and prior-injury factors, we performed adjusted multivariate logistic regression analyses. All analyses were assessed for significance at a level of $P < .05$.

RESULTS: Eight hundred twenty-three male trainees were included in this cohort with a mean $\pm$ SD age of 22.7 $\pm$ 3.9 years. Three hundred eight trainees sustained an MSKI of any kind and 232 sustained a LE MSKI. There were no observed differences in mean Sparta MSK Health scores between those who did and did not suffer any MSKI and those who did and did not suffer a LE MSKI ($P > .05$). There were differences in rates of prior MSKI, run and fin times, sit-ups, and age in those who did and did not suffer an MSKI ($P < .05$). The results of the unadjusted logistic regression analyses found no association between Sparta MSK Health scores and the likelihood of suffering an MSKI or LE MSKI ($P > .05$). After adjusting for age, BMI, prior MSKI status, and fitness scores, the adjusted logistic regression also found no association between MSK Health and the likelihood of suffering an MSKI during training.

CONCLUSIONS: The Sparta Science Force Plate assessments provided no value in identifying AFSW airmen likely to suffer an MSKI or LE MSKI during an 8-week training course.

CLINICAL RELEVANCE: Organizations interested in screening cohorts of athletes or service members for MSKI risk should consider other solutions.

SPL30

ENERGY ABSORPTION CONTRIBUTION IN DOMINANT VERSUS NONDOMINANT LIMBS IN FEMALE DIVISION I ATHLETES

Joseph Patrick Hannon, Shiho Goto, Steve B. Singleton, Craig Craig Garrison, Lindsey Dietrich, Ashley Reichert

PURPOSE/HYPOTHESIS: There is limited evidence regarding landing strategies amongst healthy, NCAA Division I female athletes. Emerging evidence suggests limb dominance may influence landing strategies in healthy and ACL-Reconstruction (ACL-R) populations. The purpose of this study was to provide normative values of energy absorption contribution (EAC) with regards to both limb dominance and sport amongst healthy NCAA DI female athletes.

NUMBER OF SUBJECTS: Eighty-eight female athletes were included (mean $\pm$ SD age, 19.26 $\pm$ 1.30 years; height, 177.12 $\pm$ 7.47 cm; weight, 72.86 $\pm$ 10.70 kg; IKDC, 95.47 $\pm$ 9.02), 22 soccer players, 23 basketball players, 15 volleyball players, and 25 sand volleyball players. All athletes were considered healthy at time of testing and did not indicate any low back or lower extremity injury in the 3 months leading up to testing.

MATERIALS AND METHODS: A 10-camera motion capture system (Qualisys AB, Göteborg, Sweden) with a sampling rate of 120 Hz and 2 force plates capturing at 1200 Hz (Advanced Mechanical Technology, Inc, Watertown, MA) were used to capture joint motions during a double-leg jump land task. Participants completed 3 double-leg jump lands off a 30-cm box which was placed a distance of 50% of their height from the force plates. Variables of interest included EAC of the hip, knee, and ankle joints. All

values were normalized to the subjects height and weight. Statistical analysis was completed using SPSS Version 25 (IBM, Armonk, NY) and dominant (Dom) versus nondominant (NonDom) limbs were compared using paired *t* tests. A subanalysis dividing athletes by sport was also completed to assess for differences across sports. The alpha level was set at .05.

RESULTS: Results of paired *t* tests demonstrate EAC is different between Dom and NonDom limbs. There was significantly greater hip contribution on the NonDom limb ($61.29\% \pm 11.1\%$) compared to the Domlimb ($20.3\% \pm 8.2\%$, $P < .001$). There was significantly greater knee contribution on the Domlimb ($61.8\% \pm 8.1\%$) compared to the NonDom limb ($13.39\% \pm 6.8\%$, $P < .001$). At the ankle, there was a significantly greater contribution on the NonDom limb ($25.31\% \pm 9.4\%$) compared to the Domlimb ($17.84\% \pm 7.6\%$, $P < .001$). When subanalyzed by sport these findings remain consistent with $P < .001$ for all comparisons.

CONCLUSIONS: During the landing phase of a DL jump, healthy DI female athletes utilize a hip strategy on the NonDom extremity, compared to knee strategy on the Dom extremity. This evidence suggests it is normal for healthy, high level, female athletes to use different strategies between limbs.

CLINICAL RELEVANCE: Emerging evidence suggests EAC is different between Dom and NonDom limbs in both healthy and ACL-R populations. Since a predominantly hip-dominant strategy is utilized in the NonDom limb during jump landing in both a healthy and ACL-R population, it is unclear if at time of return to sport, clinicians should continue to address increasing knee loading or if returning patients to be more similar to healthy controls should be the goal.

SPL31

NORMALIZED KNEE LOADING DURING GAIT AT 12 WEEKS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Joseph Patrick Hannon, Shiho Goto, Steve B. Singleton, Lindsey Dietrich, Craig Garrison

PURPOSE/HYPOTHESIS: To compare knee joint loading between individuals with ACL-R and matched healthy controls (CON) in each of the surgical and nonsurgical limb during gait at 12 weeks following ACL-R.

NUMBER OF SUBJECTS: Sixty-two participants were enrolled in this study. Thirty-one following unilateral ACL-R (mean $\pm$ SD age, 15.90 ± 1.6 years; height, 169.54 ± 8.1 cm; weight, 72.79 ± 13.4 kg) and 31 sex, age, side of dominance matched CON (mean $\pm$ SD age, 15.52 ± 2.5 years; height, 172.9 ± 14.7 cm; weight, 64.07 ± 11.1 kg).

MATERIALS AND METHODS: A 10-camera motion capture system (Qualisys AB, Göteborg, Sweden) with a sampling rate of 120 Hz and 2 force plates capturing at 1200 Hz (Advanced Mechanical Technology, Inc, Watertown, MA) were used to capture joint motions during gait. Participants walked approximately 10-m runway at a self-selected walking speed until 3 acceptable trials were collected from each limb. The gait cycle was divided into 2 phases (P1: heel strike to 50% of stance phase; P2: 50% of stance phase to toe-off). Variables of interest included average peak knee extension moment (KEM), average KEM impulse (KEMi), and knee energy absorption contribution (KEAC). Separate independent *t* tests were used to assess for between group differences on the surgical and nonsurgical limb for all variables of interest with an alpha level set at $P = .05$.

RESULTS: On the surgical limb the results of the independent *t* tests revealed no significant differences between the ACL-R and healthy controls in any variables of interest except for KEAC at P1. The ACL-R group demonstrated significantly less KEAC than the matched limb of the CON group (ACL-R, 9.54 ± 8.50 ; controls, 20.83 ± 14.3 ; $P < .001$). On the nonsurgical limb there were significant differences in all variables between the ACL-R verse the control group. Interestingly, the ACL-R group did not consistently demonstrate decreased knee loading. At P1 the ACL-R demonstrated significantly less KEAC (ACL-R, 20.5 ± 12.9 ; controls, 30.3 ± 12.7 ; $P = .006$); however, at P2, the ACL-R groups demonstrated significantly increased KEAC than the matched limb of the CON group (ACL-R, 39.5 ± 16.1 ; controls, 26.08 ± 9.57 ; $P < .001$). Both KEM (ACL-R, -0.022 ± 0.02 ; controls, -0.041 ± 0.02 ; $P < .001$) and KEMi (ACL-R, -0.004 ± 0.003 ; controls, -0.006 ± 0.003 ; $P = .017$) were significantly less in the ACL-R group compared to controls at P1, but greater in the ACL-R group

(KEM, -0.035 ± 0.02 ; KEMi, -0.004 ± 0.003) compared to controls (KEM, -0.013 ± 0.009 ; $P < .001$; KEMi, -0.001 ± 0.001 ; $P < .001$) at P2.

CONCLUSIONS: When limb dominance is accounted for, knee loading on the ACL-R limb is more similar to controls compared to the nonsurgical limb during gait.

CLINICAL RELEVANCE: The results of this study indicate that at 12 weeks following ACL-R KEM and KEMi “normalize” on the surgical limb compared to healthy controls when matched for side of dominance. The nonsurgical limb demonstrates altered loading strategies compared to controls. The findings from this study differ from previously published work and may be due to our matching of limb dominance between groups. Recent research suggests that limb dominance influences loading strategies and this seems to influence “normalization” of gait mechanics.

SPL32

IMPACT OF SELF-EFFICACY ON FUNCTION AND PAIN IN ADOLESCENTS WITH PATELLOFEMORAL PAIN

Jena Heck, Mitchell C. Selhorst

PURPOSE/HYPOTHESIS: Pain self-efficacy, defined as one's confidence in their ability to function effectively while in pain, has been considered for many chronic conditions, but has not been explored relating to adolescents. Patellofemoral pain (PFP) is a common orthopaedic condition, affecting 1 out of every 10 adolescents. The purpose of this study was to determine how baseline pain self-efficacy is related to functional ability and pain in adolescents with PFP. We hypothesized that a higher baseline pain self-efficacy score will predict short-term improvements in functional ability and pain reports.

NUMBER OF SUBJECTS: Forty-four adolescents (68% female; mean $\pm$ SD age, 14.9 ± 1.6 years) with PFP (3 months median duration of pain).

MATERIALS AND METHODS: Adolescents between the age of 12 and <18 years with PFP, who were sent for a physical therapy evaluation, were surveyed. Participants provided demographic information and completed a series of patient reported functional outcome measures. The Pain Self-Efficacy Questionnaire (PSEQ), Anterior Knee Pain Scale (AKPS), and numeric pain-rating scale were the psychometric variables of interest for this study. The participants completed these measures at baseline and at a 3-week follow-up.

RESULTS: The baseline mean PSEQ score was 48.0 ± 7.7 , while the mean AKPS score was 73.9 ± 13.9 . The mean AKPS score at the 3-week follow-up was 84.9 ± 11.8 . The baseline self-efficacy scores were shown to have a statistically significant and moderate correlation ($r = 0.57$) with baseline functional ability and predicted change in function at 3 weeks. The PSEQ scores were found to significantly predict function at 3 weeks ($R^2 = 0.21$, $P = .03$). PSEQ scores were not significantly associated with pain at 3 weeks (mean $\pm$ SD pain, 3.2 ± 2.1 ; $r = -0.15$, $P = .18$) or were a significant predictor of pain ($P = .35$).

CONCLUSIONS: Baseline pain self-efficacy scores using the PSEQ were significantly related to short-term functional ability improvements. They also predicted this improved functional ability, as 21% of the functional improvement can be explained by baseline pain self-efficacy. Baseline self-efficacy and pain did not have a significant relationship or prediction correlation. Considerations of these results include that the mean baseline PSEQ were 48 out of a 60-point scale, indicating a possible ceiling effect. The mean PSEQ was also much higher than previously published studies. This population was young and athletic, possibly explaining the increased confidence and self-efficacy scores. In summary, adolescents with a higher baseline pain self-efficacy, or PSEQ score, had a higher baseline functional ability and improved more functionally in a 3-week period.

CLINICAL RELEVANCE: The Pain Self-Efficacy Questionnaire could be a useful tool in determining functional prognosis of adolescents with patellofemoral pain.

SPL33

APPLICATION OF MACHINE LEARNING TO NATIONAL FOOTBALL LEAGUE INJURY PREDICTION

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PURPOSE/HYPOTHESIS: Machine learning (ML) is a valuable technology that allows for the expedient identification of relationships amongst many

variables in large data sets. Its use in the medical field is in its infancy, but is gaining traction. Injury risk assessment in sports medicine has traditionally been explored by looking at several variables at 1 time point followed by an injury surveillance period. ML can consider many variables dynamically and continually update injury risk assessments. The purpose of this study is to develop a machine learning decision support tool to predict National Football League (NFL) athlete next-game injuries, by comparing the prediction efficacy of a Random Forest classifier (RF), an XGboost classifier (XGB), and a Naïve Bayes classifier (NB) machine learning model in NFL injury prediction.

NUMBER OF SUBJECTS: Publicly sourced data of all nonspecialist NFL players who averaged more than 20 plays per game from the 2009-2020 seasons were included, resulting in data from 133943 player-games and 4154 injuries.

MATERIALS AND METHODS: For this study, injuries were defined as those that resulted in a player being on the injury report and resulted in at least 1 missed game (MG injury). Input variables were collected from publicly available sources and included player demographics, roster status, opponent information, weather, playing venue/surface, number of plays, player performance, and injury status. RF, XGB, and NB machine learning programming models were trained to predict MG injuries for the next scheduled game. The RF, XGB, and NB models were assessed using receiving operating characteristics.

RESULTS: For next-game injury prediction, the RF model produced the best results (AUC = 0.708; sensitivity, 0.153; specificity, 0.980; LR = 7.65) followed by the XGB model (AUC = 0.647; sensitivity, 0.148; specificity, 0.963; LR = 4), and the NB model (AUC = 0.506; sensitivity, 0.996; specificity, 0.015; LR = 1).

CONCLUSIONS: ML models can effectively identify players at increased injury risk, and the RF model outperformed XGB and NB models for next-game injury prediction.

CLINICAL RELEVANCE: This study developed a tool to aid clinicians in screening athletes for elevated injury risk without the need for additional clinical tests and measures. Unlike other screening tools that require an in-person assessment, this method uses existing data to inform medical personnel of potential risk. These predictions may be further improved with data from wearable devices, potentially providing daily updates to injury risk assessments. This study demonstrates that physical therapists can possess ML skillsets which can be used to assist clinical judgements, as well as provide clinicians with a relevant use case on how the intersection of applied science in sports medicine and emerging technology may optimize physical therapy practice.

SPL34

UNINVOLVED-LIMB HOP DISTANCE IS A RELIABLE COMPARISON FROM PREHABILITATION THROUGH 2 YEARS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Angela Hutchinson Smith, Elanna K. Arhos, Naoaki Ito, Karin Gravare Silbernagel, Lynn Snyder-Mackler

PURPOSE/HYPOTHESIS: Hop distance symmetry is one of the most common criteria used for determining readiness to return to sport (RTS) after ACLR, however the use of the uninvolved limb as a comparative measure over the course of rehabilitation has been questioned, particularly if no preoperative data is available. While hop test limb symmetry index (LSI) is known to improve with time, the changes in actual hop distance (cm) in both limbs are seldom reported. Assessing hop distances over time is advantageous over LSI alone in order to ensure the most accurate comparison is being made when making RTS decisions. The purpose of this analysis was to assess changes in each limb's single-leg hop for distance (SLHD) over 5 time points between injury and 2 years after ACLR.

NUMBER OF SUBJECTS: Eighty-two level I-II athletes (37 women; mean $\pm$ SD age, 25 ± 9 years; height, 174 ± 9 cm; weight, 75 ± 16 kg).

MATERIALS AND METHODS: This is a secondary analysis of a prospective cohort study. Level I-II athletes after isolated ACL rupture were enrolled. Participants were excluded if they had repairable meniscus, symptomatic grade III injury to other knee ligaments, or full-thickness articular cartilage lesion greater than 1 cm². Participants in the study had preoperative

physical therapy for impairment resolution and 10 sessions of neuromuscular and strength training, followed by ACLR. Participants completed 2 hop testing sessions before ACLR at pre (Pr) and post (Po) training, and 3 testing sessions after ACLR at 6 months (P6), 1 year (P12), and 2 years (P24). The 4 single-limb hop tests were completed as described by Noyes; only the SLHD was included in this analysis. Each hop was completed on the uninvolved limb first followed by the involved, with 2 practice trials followed by 2 measured trials. The average of the 2 trials was reported. A 2-by-5 (limb-by-time) repeated-measures ANOVA was performed for SLHD adjusting for height as a covariate. The minimum detectable change (MDC) for SLHD (8.09%) was used to assess clinically meaningful differences between each time point.

RESULTS: No limb-by-time interaction ($P = .65$), or main effects of time ($P = .20$) or limb ($P = .10$) were observed. No clinically meaningful changes exceeding MDC were observed in the uninvolved limb across all time points (Pr, 134 ± 30 cm; Po, 142 ± 27 cm; P6, 142 ± 29 cm; P12, 144 ± 28 cm; P24, 145 ± 27 cm). In the involved side, however, changes exceeding MDC were seen between Pr and Po (9.45%) and P6 and P12 (11.17%). (Pr, 121 ± 33 cm; Po, 132 ± 32 cm; P6, 127 ± 33 cm; P12, 141 ± 30 cm; P24, 143 ± 28 cm).

CONCLUSIONS: SLHD on the uninvolved limb did not change over 2 years. SLHD on the involved limb, however, improved from Pr to Po and between P6 to P12 based on MDC.

CLINICAL RELEVANCE: SLHD of the uninvolved limb after ACLR stays stable over time, supporting the use of hop distance from the uninvolved side as a comparison to the involved side in RTS decision making across the course of rehabilitation. Hop testing is still a reliable component of the RTS test battery, even in the absence of preoperative data. This topic warrants further investigation as our findings contradict that of previous work.

SPL35

THE DIAGNOSIS AND CLINICAL IMPLICATIONS OF CONCUSSIONS DETECTED WITH HEAD-IMPACT SENSORS: A SYSTEMATIC REVIEW

Christina Cromwell Jacquier, Paul Anthony Salanh, Garrett Scott Bullock, Jason Luck

PURPOSE/HYPOTHESIS: There is increasing popularity of head impact sensors worn to quantify head kinematics and to assist with concussion diagnosis and catalogue subconcussive exposure. A systematic review was performed (1) to understand criteria used to diagnose concussion in athletes who wear head impact sensors and (2) to gain insight on the clinical picture of individuals diagnosed with concussive events by head impact sensors.

NUMBER OF SUBJECTS: Six thousand one hundred fourteen athletes wearing head impact sensors engaging in high school, collegiate, or professional football, ice hockey, rugby, or lacrosse.

MATERIALS AND METHODS: MEDLINE, Embase, Scopus, and SPORTDiscus were searched following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Studies that were peer reviewed, conducted in vivo, and contained athletes wearing head impact sensors used for real-time monitoring during organized sport were included. Studies were excluded that employed the use of anthropomorphic test devices, utilized video or lab reconstruction of impacts, did not mention diagnosis of concussion, were written in a language other than English, or were qualitative, letters, or editorials. Risk of bias assessment was completed with the Modified Downs and Black.

RESULTS: Four thousand seven hundred fourteen citations were screened resulting in 42 included articles, and 6114 participants, with 7.9% diagnosed with a concussion. Ninety-three percent played football, 2% rugby, 2% ice hockey, 1% soccer, 1% and 0.5% other noncontact sports. The median Modified Downs and Black was 8 (6-13). 83% were low quality, 10% moderate quality, and 7% high quality. Seventy-nine percent reported head impact frequency, 41% angular acceleration, 55% linear acceleration, and 24% location of head impact. Fifty-three percent of studies did not report a clinical outcome measure when diagnosing concussion, 24% reported one, and 24% reported use of 2 or more. Nineteen percent reported ImPACT, 12% BESS, 10% King-Devick test.

CONCLUSIONS: There is a vast level of under-reporting and variability in the assessments administered when reporting the clinical presentation of diagnosed concussions in the current head impact sensor literature.

CLINICAL RELEVANCE: Concussion injury presentation is multifaceted and is comprised of different underlying neurobiological issues. Wearable sensor data provides insight into the head impact exposure athletes sustain during play. Use of these devices to identify a potential concussive event and initiate proactive sideline assessment and care is predicated on an assumption that prior studies characterized similar clinical presentations of concussion for a given head impact exposure metric. The current findings suggest this may not be the case and support in future studies a thorough exam of oculomotor, balance, cognitive, psychological, and physical domains in order to provide optimal assessment and care to concussed individuals using head impact sensors.

SPL36

LONGITUDINAL ASSESSMENT OF STRENGTH, BALANCE, JUMPING, AND RUNNING MECHANICS BEFORE TO 2 YEARS POST HIP ARTHROSCOPY

Mikel Renee Joachim, Jennifer L. Sanfilippo, Andrea M. Spiker

BACKGROUND AND PURPOSE: The incidence of hip arthroscopy (HA) to address the symptoms and functional impairments associated with femoroacetabular impingement syndrome (FAIS) has increased dramatically in the last 10 years. Recent cross-sectional investigations report altered gait and squatting mechanics and reduced hip muscle strength in patients post HA compared to healthy controls. No longitudinal studies of lower extremity (LE) biomechanics and neuromuscular function have been published. The purpose of this case study was to explore changes in LE strength, balance, countermovement jump (CMJ), and running mechanics from 2 weeks pre to 2 years post HA in a patient with FAIS.

CASE DESCRIPTION: The patient was a 36-year-old man (BMI, 24.5 kg/m²) who underwent HA for labral repair, subspine decompression, synovectomy, loose body removal, and femoroplasty with capsule repair. Beginning 2 weeks presurgery (PRE) and repeated at 7 intervals (0.5, 1, 2.5, 4, 6, 12, and 24 months) postsurgery (POST), the patient completed a battery of tests including isometric hip (flexion/extension, abd/adduction, internal (IR) and external (ER) rotation) and knee strength assessments, Y Balance Test (YBT), maximal CMJ, and treadmill running (5.36 m/s) while 3-D kinematics and ground reaction forces were recorded. Limb symmetry indices (LSI; involved (INV)/uninvolved (UN) × 100) were computed for all variables.

OUTCOMES: Two weeks POST, all hip and knee strength LSIs were >100%, except for hip IR (69%). By 1 month POST, all strength LSIs were 100% ± 9%. Bilateral strength increases were observed at 2 years POST, with the greatest magnitude of increase in hip IR (+56%-63%) and ER (+38%-60%). INV limb posterolateral YBT reach decreased from 102.8% limb length PRE to 85.5% 2 weeks POST. By 10 weeks POST, PRE reach distances had been exceeded by both limbs in all directions. From PRE to 2 years POST, INV and UN limb YBT reach distance improved by 5.0% to 9.2% and 2.9% to 4.8%, respectively, with the greatest improvement in posteromedial reach (4.8%-9.2%). CMJ height decreased from 38 cm PRE to 32 cm at 1 month POST, but recovered to PRE levels at 10 weeks. Similarly, CMJ peak power at takeoff was reduced by 8% in both limbs at 1 month POST, but returned to PRE levels at 10 weeks. Running stance phase peak hip extension angle was reduced by 5.5° (UN) and 3.8° (INV) from PRE to 10 weeks POST, but returned to PRE levels by 4 months POST. No other consistent trends in altered LE biomechanics were observed.

DISCUSSION: This case provides a unique look at longitudinal changes in LE strength, balance, CMJ and running mechanics prior to surgery through 2 years post HA for FAIS. The majority of strength, balance, and movement biomechanics were restored to preoperative levels by 10 weeks POST. Continued improvements in hip and knee strength and Y Balance Test reach distance were observed up to 2 years POST. These findings suggest that objective assessments of LE function performed within the first few months post surgery may help identify impairments for targeted clinical interventions.

SPL37

TIMING OF STRESS FRACTURE DURING SOLDIERS' FIRST 6 CAREER MONTHS: A RETROSPECTIVE COHORT STUDY

Joseph Rahmon Kardouni, Craig J. McKinnon, Julie M. Hughes, Kathryn M. Taylor

PURPOSE/HYPOTHESIS: Stress fractures (SF) are injuries that can result from beginning new or higher volume physical training regimens. The pattern of clinical presentation of SF over time after individuals start a new or more demanding physical training regimen is not well defined in medical literature. The purpose of this study was to describe the overall and weekly incidence of lower extremity stress fracture injuries over the first 6 months of soldiers' service within the US Army. Stress fracture incidence among women and men were also quantified and compared.

NUMBER OF SUBJECTS: The participants (n = 701027) in this study were US Army soldiers (n = 586412, 83.7% male; n = 114615, 16.3% female) who began their careers from 2005 to 2014.

MATERIALS AND METHODS: This retrospective cohort study was conducted using medical encounter and personnel data from US Army soldiers during the first 6 months of their career. The data set for this study was constructed using demographic and service-time data from soldiers' personnel records and diagnosis codes from medical encounter data. Weekly SF numbers and incidence were calculated overall, as well as by sex, over the first 6 months of military service for all Soldiers beginning their career during the 10-year study period. A hazard ratio (HR) was calculated comparing the hazard for incident lower extremity stress fractures in women compared to men, and the corresponding survival curves were produced for women and men.

RESULTS: SF diagnoses (n = 14155) increased steeply in weeks 3 and 4, with a peak in the overall incidence of SF diagnoses occurring during weeks 5 to 8. Although clinical incidence of stress fracture generally decreased beyond 8 weeks, incident lower extremity stress fractures continued to present for over 20 weeks. The hazard ratio (HR) for SF among women compared to men was HR = 4.14 (95% CI: 4.01, 4.27).

CONCLUSIONS: Across the 6-month study period, women showed over 4 times greater hazard for stress fracture. The results also suggest that health care providers should be particularly vigilant for stress fractures within 3 weeks after the beginning of a new or higher intensity exercise regimen. The incidence of SF may continue to climb for several weeks. Even as stress fracture incidence declines, it should be noted that these injuries may continue to appear clinically even several months after a change in activity or training.

CLINICAL RELEVANCE: These observations may help guide military health care providers in terms of clinical practice for suspicion of stress fracture in service members, and could have implications for sports medicine practitioners caring for members of the general public who have begun a novel physical training regimen.

DISCLAIMER: The views expressed in this abstract are those of the authors and do not necessarily reflect the official positions or policies of the Department of Army, Department of Defense, or the US Government.

SPL38

MORPHOLOGIC AND FUNCTIONAL COMPARISONS OF ANTERIOR CRUCIATE LIGAMENT PATIENTS WITH OR WITHOUT A FAMILIAL HISTORY OF ANTERIOR CRUCIATE LIGAMENT INJURY

Jacquelyn Lee Kleihege, Steven Richard Higbie, Nicholas Beckmann, Walter Lowe, Lane Bailey

PURPOSE/HYPOTHESIS: A family history of anterior cruciate ligament (ACL) injury has been suggested as a risk factor for sustaining an ACL rupture with up to 38% of ACL patients having a first-degree relative who sustained an ACL injury. Despite this potential association, no studies have determined whether patients with a familial history of ACL injury demonstrate differences in morphological characteristics and return to sport timelines when compared to those without a familial history. Therefore, the purpose of this study was to compare morphological radiographic characteristics and time of return to sport between ACL patients with a familial history of ACL injury and matched controls without a significant history.

NUMBER OF SUBJECTS: Sixty patients following ACL reconstruction.

MATERIALS AND METHODS: A single-surgeon database of 1402 patients undergoing ACL reconstruction between 2014 and 2019 was reviewed to identify first degree relatives. Qualifying participants were age and sex matched to a control group of patients who did not report a first-degree relative with a history of ACL injury. Objective measurements were obtained using coronal and sagittal long-leg radiographs by a fellowship trained radiologist to assess posterior tibial slope, notch width, and medial femoral condyle (MFC) width on the involved limb. The time of return to sport (months) was defined as the patient's ability to achieve $\geq 90\%$ limb symmetry indices on a functional testing battery that included single-leg balance, single-leg hop tests, and change of direction tasks. Data were analyzed using multivariate general linear model (group and gender) with an alpha level of .05.

RESULTS: Baseline demographics did not differ with regard to age (20.0 ± 9.8 years versus 23.5 ± 8.9 years, $P = .198$), female gender (43.3% versus 46.7%, $P = .981$), and BMI. In addition, there were no group differences in the time of passing return to sport criteria (7.8 ± 2.7 months versus 8.3 ± 1.2 months, $P = .337$). Overall, females exhibited smaller intercondylar notch widths (21.3 ± 3.3 mm versus 23.9 ± 3.2 mm, $P = .006$), and MFC width (26.3 ± 2.4 mm versus 29.5 ± 2.6 mm, $P < .001$) versus males. When examining the interaction between familial group by gender, there were no significant interactions for posterior tibial slope ($F = 0.645$, $P = .426$), intercondylar notch width ($F = 0.131$, $P = .719$), MFC width ($F = 0.916$, $P = .343$), or the time to pass return to sport criteria ($F = 0.269$, $P = .606$).

CONCLUSIONS: When controlling for age and gender, there were no morphological radiographic differences between ACL injured patients with a familial history of ACL injury versus those without. In addition, no differences were observed in time to passing return to sport criteria between these groups.

CLINICAL RELEVANCE: Familial history of a first degree relative with ACL injury does not appear to independently influence the morphological characteristics of the knee joint or the potential time to achieve return to sport criteria after ACL reconstruction. Future investigators should consider exploring other patient specific characteristics that may have a potential link to familial ACL injury risk.

SPL39

DISTAL FEMUR BONE DENSITY 12 MONTHS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IS NOT ASSOCIATED WITH EARLY ISOMETRIC QUADRICEPS PERFORMANCE

Keith Alan Knurr, Colten Haack, Bryan C. Heiderscheit

PURPOSE/HYPOTHESIS: Following anterior cruciate ligament reconstruction (ACLR), significant reductions in bone mineral density (BMD) of the involved distal femur have been observed. Currently, there is no consensus on the cause of BMD loss; therefore, exploration of contributing factors is warranted. Quadriceps performance is significantly impaired following ACLR, which may reduce the mechanical stress on the distal femur and contribute to the reduced BMD. As the rate of bone turnover is slow, the impact of abnormal loading early post ACLR may not be apparent until months later. This study explored the association between isometric knee extensor peak torque (PT) and rate of torque development (RTD) at 4 months (4M) with distal femur BMD deficits at 12 months (12M) following ACLR. We hypothesized that a lower limb symmetry index (LSI) for PT and RTD early post ACLR would be associated with a lower distal femur BMD LSI at 12M.

NUMBER OF SUBJECTS: Twenty-three Division I collegiate athletes (11 female; mean $\pm$ SD age, 20.2 ± 1.2 years; 22 bone-patellar tendon-bone and 1 hamstring graft).

MATERIALS AND METHODS: At 4.2 ± 0.8 months (4M) post ACLR athletes completed isometric knee extensor PT and RTD assessment on a computerized dynamometer. RTD was defined as the slope from 20% to 80% of PT during a trial where athletes were instructed to kick as fast and as hard as possible. Distal femur BMD was measured at 11.4 ± 1.6 months (12M) post ACLR via full-body dual-energy X-ray absorptiometry scans using 2-cm regions of interest placed at 15% of femur length (F15) mea-

sured from the intercondylar notch. LSIs were calculated for all variables. Simple linear regression models were constructed separately with RTD and PT LSI as the independent variables, and F15 BMD LSI as the dependent variable.

RESULTS: The mean $\pm$ SD PT and RTD LSI at 4 months were 0.57 ± 0.16 and 0.40 ± 0.22 , respectively. The average (mean $\pm$ SD) 12M F15 BMD LSI was 0.94 ± 0.09 . PT and RTD LSIs at 4M were not independently associated with 12M F15 BMD LSI. The slope estimates (standard errors), Pearson r , and P values for PT and RTD as a predictor of 12M F15 BMD LSI were -0.02 (0.13), $r = -0.03$, $P = .89$ and -0.04 (0.10), $r = -0.10$, $P = .68$, respectively.

CONCLUSIONS: Isometric PT and RTD LSIs at 4M post ACLR were not associated with distal femur BMD LSI deficits at 12M in collegiate athletes.

CLINICAL RELEVANCE: Distal femur BMD deficits post ACLR do not appear to be related to early isometric quadriceps performance. Our previous work explored the association between late BMD deficits and early postoperative running mechanics, which also failed to show a meaningful relationship. Other variables such as activity reduction, altered movement patterns other than running, or surgical techniques need to be considered. Exploring factors contributing to distal femur BMD loss after ACLR is important to better understand the long-term joint and bone health consequences, in addition to guiding future rehabilitation and treatment options.

SPL40

EFFECT OF SPEED ON RUNNING KNEE BIOMECHANICS SYMMETRY 9 MONTHS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN COLLEGIATE ATHLETES

Keith Alan Knurr, Daniel Garrett Cobian, Stephanie Kliethermes, Mikel Renee Joachim, Bryan C. Heiderscheit

PURPOSE/HYPOTHESIS: Involved limb (INV) deficits in peak knee flexion angle (PKF) and peak knee extensor moment (PKEM) during running persist beyond the typical time of return to sport after anterior cruciate ligament reconstruction (ACLR). PKF and PKEM increase with running speed in healthy subjects, but it remains unknown if both the INV and uninvolved limb (UNI) of athletes post ACLR respond similarly to changes in speed. The purpose of this study was to determine how both INV and UNI knee mechanics change with speed in athletes post ACLR.

NUMBER OF SUBJECTS: Twenty-six Division I collegiate athletes (12 female; 9.0 ± 1.8 months post ACLR; weight, 80.1 ± 15.7 kg).

MATERIALS AND METHODS: Subjects ran at 2.68, 2.95, 3.35, 3.80, and 4.47 m/s as whole body kinematics and ground reaction forces were collected. Separate linear mixed effects models, with subject and limb random effects, assessed changes in PKF and PKEM across speeds. Significance of the fixed effects ($P < .05$) and least-square means (95% confidence interval) for both limbs at all speeds are reported.

RESULTS: A significant limb-by-speed interaction was detected for PKF ($P = .02$). Significant differences between all speeds ($P < .05$) were observed with a significant limb-by-speed interaction at 3.80 ($P = .02$) and 4.47 m/s ($P < .01$) (INV: 2.68 m/s, 36.3° ; 95% CI: 33.6° , 38.9° ; 2.95 m/s, 37.4° ; 95% CI: 34.8° , 40.1° ; 3.35 m/s, 38.3° ; 95% CI: 35.7° , 41.0° ; 3.80 m/s, 39.0° ; 95% CI: 36.4° , 41.7° ; 4.47 m/s, 39.8° ; 95% CI: 37.1° , 42.5° and UNI: 2.68 m/s, 45.3° ; 95% CI: 43.3° , 47.3° ; 2.95 m/s, 46.1° ; 95% CI: 44.1° , 48.1° ; 3.35 m/s, 46.7° ; 95% CI: 44.7° , 48.7° ; 3.80 m/s, 46.9° ; 95% CI: 44.9° , 48.9° ; 4.47 m/s, 47.0° ; 95% CI: 44.9° , 49.0°). PKF between-limb differences decreased from 8.7° at 2.68 m/s to 7.2° at 4.47 m/s. For PKEM, no limb-by-speed interaction was detected, but significant main effects for limb ($P < .01$) and speed ($P < .01$) were observed (INV: 2.68 m/s, -1.27 Nm/kg; 95% CI: -1.50 , -1.04 ; 2.95 m/s, -1.38 Nm/kg; 95% CI: -1.61 , -1.16 ; 3.35 m/s, -1.48 Nm/kg; 95% CI: -1.71 , -1.26 ; 3.80 m/s, -1.58 Nm/kg; 95% CI: -1.80 , -1.35 ; 4.47 m/s, -1.68 Nm/kg; 95% CI: -1.91 , -1.45 and UNI: 2.68 m/s, -2.20 Nm/kg; 95% CI: -2.35 , -2.05 ; 2.95 m/s, -2.31 Nm/kg; 95% CI: -2.47 , -2.16 ; 3.35 m/s, -2.41 Nm/kg; 95% CI: -2.57 , -2.26 ; 3.80 m/s, -2.51 Nm/kg; 95% CI: -2.66 , -2.35 ; 4.47 m/s, -2.61 Nm/kg; 95% CI: -2.77 , -2.46). The average PKEM limb symmetry index across speeds was 61.2%.

CONCLUSIONS: Between-limb differences in PKF during running are reduced at faster speeds in collegiate athletes 9 months post ACLR, which is attributed to a greater increase in INV PKF. PKEMs in both limbs are similarly influenced by running speed. However, significant between-limb asymmetries were observed across all speeds. Both PKF and PKEM increase with increased running speed, consistent with trends in healthy athletes.

CLINICAL RELEVANCE: These findings suggest that running at faster speeds (up to 4.47 m/s) may slightly reduce between-limb asymmetries in PKF, while increasing the magnitude of PKF and PKEM of both limbs in athletes post ACLR. Clinicians should consider the potential influence of speed when evaluating running knee biomechanics symmetry post ACLR.

SPL41

PERCEIVED MOVEMENT EXPERIENCE FOLLOWING ADOLESCENT ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A MIXED-METHODS STUDY

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PURPOSE/HYPOTHESIS: Research indicates that the physical and psychological insults of anterior cruciate ligament reconstruction (ACLR) may negatively impact physical activity outcomes and one's overall movement experience. The purpose of this study was to understand participants' perceived movement experience in the years after adolescent ACLR, and determine to what extent these perspectives were influenced by function and movement quality at time of return to sport (RTS).

NUMBER OF SUBJECTS: Ten participants (median age, 20.5 years; 18-28 years) recruited from a large longitudinal cohort study.

MATERIALS AND METHODS: This study followed an explanatory mixed methods design, consisting of 2 phases: (1) a quantitative arm for purposive participant selection using data from previously collected baseline laboratory testing and (2) a qualitative arm of semi-structured interview data. During baseline testing within 4 weeks of medical clearance to RTS after ACLR, self-reported function was measured with the Knee injury and Osteoarthritis Outcome Score (KOOS). Participants who met ($n = 5$; High Function group) and did not meet ($n = 5$; Low Function group) age- and activity-relevant target scores for KOOS Sport and Quality of Life (QoL) subscales were selected for phase 2. For these participants, baseline kinematic and kinetic sagittal plane data were evaluated during the weight acceptance phase of a single-leg drop-landing task. At a minimum of 3 years following baseline testing, semi-structured interviews with each of these participants were conducted, seeking perspectives on their lived experiences related to movement after ACLR. Themes were identified using open and axial coding. Data sets from each phase were merged into a joint display table in order to integrate findings.

RESULTS: Interviews were conducted at a median of 5.3 years (3.7-9.7 years) after baseline testing. Six themes on perceived movement experience were generated from participants' perspectives related to 3 time points (RTS, present day, future): (1) barriers to movement, (2) postrehabilitation needs, (3) revising expectations to meet new normal, (4) continued barriers, (5) exploration, and (6) anticipated changes. While most participants described decreased quality of movement immediately following RTS, those in the High Function group perceived themselves to move well in the present day, and offered a positive outlook on future physical activity engagement. Those in the Low Function group voiced the unique adaptations they make to address reinjury anxiety and low confidence during current engagement in physical activity. Sagittal plane landing mechanics varied within and between groups at time of RTS, limiting the integration of biomechanical data with qualitative findings.

CONCLUSIONS: Perceptions of movement quality up to 10 years following adolescent ACLR differed between participants with high and low self-reported function at time of RTS, regardless of single-leg landing mechanics.

CLINICAL RELEVANCE: Careful consideration of psychological, social, and environmental factors at time of RTS following adolescent ACLR may serve to optimize long-term physical activity outcomes.

SPL42

SQUATS AND ROBOTS: CAN PHYSICAL THERAPISTS AGREE WITH A 2-DIMENSIONAL ARTIFICIAL INTELLIGENCE MOVEMENT-ANALYSIS SYSTEM?

Zachary Lentini

PURPOSE/HYPOTHESIS: The primary objective of this study was to establish the interrater reliability of double-leg squat (DLS) and single-leg squat (SLS) scoring via visual video analysis between trained raters. The secondary objective was to examine the interrater reliability of DLS and SLS scoring between an automated 2-D movement analysis system (Fusionetics) and the median score of the raters.

NUMBER OF SUBJECTS: Twelve healthy collegiate soccer players (7 female; mean age, 19.2 years).

MATERIALS AND METHODS: Following a 5-minute warm-up on a stationary bicycle, participants were videotaped performing 5 repetitions of the DLS with arms overhead (front and side views) and the SLS with hands on hips (front view only) using a smart phone application. The Fusionetics system automatically scored the DLS and SLS based on binary criteria for several established compensatory movements. Movements compensations for the DLS included out-toeing, knee valgus, knee varus, lateral weight shifting, excessive forward lean of the trunk, and arms falling forward. Movement compensations for the SLS included knee valgus, knee varus, lack of trunk control, and loss of balance. Five physical therapists were trained in the Fusionetics binary scoring system. The raters viewed the same videos used by Fusionetics and scored each item utilizing the same criteria. Interrater reliability was calculated with the Fleiss Kappa statistic. Kappa values were interpreted as poor (<0.20), fair (0.21-0.40), moderate (0.41-0.60), good (0.61-0.80), or excellent (>0.80).

RESULTS: Between raters, 3 of the 10 scored items for the DLS demonstrated moderate agreement (excessive forward lean and out-toeing of the right and left foot), and the rest demonstrated poor to fair agreement. For the SLS, loss of balance demonstrated fair to moderate agreement between raters, and all other items demonstrated poor agreement. Between the automated Fusionetics system and the median score of the raters, excessive forward lean during the DLS demonstrated good agreement, lateral weight shifting to the right during the DLS demonstrated moderate agreement, and knee valgus of the right leg during the SLS demonstrated moderate agreement. All other items demonstrated poor to fair agreement between Fusionetics and the raters.

CONCLUSIONS: Interrater reliability of scoring of the DLS and SLS between trained raters using the Fusionetics scoring criteria, as well as between raters and the automated Fusionetics system, may be less than acceptable for clinical practice. However, interrater reliability metrics were item dependent, indicating that some movement compensations may be more consistently identified than others.

CLINICAL RELEVANCE: For physical therapists that wish to implement 2-D artificial intelligence systems for movement analysis, they should be aware that these methods may evaluate movement differently than the human eye.

SPL43

INJURY AND ILLNESS INCIDENCE TEMPORAL TRENDS IN NATIONAL HOCKEY LEAGUE PLAYERS OVER 13 SEASONS

Allison Lieb, Chelsea Leonard Martin, John M. Tokish, Ellen Shanley, Garrett Scott Bullock

PURPOSE/HYPOTHESIS: It has been shown that approximately 50% of NHL players experience an injury during the regular season. Thus, improved injury mitigation efforts are needed. Sports injury literature recommends a series of steps that begins with establishing the extent of injuries. Previous National Hockey League (NHL) injury literature is lacking comprehensive data looking at temporal trends and injury incidence, which impedes the current clinical evaluation of injury burden. By utilizing publicly available injury data, data can be consolidated in order to create potential collaboration between sports medicine clinicians and lead to successful future injury mitigation efforts. The purpose of this study was to (1) calculate injury and illness incidence proportions stratified by positions and body part; (2) assess injury incidence proportion temporal trends over the course of 13 NHL seasons.

NUMBER OF SUBJECTS: Ten thousand five hundred forty-nine NHL players between 2007-2008 and 2019-2020 seasons.

MATERIALS AND METHODS: Publicly available data were extracted via a repeatable computer iterative process. Two blinded examiners performed external validation and concluded 98% confirmation with other reports. Inclusion criteria consisted of ≥ 18 years old and had sustained any injury or illness within the 2007-2008 to 2019-2020 seasons. Injury was defined as tissue damage or other derangement of normal physical function, regardless if it resulted in time loss. Temporal trends were assessed by season throughout the 13 years. Incidence proportion (IP) and 95% confidence intervals (CI) were calculated for overall injuries. Injuries were stratified by position (Defense, Goalie, Center, and Right Wing + Left Wing [RW+LW]) and body part, as defined by the Orchard Classification System.

RESULTS: Ten thousand five hundred forty-nine NHL players were included between the 2007-2008 and 2019-2020 seasons; 9734 incidences of illness or injury were recorded. Centers had the highest overall injury incidence (IP, 113.3; 95% CI: 108.3, 118.3), followed by RW+LW (85.2; 95% CI: 82.5, 87.8), Defense (85.1; 95% CI: 82.4, 87.7), and Goalies (48.1; 95% CI: 45.6, 50.5). Groin/Hip/Thigh had the highest IP of 8.1 (95% CI: 7.9, 8.2), followed by Head/Neck (5.1; 95% CI: 5.0, 5.2) and Knee injuries (4.3; 95% CI: 4.2, 4.4). Overall injury and illness incidence ranged from 22.3 (95% CI: 20.8, 23.7) in the COVID-shortened 2019-2020 season to 66.5 (95% CI: 62.0, 70.9) in 2013-2014. The majority of seasons demonstrated stable IPs between 53.8 (95% CI: 50.3, 57.3) and 66.5 (95% CI: 62.0, 70.9).

CONCLUSIONS: Centers demonstrated a higher incidence of injury than the other 3 positions. The most common injuries were seen in the Groin/Hip/Thigh, Head/Neck, and Knee, which is consistent with previous literature. Both the 2012-2013 (labor dispute) and 2019-2020 (COVID-19 virus) seasons were shortened and therefore demonstrated different IPs than the other 11 seasons.

CLINICAL RELEVANCE: These results can act as a first step in quantifying NHL injury burden. The publicly available data allows for further collaborative investigations of injury and progression towards injury mitigation programs.

SPL44

ADDITION OF POSTOPERATIVE PERTURBATION TRAINING DOES NOT ELIMINATE KNEE LOADING RATE ASYMMETRIES AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Sydney C. Liles, Naoaki Ito, Jacob J. Capin, Sarah Hall, Karin Gravare Silbernagel, Thomas S. Buchanan, Lynn Snyder-Mackler

PURPOSE/HYPOTHESIS: Alterations in gait mechanics after anterior cruciate ligament reconstruction (ACLR) are associated with increased risks of posttraumatic knee osteoarthritis (OA) development. Preoperative perturbation training improves gait asymmetries in athletes after ACL injury. Postoperative perturbation training, however, does not alter kinematics, kinetics, or static knee loading. Diminished neuromuscular control of the quadriceps following ACL injury could contribute to a slower knee loading rate during gait that may be a potential source of OA. Perturbation training may improve knee extension rate of moment development (RMD) during gait by targeting the neuromuscular control of the quadriceps. The purpose of this study was to identify the effect of postoperative perturbation training on RMD during gait in athletes 6 months after ACLR.

NUMBER OF SUBJECTS: Sixty-three participants (29 women, 34 men; mean $\pm$ SD age, 21.2 $\pm$ 7.8 years; height, 1.7 $\pm$ 0.1 m; weight, 78.0 $\pm$ 14.7 kg) 5.5 $\pm$ 1.9 months after ACLR.

MATERIALS AND METHODS: Participants were randomized into strengthening, agility, plyometric and prevention (SAPP, $n = 27$) or SAPP plus perturbation training (SAPP+PERT, $n = 36$) groups and underwent 10 treatment sessions after primary symptom resolution. Overground gait analyses at self-selected speeds were performed before and after training. Knee kinematics were calculated via inverse dynamics. RMD was determined by calculating the average slope of the knee extension moment

curve normalized to body mass and height (Nm/kg-m/s) at 3 different time intervals. Time intervals of interest were between the time of peak knee extension moment to 50 milliseconds prior to peak knee extension moment (RMD_{50ms}), 50 to 100 milliseconds prior to peak knee extension moment (RMD_{100ms}), and peak instantaneous rate of moment development between initial contact to peak knee extension moment (RMD_{peak}). A 2-by-2-by-2 (limb by group by time) repeated-measures ANOVA ($\alpha = .05$) was performed for the 3 variables of interest.

RESULTS: Main effects of limb were observed for RMD_{50ms} (involved, 3.2 $\pm$ 1.2 Nm/kg-m/s; uninvolved, 3.6 $\pm$ 2.3 Nm/kg-m/s; $P = .01$), RMD_{100ms} (involved, 6.2 $\pm$ 2.3 Nm/kg-m/s; uninvolved, 7.7 $\pm$ 4.4 Nm/kg-m/s; $P < .01$), and RMD_{peak} (involved, 15.1 $\pm$ 4.7 Nm/kg-m/s; uninvolved, 17.6 $\pm$ 10.2 Nm/kg-m/s; $P < .01$), characterized by slower RMD in the involved versus uninvolved limb. No interaction effects ($P = .16-.88$) or significant main effects of treatment group ($P = .06-.66$) or time ($P = .25-.90$) were observed for the 3 variables of interest.

CONCLUSIONS: Regardless of the addition of perturbation training, slower rate of knee loading during gait persists in the involved versus uninvolved limbs 5.5 $\pm$ 1.9 months after ACLR. The findings agree with previous research that postoperative perturbation training does not influence asymmetries in gait mechanics. Further research should assess how early gait specific interventions effect asymmetries during gait.

CLINICAL RELEVANCE: Slow knee loading rate persists during gait in knees 6 months after ACLR, perhaps reflecting a decline in the neuromuscular function of the quadriceps.

SPL45

PSYCHOLOGICAL READINESS TO RETURN TO SPORT AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A SYSTEMATIC REVIEW WITH META-ANALYSIS

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PURPOSE/HYPOTHESIS: Psychological readiness to return to sport (RTS) can impact many aspects of recovery following ACL injury and may be associated with risk of additional knee injury. Potential changes in psychological readiness to RTS over time, and the relationship with modifiable treatment decisions (surgical timing) has not been synthesized. The purpose of this systematic review was to investigate the trajectory of psychological readiness to RTS (assessed with the ACL-RSI) and compare ACL-RSI scores between early and delayed ACL reconstruction (ACLR) groups up to 60 months after ACLR.

NUMBER OF SUBJECTS: Ten thousand forty-five persons after ACLR from 60 studies.

MATERIALS AND METHODS: The PRISMA guidelines were followed. A literature search was conducted in 8 databases. Studies must have assessed ACL-RSI before or after ACLR to be eligible. Abstracts and full texts were screened independently by 2 reviewers. ACL-RSI score ranges from 0-100 (higher score indicates better psychological readiness). ACL-RSI scores were pooled at ≤ 1 , 3-, 6-, 12-, and 24-60 months following ACLR using a random effects meta-analysis at 95% confidence interval (CI). ACL injury management was classified as "early ACLR" (within 6 months of injury without purposeful nonoperative management) or "Delayed ACLR" (≥ 6 months from injury or crossed over after failed purposeful nonoperative management). ACL-RSI scores were compared between early and delayed ACLR groups at ≤ 1 , 6, and 12 months from ACLR using a random effects mean-difference meta-analysis at 95% CI. Heterogeneity was assessed using I^2 (high heterogeneity, $\geq 50\%$). Risk of bias was assessed as high or low using study design specific scales.

RESULTS: Risk of bias was rated low in 5 studies (8.3%) and high in 55 studies (91.7%). Pooled ACL-RSI scores were 43.2 (95% CI: 37.0, 49.5; $I^2 = 98\%$) at ≤ 1 month, 56.2 (95% CI: 45.7, 66.8; $I^2 = 0\%$) at 3 months, 64.8 (95% CI: 62.5, 67.1; $I^2 = 93\%$) at 6 months, 65.7 (95% CI: 61.7, 70.0; $I^2 = 98\%$) at 12 months, and 44.7 (95% CI: 12.9, 76.4; $I^2 = 39\%$) at 24 to 60 months from ACLR. The early ACLR group had better ACL-RSI score (66.0; 95% CI: 63.5, 68.4; $I^2 = 93\%$) compared to the delayed group (55.7;

95% CI: 53.9, 57.6; $I^2 = 0\%$) at 6 months after ACLR ($P < .0001$). No between group differences were observed at ≤ 1 month (delayed, 40.6; 95% CI: 25.4, 55.8; $I^2 = 99\%$ versus early, 43.2; 95% CI: 37.0, 49.5; $I^2 = 93\%$, $P = .54$) or 12 months after ACLR (delayed, 65.4; 95% CI: 58.8, 72.0; $I^2 = 96\%$ versus early, 65.8; 95% CI: 60.9, 70.6; $I^2 = 98\%$, $P = .93$).

CONCLUSIONS: Psychological readiness to RTS meaningfully improves from time of ACLR to 12 months after ACLR. ACL-RSI scores were similar between people managed with early compared to delayed ACLR within 12 months of surgery. People with early ACLR reported better ACL-RSI scores at 6-month follow-up, compared to those with delayed ACLR, and this exceeded known minimal clinically important differences.

CLINICAL RELEVANCE: Despite differences at 6 months, both early and delayed ACLR groups had similar ACL-RSI scores at a time point consistent with when RTS is recommended (9-12 months). Clinicians should discuss these nuances of psychological recovery and relative similarities between surgical options with athletes prior to surgery to help inform their individualized treatment decision.

SPL46

MENSTRUAL HEALTH AND INJURY IN FEMALE NCAA DIVISION III CROSS-COUNTRY AND TRACK ATHLETES

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PURPOSE/HYPOTHESIS: Menstrual abnormalities, including amenorrhea, have been associated with increased risk of injury in high school athletes and with bone stress injuries in collegiate athletes. The purpose of this study was to investigate whether self-reported menstrual health factors were related to injury during a competitive collegiate season. We hypothesized that athletes with menstrual irregularities, particularly those who missed 3 or more periods in the past year, would have a higher risk of injury.

NUMBER OF SUBJECTS: Seventy-eight female NCAA Division III collegiate cross-country ($n = 24$) and track and field ($n = 54$) athletes (mean $\pm$ SD age, 19.7 ± 1.2 years; height, 166.2 ± 6.1 cm; weight, 60.5 ± 9.8 kg; BMI, 21.9 ± 2.7 kg/m²).

MATERIALS AND METHODS: During the first week of their season, athletes completed a survey on demographics, menstrual history, and prior injury. Athletes were prospectively followed by athletic trainers during their season to identify any injury that caused the athlete to miss 1 or more practices or competitions. Injuries were classified as overuse or acute. T tests were used to assess mean differences of continuous variables between injured and uninjured athletes. Odds ratios (OR) and 95% confidence intervals (CIs) were used to assess injury risk.

RESULTS: Thirty athletes (38.5%) experienced a time-loss injury with 23 athletes (29.5%) classified as having an overuse injury. Forty-three athletes (55.1%) reported a prior injury in the past year. Twenty-two athletes (28.2%) reported missing at least 1 period in the last year while 14 (17.9%) reported missing 3 or more periods. Twelve athletes (15.4%) reported that missing multiple menstrual periods in a year was a sign of being more fit or in better shape. No significant differences were found for age, height, weight, BMI, or number of missed periods between those who experienced or did not experience a time-loss injury ($P > .05$). No significant relationships were found between athletes missing 3 or more periods in the past year for any injury ($P = .71$) or overuse injury ($P = .57$). Athletes who believed missing multiple periods was a sign of being more fit or in better shape had a higher rate of any injury (OR = 4.0; 95% CI: 1.1, 14.8; $P = .03$) and overuse injury (OR = 7.0; 95% CI: 1.8, 26.7; $P = .002$). Athletes with prior injury in the past year had a higher rate of any injury (OR = 2.8; 95% CI: 1.1, 7.2; $P = .04$) and overuse injury (OR = 3.2; 95% CI: 1.1, 9.2; $P = .03$) during the competitive season than those without a history of prior injury.

CONCLUSIONS: Missing 3 or more periods in the past year was not associated with injury in collegiate cross country or track athletes. However, the belief that missing periods is a sign of being more fit was associated with a higher risk of any injury and overuse injury. Consistent with previous studies, prior injury was associated with increased risk of injury.

CLINICAL RELEVANCE: Over 15% of female collegiate cross country and track athletes believed that missing periods was a sign of increased fitness.

These athletes experienced a higher rate of injury during the season. Future studies should assess educational strategies on menstrual health for female athletes and its impact on injury risk.

SPL47

UNANTICIPATED CUT AND BACKPEDAL KINEMATICS IN FEMALE SOCCER PLAYERS AT HIGH RISK FOR ANTERIOR CRUCIATE LIGAMENT INJURY

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PURPOSE/HYPOTHESIS: A rapid, single leg deceleration with a change of direction is often cited as a typical noncontact anterior cruciate ligament (ACL) injury mechanism in female soccer players. However, screening tests with a double leg drop vertical jump (DVJ) have been utilized to prospectively predict injury and group female athletes into high-risk and low-risk groups. The relationship between a screening classification and more dynamic, single leg unanticipated cutting and backpedaling is unknown. The purpose of this study was to determine if "high-risk" compared to "low-risk" athletes, screened with a DVJ, exhibit aberrant kinematics during a rapid, single leg unanticipated changes of direction.

NUMBER OF SUBJECTS: Eighty-nine postpubertal female soccer players were included in this subgroup analysis.

MATERIALS AND METHODS: Three-dimensional motion analysis of an approach run with an unanticipated cue to either cut or backpedal was performed by each participant over artificial turf with embedded force platforms. Three randomly ordered trials of each movement were collected on each leg. 3 trials of a DVJ were also collected and used to stratify participants into low-risk ($n = 43$; mean $\pm$ SD age, 14.8 ± 1.5 years; height, 162.5 ± 6.6 cm; weight, 57.6 ± 54.9 kg) and high-risk ($n = 46$; mean $\pm$ SD age, 14.5 ± 1.6 years; height, 162.9 ± 4.5 cm; weight, 54.9 ± 8.3 kg) groups based on a previously determined cut point of 25.25 Nm of knee abduction moment. Independent t tests were utilized ($P < .05$) to determine if differences exist between risk groups (high, low) at initial contact (IC) in sagittal and frontal plane kinematics (ankle, knee, hip) during the unanticipated cut and backpedal conditions. Cohen's d effect size was also calculated.

RESULTS: Significantly greater knee abduction IC kinematics were found in the high-risk group (cut, $3.5^\circ \pm 2.4^\circ$; backpedal, $1.9^\circ \pm 2.2^\circ$) compared to the low-risk group (cut, $1.4^\circ \pm 3.2^\circ$; backpedal, $0.5^\circ \pm 2.6^\circ$) during both the cut ($P < .001$) and backpedal ($P = .006$). Further, the effect sizes (cut, $d = 0.76$; backpedal, $d = 0.60$) indicate a moderate to high effect. Statistically significant differences were not found in frontal plane ankle or hip kinematics ($P > .05$). In the sagittal plane at IC, there was less flexion at the hip in the high-risk group (cut, $38.8^\circ \pm 6.7^\circ$; backpedal, $38.2^\circ \pm 6.3^\circ$) compared to low-risk group (cut, $41.8^\circ \pm 5.7^\circ$; backpedal, $41.2^\circ \pm 6.9^\circ$; $P < .025$, $P = .037$). Moderate effect sizes between groups were found (cut, $d = 0.48$; backpedal, $d = 0.45$). Ankle and knee sagittal plane kinematics were not statistically different between groups ($P > .05$).

CONCLUSIONS: The high-risk athletes displayed decreased hip flexion as well as an increased knee abduction angle. Performing the cut and backpedal motions in a more hip extended posture may decrease the body's ability to absorb the forces of the movement, along with an increased abduction angle at the knee, may lead to future ACL tears.

CLINICAL RELEVANCE: Unanticipated, reactionary movements that mimic game-like scenarios evoke greater at-risk mechanisms of injury than a preplanned motion. Through proper screening and biomechanical analysis of unanticipated cutting and backpedaling movements, the sports medicine team may be able to intervene and reduce the risk of devastating ACL injuries.

SPL48

INITIAL VERSUS SUBSEQUENT INJURY AND ILLNESS INCIDENCE AMONG NATIONAL HOCKEY LEAGUE PLAYERS

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PURPOSE/HYPOTHESIS: Injury surveillance research in the National Hockey League (NHL) is scarce and oftentimes only reflects individual organization injury incidence. Furthermore, research is limited investigating initial versus subsequent injuries or illness incidence, impacting under-

standing of the extent of league wide injury burden. Technological advancements have provided opportunities to utilize publicly available data, offering potential for shared league wide injury surveillance and risk identification to determine initial and subsequent injury incidence. Thus, this study sought to determine initial versus subsequent illness and injury incidence stratified by body region and position.

NUMBER OF SUBJECTS: Ten thousand five hundred forty-nine (9734 injury or illness) NHL players between 2007-2008 and 2018-2019 seasons.

MATERIALS AND METHODS: Publicly available data were utilized through a computer iterative repeatable process. External validation demonstrated 98% accuracy with other reports. Players were 18 years or older playing during the study time frame. Injury was defined as an injury to a tendon, ligament, nerve, muscle, or bone. Illness was defined as a complaint or disorder reported by a player or team, not related to injury. Initial injury was defined as the first injury documented and all other injuries following the initial injury was defined as a subsequent injury. Incidence proportion (IP) and 95% confidence intervals (CI) for initial and subsequent injury and illness were calculated and stratified based on the orchard injury classification system and position played.

RESULTS: Ten thousand five hundred forty-nine (9734 injury or illness) athletes were included. Combined initial IP for injury and illness was 55.06 (95% CI: 54.06, 56.06) whereas subsequent injury and illness IP was 30.39 (95% CI: 29.84, 30.94). By position, centers had the highest initial and subsequent IP at 76.55 (95% CI: 73.20, 79.89) and 36.81 (95% CI: 35.21, 38.41); the wingers initial 54.43 (95% CI: 52.75, 56.11), subsequent 30.80 (95% CI: 29.86, 31.74); defense initial 53.09 (95% CI: 51.45, 54.73), subsequent 31.99 (95% CI: 31.01, 32.97); goalie initial 31.11 (95% CI: 30.51, 33.72), subsequent 15.96 (95% CI: 15.17, 16.74). Among body regions, Groin/Hip/Thigh represented highest initial IP at 5.05 (95% CI: 4.97, 5.13) and subsequent IP at 3.02 (95% CI: 2.98, 3.07), followed by Head/Neck initial IP of 3.56 (95% CI: 3.50, 3.61) and subsequent IP of 1.55 (95% CI: 1.53, 1.56). Initial illness IP was 6.26 (95% CI: 6.16, 6.37) compared to 4.79 (95% CI: 4.72, 4.87) subsequent IP.

CONCLUSIONS: Injury and illness incidence is high among NHL players with approximately 55 out of 100 players reporting an initial injury or illness and 30 out of 100 players reporting a subsequent injury or illness. Groin/Hip/Thigh followed by Head/Neck demonstrating the most injured body regions with center position players displaying the highest proportion of injuries among all position players.

CLINICAL RELEVANCE: Understanding injury burden by body region and position may aid clinicians and researchers to better target future injury mitigation programs based on the individualized needs of players. By understanding injury incidence based on initial versus subsequent injuries, clinicians may better understand cumulative injury burden among players.

SPL49

EFFECTS OF EARLY AND LATE ADOLESCENCE GROUPS ON IMMEDIATE POSTTRIAL FEEDBACK LANDING IN FEMALE ATHLETES

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PURPOSE/HYPOTHESIS: Neuromuscular training appears beneficial in reducing the risk of ACL injury. Immediate feedback is one element of such training that has been used to improve performance during motor tasks. However, landing mechanics may change with the maturation status of female athletes. The response to immediate feedback across levels of maturity is unknown. Our goal was to examine how the response to immediate post-trial feedback for landing may differ for early and late adolescent female athletes on vertical ground reaction force (vGRF) and knee to ankle (K/A) ratio. We hypothesized that late adolescents will have decreased vGRF and higher K/A ratios at pretest, posttest, and transfer task blocks and both groups will maintain these improvements during the transfer task.

NUMBER OF SUBJECTS: One hundred thirty female athletes, divided into 2 groups: 66 early (age, 11-14 years) and 64 late (age, 15-18 years).

MATERIALS AND METHODS: Participants completed drop landings from a 50-cm platform. Peak vGRF from each trial were measured from 2 custom

force plates (2000 Hz) and frontal plane video (100 Hz) were acquired for feedback. Immediate posttrial feedback of numeric peak vGRF, teeter totter image of loading symmetry, and frontal plane video reviewed with internally or externally focused feedback was provided in a standardized manner during 2 blocks of training (6 trials each). Pretests and posttests (6 trials each) with no feedback were completed after the training blocks, then a transfer task (6 trials) was completed where participants had to respond to a task where a ball was tossed to the participant to catch while landing. A 2-way repeated-measures ANOVA was used to determine if there were differences between groups (early and late) and across testing blocks (pre/post/transfer) on the mean of each block for peak vGRF and K/A ratio ($\alpha = .05$).

RESULTS: Peak vGRF was different between groups ($P = .035$), but not K:A ratio ($P = .146$). Changes across blocks (pre/post/transfer) were shown for both variables (each, $P < .001$). No interactions were present. Group differences were 5% to 10% greater for the early adolescents across testing blocks while K/A ratios were more similar (3%-5%). A 30% reduction in vGRF occurred immediately post training but increased 16% for the transfer task. Similarly, K/A ratio improved 11% post training but regressed 3% for the transfer task.

CONCLUSIONS: Both early and late adolescent female athletes demonstrated improvements in vGRF and K/A ratio immediately following feedback training. Both measures regressed during the transfer task but remained improved compared to the pretest block. The early adolescent females tended to land overall with greater vGRF, but had similar K/A ratios to the older adolescents across all testing blocks (pre/post/transfer).

CLINICAL RELEVANCE: Immediate visual feedback may be a useful tool for adolescent female athletes to influence vGRF and K/A ratio. Further investigations appear warranted to determine if such performance changes can be retained and reduce ACL injury rates.

SPL50

PATIENT-REPORTED MEASURES PREDICT RETURN TO PREINJURY SPORT ACTIVITY 2 YEARS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Patient-reported measures including International Knee Documentation Committee (IKDC2000) and Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaires are commonly used for assessing patients' perspectives of their knee symptoms, pain, function, sports activity, and disability. However, there is limited data on their ability to predict return to sport activities after anterior cruciate ligament reconstruction (ACLR). The purpose of this study was to determine whether IKDC2000 and KOOS subscales can discriminate return to preinjury sport activity 2 years after ACLR.

NUMBER OF SUBJECTS: Forty level I/II athletes 2 years after ACLR.

MATERIALS AND METHODS: Athletes completed the IKDC2000 and KOOS at 2 years after ACLR and indicated if they had returned to the same frequency, duration, and intensity of preinjury sport activities. All of IKDC2000 and KOOS subscales (KOOS-pain, KOOS-symptoms, KOOS-ADL, KOOS-Sport/Rec, and KOOS-knee-related quality of life [KOOS-QOL]) were evaluated by the univariate and multivariate logistic regression to determine discriminators of return to the same preinjury sport activity 2 years after ACLR. An analysis of the receiver operating characteristic (ROC) curve was used to determine the cutoff value for each scale that best identify those who return from not return to preinjury level of sports.

RESULTS: The rate of return to the same preinjury sport activity at 2 years after ACLR was 20% ($n = 8$). The univariate logistic regression model showed that the IKDC2000 (OR = 1.5; 95% CI: 1.02, 2.20; $P = .042$; ROC, 89.66; sensitivity, 1; 1 - specificity, 313), KOOS-QOL (OR = 1.03; 95% CI: 1.03, 1.24; $P = .008$; ROC, 59.38; sensitivity, 1; 1 - specificity, 344), KOOS-Sport/Rec (OR = 1.11; 95% CI: 1.00, 1.24; $P = .051$; ROC, 77.5; sensitivity, 1.00; 1 - specificity, 594) were significant discriminators of return to the same preinjury sports activity at 2 years after ACLR.

KOOS-pain ($P = .061$), KOOS-symptoms ($P = .092$), and KOOS-ADL ($P = .191$) were not discriminators for return to sport. In the multivariate model, the KOOS-QOL (OR = 1.14; 95% CI: 1.01, 1.30; $P = .044$) was the only predictor for return to preinjury level of sports.

CONCLUSIONS: The IKDC2000, KOOS-QOL, and KOOS sport and recreation predicted the return to preinjury sport activity at 2 years after ACLR. However, the KOOS-QOL subscale was the only predictor in the multivariable model and explained 75.7% of the variance.

CLINICAL RELEVANCE: Clinicians may improve athletes' awareness of their knee problems, improve athletes' confidence of their knee, and address knee difficulty to help with returning to preinjury sports activities. Clinicians may also use cutoff values for patient reported outcomes as identifiers for athletes that may not return to prior level of sports and give more attention to these aspects to increase the likelihood for return to sports.

SPL51

SINK OR SWIM? CLINICAL MEASURES ASSOCIATED WITH PAIN AND INJURY IN SWIMMERS: A SYSTEMATIC REVIEW

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PURPOSE/HYPOTHESIS: Shoulder injuries represent up to 91% of swimming injuries and can result in time loss from training and competition. The primary purpose of this study is to investigate objective measures utilized to assess swimmers, and to assess the relationship of abnormal test values to shoulder pain and injury in distinct age group/competition levels. A secondary aim to establish normative/expected values for these tests.

NUMBER OF SUBJECTS: Not applicable.

MATERIALS AND METHODS: Databases including MEDLINE (via OVID), Embase, CINAHL Complete, SPORTDiscus, and Scopus were searched from inception to November 2020. Studies assessing an objective measure (s) and shoulder pain and/or injury in age-group, collegiate, or elite level swimmers were identified for screening. A systematic review was conducted utilizing Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines employing 2 reviewers at each phase of the process and a third reviewer for conflict resolution. A risk of bias assessment for all articles included in this review was performed independently by 2 reviewers using the Methodological Items for Non-Randomized Studies (MINORS) assessment tool. The level of evidence for each study was ranked using the Oxford Center of Evidence Based Medicine guidelines. Disagreements for risk of bias and level of evidence were resolved by consensus. Objective measures, age/competition level of swimmers, and the relationship between objective measures and pain/injury was extracted for included studies. Clinical implications were evaluated qualitatively.

RESULTS: Twenty-two studies were included in this systematic review (Level I, 0; Level II, 4; Level III, 14; Level IV, 4). Level of agreeability of the risk of bias between the 2 reviewers was calculated with a correlation coefficient ($r = 0.80$). Moderate/strong level of evidence supported a relationship to shoulder pain/injury for increased laxity and lower values for horizontal adduction (HA) and internal rotation (IR) range of motion, middle trap strength, pectoralis minor and latissimus dorsi extensibility, and side bridge core endurance. Low level evidence supported a relationship between shoulder pain/injury and external rotation (ER) to IR strength ratios less than 0.68. Meta-analysis was not performed due to heterogeneous data collection techniques.

CONCLUSIONS: Clinical examination of the swimmer's shoulder should include the following objective clinical tests: (1) rotator cuff external rotation and internal rotation strength with the development off ER/IR ratios at 90° of abduction; (2) periscapular strength and scapular upward rotation excursion; (3) lateral core stability; (4) shoulder HA, ER and IR range of motion; (5) pectoralis minor and latissimus dorsi extensibility; and (6) assessment of glenohumeral laxity. There was insufficient data to determine normative values for these objective tests at varied age/competition levels.

CLINICAL RELEVANCE: This systematic review provides clinicians with an evidence-based array of objective clinical tests for evaluating swimmers at risk for shoulder pain and injury.

SPL52

REHABILITATION FOLLOWING SUBSCAPULARIS REPAIR WITH BICEPS TENODESIS IN AN ADOLESCENT OVERHEAD ATHLETE: A CASE REPORT

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BACKGROUND AND PURPOSE: Subscapularis tears are uncommon in adolescent athletes and limited information exists to guide physical therapy treatment. This case report describes the postoperative physical therapy progressions and outcome of an adolescent overhead athletes after subscapularis repair and biceps tenodesis.

CASE DESCRIPTION: A 14-year-old right hand dominant male overhead athlete presented to an orthopaedic clinic 1 month after a fall on outstretched dominant shoulder. Chief complaint was anterior shoulder pain during the late cocking phase of the overhead throwing motion with resultant decrease in control and velocity. Imaging revealed a complete tear of the subscapularis and a partial-thickness tear of the biceps tendon. Patient underwent a subscapularis tendon repair and biceps tenodesis. Physical therapy interventions followed a sequential and multiphased approach based on time for tissue physiologic healing and individual patient progression. Rehabilitation consisted of 4 phases: immediate postoperative (protecting the integrity of the repair and passive range of motion), controlled motion (gradual improvement of strength and neuromuscular control), advanced strengthening (power), and return to sport (interval sports program with emphasis on strength and neuromuscular control). We measured: (1) shoulder range of motion (flexion, external rotation [ER] at 90°, and internal rotation [IR] at 90°); (2) shoulder strength (elevation, and ER and internal rotation [IR] at 90°); and (3) patient-centered questionnaires (Pennsylvania Shoulder Score [PENN] and Patient-Specific Functional Scale [PSFS]). At discharge, we used the Shoulder Arm Return to Sport (SARTS) battery to assess readiness of return to sport.

OUTCOMES: The patient completed 22 sessions of physical therapy over 31 weeks before being cleared to return to sport. At discharge, PENN score increased 54 points (minimal clinically important difference [MCID], 11.4 points), PSFS increased 7.33 points (MCID, 3 points); shoulder flexion range of motion increased 160°, ER increased 95°, IR increased 30°; shoulder elevation strength increased 7.71 kg, ER increased 6.35 kg, and IR increased 8.16 kg. SARTS results at discharge: closed kinetic chain upper extremity stability test (18 repetitions), drop test (29 repetitions), ball abduction external rotation (11 repetitions), and overhead snatch (19 repetitions).

DISCUSSION: Subscapularis and biceps tendon injuries in the overhead adolescent athletes typically presents as activity-related dysfunction with loss of velocity and increased pain. Returning an adolescent overhead athlete back to sport after subscapularis repair and biceps tenodesis requires an extensive physical therapy treatment and patient's compliance is critical. After our multiphase physical therapy progression, our patients made improvements on all outcome domains that surpassed established threshold of clinical significance changes. Due to the lack of references for adolescent overhead athletes with this injury, further research is necessary.

SPL53

A FOLLOW-UP STUDY OF PHYSICAL THERAPIST KNOWLEDGE AND STRATEGIES USED FOR TREATMENT AND PREVENTION OF RELATIVE ENERGY DEFICIENCY IN SPORTS

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PURPOSE/HYPOTHESIS: The Female Athlete Triad was first described as 3 components occurring on a continuum: low energy availability (LEA), menstrual dysfunction (MD), and low bone mineral density (LBD). In 2014, it was renamed Relative Energy Deficiency in Sports (RED-S) to include both men and women having 1 or more of the components PT education about the syndrome has been promoted over the years but it is unclear if knowledge and practice patterns regarding prevention and treatment of the condition have improved. The purpose of this study was to compare knowledge and practice behaviors PTs currently use for the FAT/RED-S to knowledge and strategies used 15+ years ago.

NUMBER OF SUBJECTS: Three hundred six Academy of Orthopaedic Physical Therapy and American Academy of Sports Physical Therapy members.

MATERIALS AND METHODS: A survey instrument of approximately 35 questions was tested for content validity and administered to PTs practicing in the United States in 2005 and 2021. Descriptive statistics summarized demographic and general practice information. Likert scales ranked the likelihood that PTs employed certain treatments and referrals. Narrative descriptions of treatment and prevention strategies were compared.

RESULTS: In 2021, 106 PTs responded to the survey, compared to 205 in 2005. In 2021, 55% of the respondents were female and mostly between 25 and 35 years; in 2009 50% were female and mostly between 36 and 55 years; and practiced for 16+ years. Although the majority of participants in both studies stated that they could accurately list the components of the syndrome, the 2021 respondents had a much higher percentage of accurate answers, compared to those in 2005. The most frequently practiced treatment strategies reported in 2021 were similar to those in 2005, and included: nutritional education, multidisciplinary consultation, and replacing cardiovascular exercise with resistance training. The most common Prevention strategies for the 2021 respondents included multidisciplinary education and the use of preparticipation screening examinations; and in 2005, screening exams and observing for at-risk behaviors were top priorities. The Likert Scale results indicated that treatment strategies and referral sources used in 2021 were similar to those used in 2005 with priority given in the following order: discussing the condition with the athlete; discussing the condition with the athlete's physician and parents, and referring the athlete to a Dietitian. A significantly greater frequency of referrals to dietitians, ATCs, and psychologists (in that order) was reported in the 2021 survey compared to the results in 2005 ($P = .0001$).

CONCLUSIONS: This study found that overall knowledge of the FAT/RED-S for physical therapists has improved with regard to recognition and strategies for treatment and prevention of the condition.

CLINICAL RELEVANCE: Improved knowledge and strategies used for the treatment and prevention of FAT/RED-S observed in this study may be attributed to greater exposure and improved education about the condition, greater access to health care professionals who specialize in FAT/RED-S, and a broader emphasis on a multidisciplinary team approach.

SPL54

RELATIONSHIP OF SPORT VARIABLES WITH STRESS URINARY INCONTINENCE IN NULLIPAROUS COLLEGIATE ATHLETES

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PURPOSE/HYPOTHESIS: Female athletes have a significantly higher prevalence of stress urinary incontinence (SUI) than their nonexercising peers. While exercise appears to be protective against many other disease conditions, it may be linked to the development of SUI in an otherwise healthy population. The purpose of this study was to explore the relationship between sport and athlete characteristics and SUI prevalence in nulliparous female collegiate athletes.

NUMBER OF SUBJECTS: Two hundred nine NCAA Division II female nulliparous collegiate athletes, aged 18 to 29 years.

MATERIALS AND METHODS: A survey was distributed through Qualtrics, an online survey platform, to all female student-athletes at 3 NCAA Division II universities. The International Physical Activity Questionnaire (IPAQ) was used for physical activity measures (intensity and volume) and the International Consultation on Incontinence Questionnaire Short Form (ICIQ UI SF), was used to classify SUI. Survey measures included participant demographics (height, weight, BMI, age), history of disordered eating, incontinence status, physical activity intensity, and sport/activity characteristics (type of sport, years of sport participation, and volume of sport training). Data were assessed for normality and analyzed using Mann-Whitney U tests in SPSS. Significance of $P < .05$ was established a priori.

RESULTS: Mann-Whitney U analyses revealed athletes participating in high impact sports demonstrated greater SUI rates and severity than low and moderate impact sports ($P = .03$). Other variables associated with an increase in SUI were participation in vigorous physical activity >5 days per week ($P = .037$), and a BMI ≥ 25 kg/m² ($P = .05$). No statistically significant differences were found with physical activity intensity, disordered eating, years of training, or training volume.

CONCLUSIONS: This study confirms that SUI is highly prevalent in nulliparous female athletes. Athletes most at risk are those with a BMI ≥ 25 kg/m² or who engage in high impact and/or high intensity activity >5 days of the week.

CLINICAL RELEVANCE: The results of this study helps physical therapists, athletic trainers, and other medical professionals to understand training elements related to SUI. Efforts are needed for education and early prevention to mitigate development of SUI in this population. Physical therapists with pelvic health training should work closely with the collegiate sports medicine, athletic training, and strength and conditioning teams to develop an appropriate pelvic floor muscle training program for athletes most at risk.

SPL55

PATIENT AND PROVIDER PERSPECTIVES ON BOOSTER VISITS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A NOVEL DELIVERY MODEL

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PURPOSE/HYPOTHESIS: The current model of care after ACL reconstruction (ACLR) in young athletes is failing. Over 30% suffer a second ACL injury and as few as 50% return to preinjury level of activity. Booster visits, or periodic follow-up after standard care, can improve outcomes and decrease cost in patients with conditions such as knee osteoarthritis. The aim of this study was to explore patient/parent and physical therapist perspectives on booster visit implementation in young patients after ACLR and return to sport (RTS) as a means to improve outcome.

NUMBER OF SUBJECTS: Ten patients (mean $\pm$ SD age, 15.2 ± 2.2 years) after ACLR who received 2 booster visits after release to RTS (with parent/guardian) and 5 physical therapists who delivered booster visits.

MATERIALS AND METHODS: Semi-structured interviews using an open-ended interview guide were conducted, digitally recorded, and transcribed. A pragmatic realist approach with thematic analysis was utilized over 4 stages. The first stage entailed open-coding performed by 2 investigators with a focus on the specified aim of the study. Next, the codes were cross-checked and synthesized through multiple rounds of discussion until a consensus on a set of primary and secondary themes was reached. The third stage involved case-by-case analysis of each transcript to determine theme saturation, identify theme frequencies among the interviews, and detect any inconsistencies among participants' perceptions. The final stage of analysis utilized inductive open coding with thematic integration to the Practical, Robust Implementation and Sustainability Model (PRISM) framework.

RESULTS: Using the PRISM framework, topics related to design themes, recipient characteristic themes, external environment factors and implementation/sustainability infrastructure themes were identified with respect to perceived barriers and facilitators to successful booster visit implementation. Characteristics of the PRISM domain of intervention design included boosting confidence and assisting with transitioning to sport. Characteristics of the recipient domain included resource availability and balance of treatment and RTS demands. External environment characteristics included access to resources and insurance limitation concerns and were reported most by patients. Characteristics for implementation/sustainability infrastructure included optimization of frequency and ease of clinical use. Additional benefits noted mostly by patients, included ability to maintain patient/therapist alliance while physical therapists noted an opportunity to create a shared decision-making model to customize the booster intervention.

CONCLUSIONS: This study provides insight into the perceived experiences of patient, parents, and physical therapists as they participate in booster visits after ACLR and RTS. Improved awareness of the challenges and facilitators offers the opportunity for physical therapists to help personalize and optimize the delivery of booster visits after ACLR.

CLINICAL RELEVANCE: This study provides insight regarding elements of booster visit service delivery that physical therapists can use to optimize the rehabilitation process for adolescent patients after ACLR.

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RELATIONSHIP BETWEEN 2-DIMENSIONAL FRONTAL PLANE PROJECTION ANGLE AND 3-D KINEMATICS IN PATIENTS WITH PATELLOFEMORAL PAIN

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PURPOSE/HYPOTHESIS: Visual movement assessments are commonly used in clinical practice to objectively measure aberrant movement patterns in the frontal plane. Clinicians use frontal plane projection angle (FPPA) to assess lower extremity functional movements/tasks, particularly in patients with patellofemoral pain (PFP), as lower extremity malalignment has been suggested as a possible contributor to the etiology of PFP. The purpose of this study was to describe the variability in the contributions of 3-D lower extremity kinematics to FPPA in active Service members with PFP.

NUMBER OF SUBJECTS: Thirty-six active-duty service members with PFP (mean $\pm$ SD age, 32.0 $\pm$ 8.9 years; 11 female).

MATERIALS AND METHODS: Patients performed 1 set of 5 consecutive anterior step-downs on the painful limb on a 4- or 6-inch box with their hands on their hips. Peak hip internal rotation (IR), hip adduction (ADD), rearfoot eversion (EV), and pelvic drop (PD) were measured using 3-D kinematics recorded using a 12-camera, passive-optical motion capture system at 120 Hz with simultaneous digital camera video. Two-dimensional frontal plane projection angle (2-DFPPA) was measured from the videos using Kinovea software, taken at the point of maximal knee flexion and compared to the FPPA extrapolated from the 3-D motion capture data (3-DFPPA). Pearson correlations were used to examine the associations between 2-DFPPA and 3-D kinematic variables. Linear regression was used to determine if the 3-D variables could predict 2-DFPPA. Commonality analysis was also used to decompose the variance into the amount of 2-DFPPA uniquely explained by the 3-D variables into independent commonality coefficients.

RESULTS: Two-DFPPA and 3-DFPPA demonstrated a moderate correlation ($r = -0.55$, $P < .01$). 2-DFPPA showed a weak but significant independent correlations to IR and EV (both $r = -0.33$, $P = .05$). ADD was excluded from the regression and commonality analyses secondary to both high correlation with the other independent variables to reduce multicollinearity. 2-DFPPA can be predicted from IR, EV, and PD, $F_{3,32} = 3.2$, adjusted $R^2 = 0.19$, $P = .02$; with EV being a significant independent predictor at $P = .03$, and IR trending towards significant independent prediction at $P = .06$. From the commonality analysis, IR, EV, and PD explained 11%, 11%, and 2% of the total variance in 2-DFPPA, respectively; IR, EV, and PD explained 8%, 12%, and 6% of the unique variance, respectively.

CONCLUSIONS: The moderate correlation between 2-D and 3-D analysis of FPPA suggests that, although 2-D FPPA analysis is a reliable and valid measure, it cannot be considered a direct measurement of frontal plane alignment. The interactions of IR, EV, and PD should be considered when investigating their associations with 2-D FPPA.

CLINICAL RELEVANCE: Secondary to the contribution of pelvic, hip, and ankle motion, 2-D FPPA analysis should be considered as a composite assessment of dynamic lower extremity alignment.

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PATIENT TOLERANCE AND SIDE EFFECTS OF BLOOD FLOW RESTRICTION TRAINING AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN ADOLESCENTS

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PURPOSE/HYPOTHESIS: Blood flow restriction training (BFRT) has gained popularity in the rehabilitation setting due to its benefits in reducing muscle atrophy and mitigating strength deficits following anterior cruciate ligament reconstruction (ACLR). While the effectiveness and safety of BFRT has been well studied in the healthy adult population, there is limited information about the use of BFRT in the adolescent population, in relation to patient tolerance and reported side effects post ACLR. The purpose of this study was to investigate and record patient tolerance and reported/observed side effects to BFRT during postsurgical ACL rehabilitation in adolescents. We hypothesized that patient tolerance and adverse events to BFRT will be consistent with previously published literature.

NUMBER OF SUBJECTS: Fourteen patients post ACLR (8 female; mean $\pm$ SD age, 15.17 $\pm$ 1.74 years).

MATERIALS AND METHODS: Patients followed a standardized BFRT exercise protocol over 12 weeks, completing 3 exercises per session, with load progression based on the patient's perceived level of exertion (RPE). Patients utilized a Personalized Tourniquet System with a regulated limb occlusion pressure (LOP) of 80%. Upon completion of exercise, patients reported any side effects and adverse events, which were also observed/monitored by a physical therapist at subsequent visits. Occurrences were recorded per session, and tallied for weeks 1 to 4, 5 to 8, 9 to 12, and cumulatively over the 12-week period.

RESULTS: This prospective study included 14 patients, between 12 and 18 years of age, enrolled in an ongoing registered clinical trial investigating the impact of BFRT after primary ACLR at Connecticut Children's from January 2020 to present. Three hundred twenty-seven total sessions were completed between all patients, with each patient completing an average of 23.36 sessions. The highest reported adverse events to BFRT included itchiness of the occluded limb (9.17%) and the inability to finish the prescribe exercise (9.79%). Other reported adverse events included dizziness (0.61%), transient numbness (0.92%), tingling (2.45%), and needing to decrease the LOP (2.54%). There were zero reports of deep vein thrombosis (DVT), subcutaneous hemorrhage (SubQ hemorrhage), and fainting across all patients.

CONCLUSIONS: Our results show the utilization of BFRT in adolescents after ACLR is consistent with that published in adults. This preliminary data suggests BFRT may be well tolerated in the ACLR adolescent population with minor reported side effects. Further investigations are warranted to continue to evaluate patient tolerance and safety with BFRT as our results represent a small sample size.

CLINICAL RELEVANCE: With minor reported side effects, the utilization of BFRT may be a useful intervention to implement in the early stages of postoperative rehabilitation, as it has been posed to allow increased muscle adaptation and hypertrophy under low loads and intensity.

SPL58

PREDICTIVE MODELS FOR MUSCULOSKELETAL INJURY RISK: STATISTICAL APPROACH MAKES ALL THE DIFFERENCE

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PURPOSE/HYPOTHESIS: To compare performance between an injury prediction model that categorized predictors and one that did not, and to compare selection of relevant predictors for a final model when using univariable significance versus assessing nonlinear relationships. Study design was a validation and replication of a previous prospective prediction model.

NUMBER OF SUBJECTS: One thousand four hundred sixty-six healthy military service members.

MATERIALS AND METHODS: Individuals were followed for 1 year after physical performance, medical history, and sociodemographic variables were collected. The first model was the original model which dichotomized 8 predictors. The second model (M2) included the 8 original predictors and the third model (M3) included 15 predictors. For M2 and M3, continuous predictors were kept continuous and were assessed for nonlinearity. Model performance was assessed with R^2 , calibration slope, and discrimination. Decision curve analysis was performed with risk thresholds from 0.25 to 0.50.

RESULTS: Four hundred seventy-eight personnel sustained an injury. The original model demonstrated poorer R^2 (Original, 0.07; M2, 0.64; M3, 0.65), calibration slope (Original, 0.86; 0.62, 1.10; M2, 0.93; 0.77, 1.09; M3, 0.90; 0.75, 1.05), and discrimination (Original, 0.62; 0.58, 0.66; M2, 0.90; 0.89, 0.92; M3, 0.90; 0.89, 0.92). At 0.25 injury risk, M2 and M3 demonstrated a 0.47 net benefit improvement, at 0.50 injury risk, M2 and M3 demonstrated a 0.36 net benefit improvement compared to the original model.

CONCLUSIONS: Model performance was substantially worse in the original model with dichotomized variables, resulting in very poor performance compared to the other 2 models. This demonstrates how prediction models suffer in performance when established recommendations for developing prediction models are not followed.

CLINICAL RELEVANCE: It is imperative to keep predictors continuous when evaluating injury risk, which is not commonly reflected in most of the current sports-related injury prediction publications. Solutions for personalizing prediction models can still be clinically easy to understand and use by implementing interactive nomograms, while maintaining continuous level predictors.

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RETURN-TO-SPORT OUTCOMES FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION WITH CONCOMITANT MENISCUS ALLOGRAFT TRANSPLANTATION VERSUS ISOLATED ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Meniscus allograft transplantation (MAT) is often performed in the setting of ACL reconstruction (ACL-R) in an attempt to restore proper arthrokinematics and load distribution in meniscus deficient knees. Clinical outcomes following combined MATs with ACL-R in athletic populations are scarce and highly variable. In addition, success indicators for most existing studies are often isolated to patient reported outcomes, leaving little evidence to determine the functional capacity of these individuals. Therefore, the purpose of this study was to compare (1) patient reported outcomes, (2) objective functional performance, and (3) reinjury and return-to-sport rates for patients receiving ACL-R with concomitant MAT versus isolated ACL-R.

NUMBER OF SUBJECTS: Seventy-nine patients (34 ACL-R with MAT, 45 with isolated ACL-R) from a single surgeon patient registry.

MATERIALS AND METHODS: All data were obtained between November 2014 and May 2019. Patients undergoing isolated ACL-R were age and gender matched to patients following ACL-R with concomitant MAT. Functional performance testing included: passive knee range of motion (ROM), isometric hip abduction strength, single-leg balance, single-leg hop testing, and agility testing. Patient-reported outcomes consisted of the International Knee Documentation Committee (IKDC-2000) and ACL Return to Sport after Injury scale (ACL-RSI) psychological readiness scores at time of return-to-sport, and single assessment numeric evaluation (SANE) at 2 years. Surveillance was conducted for the time of return-to-sport, level of sports participation, and reinjury and complication rates following surgery. Group comparisons were analyzed using generalized linear models and an a priori alpha level of .05 was selected for all comparisons.

RESULTS: At time of return-to-sport the ACL-R with concomitant MAT group exhibited lower knee function (IKDC-2000, 82.4 ± 13.8 versus 93.7 ± 10.1 , $P = .001$), psychological readiness (ACL-RSI, 62.8 ± 21.3 versus 80.3 ± 9.7 , $P = .001$) and a longer time to return-to-sport (10.8 ± 3.2 months versus 7.8 ± 1.8 months, $P = .001$), when compared to the isolated ACL-R group. Additionally, the ACL-R with concomitant MAT group had higher knee flexion ROM deficits (6.4 ± 5.6 versus 3.0 ± 2.6 , $P = .011$) and lower single-leg hop symmetry (90.2 ± 12.3 versus 97.1 ± 5.3 , $P = .001$). At 2 years the ACL-R with concomitant MAT group also displayed lower self-reported knee function (SANE score, 80.9 ± 16.1 versus 92.5 ± 8.3 ; $P = .001$). There were no differences between groups regarding ACL graft reinjury rate (3.0% versus 3.3%, $P = .943$).

CONCLUSIONS: Patients undergoing ACL-R with concomitant MAT exhibit lower rates of return-to-sport, delayed return-to-sport timeline, and return to a lower level of sport participation compared to those undergoing an isolated ACL-R.

CLINICAL RELEVANCE: Providers should consider the potentially diminished functional capacity and decreased level of return-to-sport when counseling patients following ACL-R with concomitant MAT.

SPL60

KNEE STRENGTH OUTCOMES IN ADOLESCENTS BY AGE AND SEX DURING LATE-STAGE REHABILITATION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: To determine if knee strength differences exist according to age group and sex among adolescents during late-stage anterior cruciate ligament reconstruction (ACLR) rehabilitation.

NUMBER OF SUBJECTS: One hundred forty-four (56.9% female; mean $\pm$ SD age, 15.3 ± 1.5 years; days since surgery, 228.2 ± 41.2).

MATERIALS AND METHODS: A retrospective review of adolescent patients who underwent primary ACLR with a hamstring tendon autograft was performed. Patients completed a standardized isokinetic ($60^\circ/\text{s}$) knee extension and flexion strength assessment during late-stage rehabilitation testing. Peak torque was normalized to the patient's body mass (Nm/kg) and used to calculate Limb Symmetry Index (LSI). Patients were categorized into early (age, 11-14 years) and middle (age, 15-17 years) adolescence. A 2-way MANOVA was used to examine strength differences according to age group and sex.

RESULTS: Differences in quadriceps peak torque were identified between age groups on the involved ($P = .001$) and uninvolved limbs ($P < .001$), however, no differences in quadriceps peak torque were found between age groups when normalized to body mass ($P = .16-.49$). Differences between groups according to sex were identified for each strength outcome ($P < .01$), with decreased normalized quadriceps (12%-13%) and hamstring (13%-16%) peak torque for females. No interactions between age group and sex were noted ($F_{8,133} = 1.48$, $P = .17$).

CONCLUSIONS: Early adolescents produced less quadriceps and hamstring peak torque compared to middle adolescents during late-stage rehabilitation after ACLR, however, no differences were found between age groups when peak torque was normalized to body mass. Females had decreased normalized quadriceps and hamstring peak torque compared to males.

CLINICAL RELEVANCE: There is limited evidence guiding return to sport decision making in the management of young adolescents with ACL injuries and current literature is biased towards older adolescents. These results may add useful context when aiming to develop adolescent-specific strength goals, examine patient function, or design studies to investigate patient outcomes. Normalized knee extension strength in young adolescents may differ from adults and these sex- and age-specific strength outcomes could help inform targeted rehabilitation strategies when treating adolescents after ACLR.

SPL61

PRESEASON TESTING AND INJURY RATES IN MEN'S AND WOMEN'S DIVISION II SOCCER PLAYERS

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PURPOSE/HYPOTHESIS: Athletes perform preseason tests to help collegiate coaches and trainers determine an athlete's readiness to compete. A common preseason endurance test is the beep test (a 20-m shuttle run in time with beeps). Minimal research has been done to identify relationships between preseason performance testing and lower extremity injuries. Therefore, the purpose of this study was to determine if the beep test had any relationship to lower kinetic chain injuries and other preseason tests.

NUMBER OF SUBJECTS: Division II athletes ($n = 67$) from Maryville University men's ($n = 40$) and women's soccer teams ($n = 27$) between the seasons of 2018 and 2020.

MATERIALS AND METHODS: Variables included: beep test distance, coach-selected beep test cut-score (men, 2400 m; women, 1240 m), sprint speed, 4 force plate tests (jump height, peak propulsive force, peak landing force, and time to stabilization). Data Analysis: An odds ratio between injury rates and the beep test cut scores for the men's and women's teams was performed to see if below-the-cut beep testing scores were an accurate predictor of injuries. An independent t test was performed to determine if meeting the expected beep test cut score, implying the athlete's readiness for sport, created a significant difference between groups within any of the other preseason tests.

RESULTS: The number of athletes who met or surpassed the coach-selected beep test cut score was 17/40 men and 9/27 women. There were a total of 11 injuries (7 men, 4 women). Those who performed above the beep test cut score had no significant difference in scores across all preseason

testing compared to those that did not (jump height, $P = .38$; peak propulsive force, $P = .95$; peak landing force, $P = .28$; and time to stabilization, $P = .07$). Although there was a trend for time to stabilization, it was in the opposite direction as expected; those who were above the cut score took longer to stabilize following a single-leg hop than those under the cut score. The odds ratio (2.21, $P = .24$) showed that below-the-cut beep testing scores were not a significant means to predict an injury in an athlete. **CONCLUSIONS:** Achieving the coach-selected cut score for the beep test was not a significant predictor of lower kinetic chain injury in DII soccer players, nor did the cut score demonstrate a difference in performance on any other preseason test.

CLINICAL RELEVANCE: While use of intermittent endurance testing has been validated to show the aerobic fitness of the athlete, our results indicated that the use of a beep test cut score was not a predictor of injury or field readiness in DII soccer players. Future research should aim to explore tests that are better able to assess the quality of movement (strength, power, speed, endurance, agility and coordination) to determine an athlete's readiness for sport.

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EFFECT OF HEAD ACCELERATIONS ON DYNAMIC BALANCE IN COLLEGIATE WOMEN'S RUGBY

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PURPOSE/HYPOTHESIS: While the effect of concussive events on balance are well reported, the effect of subconcussive impacts on balance are not well known. The objective of this study is to determine the effect of subconcussive impacts on dynamic balance over the course of a competitive rugby season. We hypothesize there will be a positive linear relationship between number/severity of impacts and degradation of dynamic balance performance over the course of a season.

NUMBER OF SUBJECTS: Twelve female collegiate club rugby athletes (mean $\pm$ SD age, 20 ± 0.9 years; height, 167 ± 8 cm; weight, 81 ± 18 kg).

MATERIALS AND METHODS: Athletes participated in a battery of pre and post-season tests including the Y Balance Test (Perform Better, West Warwick, RI). Through the course of the season, head accelerations were monitored using the Prevent Biometrics Inertial Measurement Mouthguard (IMM) (Edina, MN). Athletes were given as many practice trials as desired prior to performing 3 trials of the Y Balance Test. Y Balance reach scores were averaged within anterior, posterior-lateral, and posterior-medial directions, normalized to leg length, then summed to create a composite score. The composite score for both legs was then combined to provide a bilateral measure of reach distance. Participant's hands and heel position were unconstrained during testing and shoes were removed. Data were collected at each practice and game throughout the season. The trigger threshold for each IMM was set at 10 g. Data were collected on peak linear acceleration (PLA) and peak rotational acceleration (PRA) for each impact through the Prevent data management system.

RESULTS: Significant linear correlations were found between sum total of PLA and composite dominant leg ($r = -0.585$, $P = .046$) and combined bilateral score ($r = -0.615$, $P = .033$). Correlations were also found between total count of impacts over 10 g and composite dominant leg ($r = -0.653$, $P = .021$), the composite nondominant leg ($r = -0.687$, $P = .014$), and the combined total ($r = -0.731$, $P = .007$). There were no correlations between PRA sum and total results or season median measures of PLA and PRA.

CONCLUSIONS: Results indicate subconcussive impacts may affect dynamic balance over the course of a competitive season of women's collegiate rugby. This research indicates impacts that do not result in concussions may still negatively affect balance in athletes. The number of impacts and the total linear acceleration impact load are correlated with decreased dynamic balance. Median impact severity and rotational accelerations were not significantly associated with changes in dynamic balance.

CLINICAL RELEVANCE: Recognizing the effect of subconcussive impacts underscores the importance of minimizing the number and severity head impacts during participation. Tackling training, competition laws, and contact restrictions during training may be an effective avenue to reduce these impacts.

SPL63

INITIAL KINETIC-CHAIN INJURIES INCREASE RISK FOR SUBSEQUENT ARM INJURIES IN BASEBALL PITCHERS

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PURPOSE/HYPOTHESIS: (1) To investigate the relationship between initial trunk or lower extremity injury and subsequent arm injury; (2) To investigate the relationship between initial shoulder or elbow injury and subsequent arm injury.

NUMBER OF SUBJECTS: Two hundred ninety-seven pitchers.

MATERIALS AND METHODS: A 7-year prospective injury risk study was conducted with MiLB pitchers. Pitches, athlete exposures (AE), and arm injuries (1 day's time loss) were collected. An injury was considered initial when it was the first injury, and until the pitcher had fully recovered and been cleared by the sports medicine team to return to competition for at least 1 game. A subsequent injury was defined as an injury to a body part following initial injury. At a beta of 0.80, alpha of .05, a follow-up during full season, and an injury rate of 30% from preliminary data from 2012, a total of 290 pitchers were required to perform a Cox survival analysis. Cox survival analyses with 95% confidence intervals (95% CIs), risk ratio (RR), and risk difference (RD) were performed. Confounders controlled for included: age, body mass index, arm dominance, seasonal pitch load, number of pitching appearances, and prior arm injury. Sensitivity Cox analyses included only moderate or severe lower extremity or trunk injuries and only moderate or severe initial arm injuries.

RESULTS: Two hundred ninety-seven pitchers participated (player days, 85270). Arm injury incidence was 11.4 arm injuries/10 000 AEs and lower extremity and trunk injury incidence was 5.2 injuries per 10 000 AEs. Pitchers that sustained a lower extremity or trunk injury demonstrated a greater hazard (2.6; 95% CI: 1.2, 5.6; $P = .019$) of sustaining an arm injury. Pitchers that sustained an initial shoulder injury demonstrated greater hazard of 9.3 (95% CI: 1.1, 83; $P = .047$) of sustaining a subsequent shoulder or elbow injury compared to pitchers that sustained an initial elbow injury. Pitchers that sustained a lower extremity or trunk injury demonstrated no difference in subsequent arm injury risk (RR = 1.1; 95% CI: 0.9, 1.2; RD, 3.0; 95% CI: -9.7, 15.6). Pitchers that sustained an initial shoulder injury demonstrated increased risk (RR = 4.3; 95% CI: 1.1, 17.4; RD, 19.7; 95% CI: 6.1, 33.3). Sensitivity analyses demonstrated similar results.

CONCLUSIONS: The incorporation of time and exposure demonstrated an increased subsequent arm injury risk in pitchers that sustained an initial lower extremity or trunk injury. Pitchers that sustained an initial shoulder injury demonstrated a greater risk and hazard of sustaining a subsequent arm injury, compared to pitchers that sustained an initial elbow injury. However, this secondary analysis should be interpreted with caution.

CLINICAL RELEVANCE: While absolute subsequent arm injury risk is similar following a lower extremity or trunk injury, clinicians should monitor risk with workload accumulation, which may be related to pitching compensatory strategies in a fatigued state. Pitchers that sustain a shoulder injury should be evaluated and perform both shoulder and elbow rehabilitation strategies prior to return to sport.

SPL64

ELITE YOUTH SOCCER PLAYERS INCREASED HAMSTRING STRENGTH THROUGHOUT A 9-MONTH SEASON

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PURPOSE/HYPOTHESIS: The relationship of decreased hamstring strength and increased prevalence of hamstring injury have previously been reported in senior level elite men's soccer. Targeted strengthening of the hamstrings throughout the course of a season with the Nordic Hamstring Exercise (NHE) has demonstrated an increase of hamstring strength and decreased prevalence of hamstring injury. The purpose of this study was to examine hamstring strength in elite youth academy over the course of a competitive season. We hypothesized that soccer players would demonstrate increased hamstring strength as a result of soccer participation.

NUMBER OF SUBJECTS: Participants were healthy elite youth soccer players (mean $\pm$ SD age, 14.29 $\pm$ 1.89 years; height, 168.34 $\pm$ 11.3 cm; mass, 59.39 $\pm$ 13.9 kg) spread across U19, U17, U15, and U14 teams of a youth soccer academy program. All participants were fully participating in matches and training at the time of testing.

MATERIALS AND METHODS: Participants were tested in 6 to 8 weeks over the course of increments over the course of 38 weeks. Testing was dictated by match schedule with testing always occurring at least 2 days following match participation. Demographics were taken each time to control for rapid growth during maturity and identify currently injured athletes by team athletic trainer report. Strength measurements were assessed utilizing the NordBord (Vald Performance, Brisbane, Australia) while the athlete performed the NHE. All measurements were summed and normalized to athlete tibia length and body mass. A 1-way repeated-measures ANOVA was used to assess for changes in hamstring strength across time ($P < .05$).

RESULTS: Mauchly's test of sphericity indicated that the assumption of sphericity had been violated ($\chi^2_{14} = 235.25$, $P < .0001$) and therefore, a Greenhouse-Geisser correction is reported $\epsilon = .293$. The results show that hamstring strength significantly changed over time ($F_{1.46, 68.06} = 4.48$, $P = .024$). Pairwise comparisons demonstrated that strength trended to increase over time with week 6 testing (mean $\pm$ SD, 3.85 $\pm$ 0.63) demonstrating significantly greater strength values than week 1 (mean $\pm$ SD, 3.49 $\pm$ 0.72; $P < .001$), week 2 (mean $\pm$ SD, 3.59 $\pm$ 0.53; $P < .001$), and week 3 (mean $\pm$ SD, 3.56 $\pm$ 0.60; $P < .001$).

CONCLUSIONS: Eccentric hamstring strength increases over the course of a season through regular soccer participation in healthy elite youth soccer players.

CLINICAL RELEVANCE: Youth soccer athletes can increase their eccentric hamstring strength throughout the season without regular isolated strengthening. Soccer athletes do not achieve increased eccentric hamstring strength until halfway through a competitive season which may have an impact on early season hamstring injury risk.

SPL65

PHYSICAL ACTIVITY PREDICTS KINESIOPHOBIA AT RETURN TO PLAY FOR ADOLESCENT ATHLETES WITH PERSISTENT POSTCONCUSSION SYMPTOMS

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PURPOSE/HYPOTHESIS: Physical activity (PA) is recommended following concussion to improve recovery time, however, postinjury fear of pain with movement (ie, kinesiophobia) may limit activity levels. The relationship between PA during concussion recovery with kinesiophobia is unknown. The purpose of our study was to examine the correlation between PA level and kinesiophobia between initial evaluation and return to play (RTP) clearance among adolescents who did and did not experience persistent postconcussion symptoms (PPCS). We hypothesized that higher levels of PA would be associated with greater reductions in kinesiophobia from initial to RTP visits among both groups.

NUMBER OF SUBJECTS: Forty-one.

MATERIALS AND METHODS: Participants rated their kinesiophobia severity using the Tampa Scale of Kinesiophobia (TSK) at initial (≤ 14 days post concussion) and RTP clearance visits. They wore activity monitors that quantified daily step count, exercise frequency and duration, and mean heart rate (HR) during exercise between initial and RTP clearance visits. Our primary outcome variable was TSK score change from initial to RTP visits. We analyzed participants separately based on whether they experienced PPCS (symptoms, 28 days) or not (symptoms, 28 days), and calculated correlation coefficients (Pearson r for normally distributed and Spearman rho for nonnormally distributed variables) between each activity variable and TSK change scores.

RESULTS: We enrolled 41 athletes ages 10 to 18 years diagnosed with concussion and evaluated initially within 14 days of injury, all who were compliant with wearing their activity monitoring device. Among our sample, 44% developed PPCS ($n = 18$; mean $\pm$ SD age, 14.5 $\pm$ 2.0 years; 50% female; symptom resolution time, 57.3 $\pm$ 6.2 days; RTP time, 66.8 $\pm$ 6.4 days) and 56% did not ($n = 23$; mean $\pm$ SD age, 14.9 $\pm$ 1.8 years; 48% female; symptom resolution time, 15.2 $\pm$ 1.5 days; RTP time, 21.7 $\pm$ 1.9 days). For the

PPCS group, TSK change scores were significantly and moderately correlated with daily step count ($r = -0.60$, $P = .008$) and exercise frequency ($r = -0.63$, $P = .005$), but weakly and nonsignificantly correlated with exercise duration ($\rho = -0.12$, $P = .65$). Among the no PPCS group, we found weak and nonsignificant correlations between activity variables and TSK change scores (step count: $r = -0.18$, $P = .41$; frequency: $r = -0.34$, $P = .12$; duration: $\rho = 0.10$, $P = .67$). Correlations between mean exercise HR and TSK change scores were weak and nonsignificant for the PPCS ($r = 0.03$, $P = .92$) and the no PPCS group ($r = -0.08$, $P = .72$).

CONCLUSIONS: Our results suggest that higher daily step count and exercise frequency during concussion recovery are moderately correlated with greater reductions in kinesiophobia at RTP among those who experience PPCS, but weakly correlated for those who did not.

CLINICAL RELEVANCE: Regular PA during concussion recovery, regardless of duration or intensity, may help reduce kinesiophobia for those with persistent symptoms. Encouraging early initiation of PA may facilitate this fear reduction which could have implications for recovery and subsequent injury risk following concussion RTP.

SPL66

ATHLETE FEAR AVOIDANCE AND ASSOCIATION WITH SYMPTOMS AND MOOD DISTURBANCE FOLLOWING REHABILITATION FOR SPORT-RELATED CONCUSSION

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PURPOSE/HYPOTHESIS: About half of athletes with sport-related concussion have residual symptoms and mood disturbance beyond typical recovery timeframes. Fear avoidance is a psychological factor that relates to persistent symptoms, mood disturbance (eg, depression) and disability in musculoskeletal injury populations. The purpose of this study was to examine fear avoidance in athletes with sport-related concussion who received multimodal rehabilitation. The hypothesis was that fear avoidance would improve over time and this would be related to improvement in symptom severity, mood disturbance and disability.

NUMBER OF SUBJECTS: Twenty athletes (12 female; mean $\pm$ SD age, 17.1 $\pm$ 2.7 years) evaluated and referred to physical therapy (PT) within a comprehensive concussion program.

MATERIALS AND METHODS: Testing was conducted at initial PT visit, discharge PT visit and 6 months after discharge (follow-up). Demographics and responses on fear-avoidance (Athlete Fear Avoidance Questionnaire, AFAQ; 10 to 50 points), symptom (Post-Concussion Symptom Scale, PCSS; 0 to 132 points), mood disturbance (short Profile of Mood States, POMS; -4 to 124 points), and disability (Dizziness Handicap Inventory, DHI; 0 to 100 points) questionnaires were collected. On each questionnaire, high scores indicate high levels of the construct measured. Multi-modal PT included vestibular rehabilitation, musculoskeletal rehabilitation, exertion therapy and return-to-sport activity progressions as indicated. Repeated measures general linear regression models analyzed longitudinal change in questionnaire scores. Regression lines were created from scores of each questionnaire to determine slope, and Pearson correlation assessed the association of slope of AFAQ scores with slopes of PCSS, POMS and DHI scores.

RESULTS: Mean time from injury to initial PT visit was 18.0 $\pm$ 11.6 days (range, 7-56 days). Mean number of PT visits was 3.0 $\pm$ 1.9 visits. Scores (mean $\pm$ SD points) on each questionnaire improved over time ($P < .001$): AFAQ (21.0 $\pm$ 5.1, 17.8 $\pm$ 5.6, 15.3 $\pm$ 6.0), PCSS (22.4 $\pm$ 16.7, 4.9 $\pm$ 5.5, 9.4 $\pm$ 15.9), POMS (99.2 $\pm$ 14.9, 82.6 $\pm$ 11.9, 83.5 $\pm$ 14.2) and DHI (23.6 $\pm$ 14.8, 5.2 $\pm$ 7.1, 5.1 $\pm$ 7.7). However, only AFAQ significantly improved from discharge to follow-up ($P = .034$). Slope of AFAQ scores was significantly correlated with slopes of PCSS ($r = 0.61$, $P = .01$), POMS ($r = 0.53$, $P = .05$), and DHI ($r = 0.60$, $P = .01$) scores.

CONCLUSIONS: Across patients with sport-related concussion, fear avoidance improved during and after rehabilitation. Greater improvement in fear avoidance from initial PT visit to 6 months after discharge was associated with greater improvement in symptom severity, mood disturbance and disability.

CLINICAL RELEVANCE: Similar to musculoskeletal injury populations, fear avoidance appears to be elevated and associated with trajectory of recovery after sport-related concussion. It may be beneficial to consider fear avoidance in concussion rehabilitation.

SPL67

CADENCE IN YOUTH LONG-DISTANCE RUNNERS IS PREDICTED BY LEG LENGTH AND RUNNING SPEED

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PURPOSE/HYPOTHESIS: Low cadence has been associated with injury in high school cross country runners. Previous studies have found that variations in cadence may be related to experience, speed, and anthropometric variables such as body mass and leg length. It is unknown what factors, if any, predict cadence in a large cohort of healthy youth long-distance runners. Therefore, the purpose of this study was to investigate if demographic, anthropometric and/or biomechanical variables predict cadence in youth long-distance runners. The tested hypothesis was 2-fold: (1) leg length, speed, and running experience would predict cadence in runners and (2) runner's sex will modify the predictive value of the independent variables.

NUMBER OF SUBJECTS: One hundred thirty-eight uninjured youth distance runners (62 male, 76 female; mean $\pm$ SD age, 13.7 ± 2.7 years; mass, 47.9 ± 13.6 kg; height, 157.9 ± 14.5 cm; running volume, 19.2 ± 20.6 km/wk; running experience: male, 3.5 ± 2.1 years; female, 3.3 ± 2.0 years).

MATERIALS AND METHODS: Leg length was measured with each participant in supine using a tape measure (cm) from the ASIS to the most proximal portion of the medial malleolus. Participants underwent a 3-D running analysis on a motorized, noninstrumented treadmill at a self-selected speed (mean $\pm$ SD, 2.8 ± 0.6 m/s). Cadence (steps per minute), running speed (m/s), and stride length (normalized to percent leg length) were extracted from the analysis. Multiple linear regression with a stepwise approach that only included variables that were significantly correlated to cadence was used in the statistical analysis to predict self-selected cadence. Age, BMI, leg length, running experience, speed, and stride length were examined in the model. Regression models were developed for total sample and by sex.

RESULTS: For all models, a high intercorrelation was found between speed and stride length ($VIF > 5$), therefore we removed stride length from all models. Only leg length and speed were significantly correlated ($P < .001$) with cadence in the regression models for total sample ($R^2 = 51.9\%$) and females ($R^2 = 48.2\%$). The regression model for all participants was cadence = $-1.251 \times \text{leg length} + 3.665 \times \text{speed} + 254.858$ and the regression model for females was cadence = $-1.190 \times \text{leg length} + 3.705 \times \text{speed} + 249.688$. For males, leg length, cadence, and running experience were significantly predictive ($P < .001$) of cadence in the model ($R^2 = 54.7\%$). The regression model for males was cadence = $-1.268 \times \text{leg length} + 3.471 \times \text{speed} - 1.087 \times \text{running experience} + 261.378$.

CONCLUSIONS: The models accurately predict cadence for healthy youth long-distance runners. For all models, cadence decreased with longer leg lengths and slower running speeds. For males only, cadence also decreased with a greater number of years running. Future studies are necessary to ascertain other variables that may help further refine the models.

CLINICAL RELEVANCE: Low cadence has been previously linked to injury in high school long-distance runners. Correctly predicting cadence using clinically relevant and attainable variables may help coaches and health care professionals provide a recommendation for running cadence when working with healthy youth long-distance runners.

SPL68

NORMATIVE MEASURES OF HIP STRENGTH AND RELATION TO PREVIOUS INJURY IN COLLEGIATE CROSS-COUNTRY RUNNERS

Charles Nathan Vannatta, Thomas Kernozek

PURPOSE/HYPOTHESIS: Running related injury occurs frequently in collegiate cross-country runners. Hip strength is one factor that may be important in the rehabilitation and training of cross-country runners. However, no normative values exist to inform these strategies. Therefore, the

purpose of this study was to establish normative values for hip abduction and external rotation isometric strength in collegiate cross-country runners and explore the association between strength and previous injury.

NUMBER OF SUBJECTS: Eighty-two NCAA Division III cross-country runners (38 male, 44 female).

MATERIALS AND METHODS: Athletes were enrolled at the beginning of the cross-country season. A running history form including self-reported injury and training patterns was completed. Isometric strength testing was completed for hip abduction (in supine) and hip external rotation (in prone and seated). Absolute scores were recorded and normalized scores were calculated by multiplying the absolute score by the athlete's height and then was divided by the athlete's mass. Means and 95% confidence intervals (CI) were calculated for each strength assessment. A limb symmetry index was completed by taking the strength of the left leg and dividing it by the strength of the right leg then multiplying by 100. The absolute value of the difference of this score from 100% was reported as the strength asymmetry score where a score $>10\%$ was utilized to indicate strength asymmetry. Athletes were then categorized as either having 1 or both legs identified as weak if their strength measure was outside the lower boundary of the 95% CI and if any strength asymmetry ($>10\%$) was present between limbs. A stepwise binary logistic regression was then completed using these categorical variables to identify if they predicted athletes previous injury classification. Alpha level was set to .05.

RESULTS: Males demonstrated greater absolute hip strength than females. However, measures of hip strength were not different between sexes when normalized to height and mass (seated ER, 2.88-3.36 Nm/kg; abduction, 2.85-3.35 Nm/kg; prone ER, 2.81-3.69 Nm/kg). Hip abduction asymmetry was associated with previous injury in males (sensitivity, 81.25%; specificity, 61.90%). A combination of at least 1 leg with hip abduction weakness and bilateral external rotation weakness was associated with previous injury in females (sensitivity, 88.24%; specificity, 77.78%).

CONCLUSIONS: Male and female Division III collegiate cross-country runners demonstrate similar normalized values of hip strength. However, previously injured male and female runners may differ in hip strength where males tend to show an asymmetry in abduction while females tended to demonstrate weakness in abduction and external rotation.

CLINICAL RELEVANCE: Knowledge of normative values of hip strength may help inform rehabilitation strategies in collegiate cross-country runners. Males and females may demonstrate differing strength profiles following running related injury which may need to be addressed with different exercise selection depending on the strength profile demonstrated.

SPL69

THE EFFECTS OF ATTENTIONAL FOCUS ON JOINT COORDINATION PATTERNS DURING LANDING IN FEMALE ATHLETES

Lindsey Ann Waite, Molly Ann Stewart, Thomas Gus Almonroeder

PURPOSE/HYPOTHESIS: Anterior cruciate ligament (ACL) injury prevention programs often incorporate instructions intended to modify athletes' landing patterns. These instructions may promote either an internal focus, where the athlete is encouraged to focus on a specific aspect of their body's movement (eg, "bend your knees more"), or an external focus, where they are encouraged to focus on the overall effect of their movement (eg, "land softly"). Previous studies have found that providing athletes with instructions that promote an external focus tends to result in a safer landing pattern (eg, greater knee flexion), compared to when instructions promote an internal focus. However, these studies have only examined kinematics at individual joints. It may be important to consider how different types of verbal instructions effect the relative motion of multiple joints ("joint coordination"), as well as the variability in the joint coordination patterns. The purpose of this study was to examine how instructions promoting different attentional foci influence the coordination patterns of the lower extremity joints during landing.

NUMBER OF SUBJECTS: Sixteen uninjured female athletes.

MATERIALS AND METHODS: Athletes completed drop landings from a 31-cm height using their typical technique (baseline). They then performed additional drop landings after receiving instructions promoting an internal

focus (IF condition) and an external focus (EF condition), with the order of the conditions counterbalanced. 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." Three-dimensional kinematic data were recorded during the landings and vector coding was used to calculate coupling angles that reflected the relative motion between the joints during the initial landing phase, which was the period from initial contact to the peak vertical ground reaction force. Coupling angles were calculated for the sagittal plane hip-ankle, hip-knee, and knee-ankle angle pairings. Repeated-measures ANOVA was used to compare the mean coupling angles, intraphase coupling angle variability, and trial-to-trial coupling angle variability across the conditions (baseline, IF, EF), with post hoc tests in the case of a significant omnibus test.

RESULTS: There were differences in trial-to-trial coupling angle variability for the hip-ankle ($P = .004$) and knee-ankle ($P = .01$) angle pairings. Post hoc tests indicated that athletes demonstrated greater trial-to-trial variability in their hip-ankle and knee-ankle coupling angles for the EF condition, compared to both the baseline and IF conditions ($P < .05$).

CONCLUSIONS: Athletes exhibited greater trial-to-trail variability in their joint coordination patterns when they received instructions promoting an external focus. This greater trial-to-trial variability may reflect the athletes exploring a wider array for motor control strategies.

CLINICAL RELEVANCE: Greater variability during training could promote more adaptable and robust movement pattern changes.

SPL70

PHYSICAL ACTIVITY AFTER ANTERIOR CRUCIATE LIGAMENT INJURY BEFORE AND DURING THE COVID-19 PANDEMIC: A PRELIMINARY ANALYSIS

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PURPOSE/HYPOTHESIS: Physical activity (PA) is low 2 years after ACL reconstruction (ACLR), but PA levels before and early after surgery are unknown. This period of recovery is significant because changes in cartilage structure are already present, and cartilage health is dependent on loading activities such as walking. This study aimed to determine if PA levels change and vary by sex from before through 6 months after ACLR. We hypothesized that PA levels would increase at each time point. COVID-19 pandemic guidelines affected PA levels; thus, we also explored if PA levels differed during the pandemic.

NUMBER OF SUBJECTS: Twenty-six (mean $\pm$ SD age, 19.9 ± 5.1 years; 65.4% female; BMI, 24.7 ± 3.8 kg/m²).

MATERIALS AND METHODS: PA was measured using a 3-axis accelerometer (Actigraph wGT3X-BT) worn at the right iliac crest during the waking hours of 1 week before ACLR (within 1 month of injury) and at 2, 4 and 6 months after ACLR. At least 4 days with at least 10 hours of daily wear was required. Percentage of wake time in sedentary activity (percent SED), daily steps, and daily minutes of MVPA were measured. Data collected after March 16, 2020 were considered to be collected during the COVID-19 pandemic. This date reflects when face-to-face human subject research was halted at our university. Two-by-4 (sex by time) repeated measures analyses of variance (ANOVA) with post hoc testing using the least significant difference were used to test if PA levels changed from before to after ACLR. Due to nonnormal data, Mann-Whitney U tests were used to test if PA levels differed before compared to during the pandemic at each time point.

RESULTS: A main effect of time was present for percent SED ($P = .028$; PreOp, 70.5 ± 8.4 ; 2 months, 68.0 ± 6.7 ; 4 months, 65.8 ± 8.2 ; 6 months, 63.9 ± 9.5), daily steps ($P < .001$; PreOp, 5830 ± 2495 ; 2 months, 5644 ± 1732 ; 4 months, 7397 ± 2386 ; 6 months, 8124 ± 3007), and daily minutes of MVPA ($P < .001$; PreOp, 22.8 ± 18.9 ; 2 months, 20.7 ± 15.5 ; 4 months, 35.7 ± 22.3 ; 6 months, 37.3 ± 23.8). Percent SED did not change between any consecutive time points. Daily steps and MVPA only increased from 2 to 4 months (both, $P < .001$). A main effect of sex was also present across all variables. Women spent more time in sedentary activity ($P = .007$; women, 69.2 ± 6.9 ; men, 63.1 ± 8.9), walked fewer daily steps ($P = .006$; women, 6208 ± 1859 ; men, 7771 ± 2900), and spent less time in MVPA

($P = .028$; women, 24.2 ± 14.2 ; men, 38.4 ± 25.8). PA levels did not differ at time points before compared to during the COVID-19 pandemic (all, $P > .05$), with large variation in pandemic MVPA data.

CONCLUSIONS: PA levels increased from 2 to 4 months after ACLR but did not show significant improvements from before to 2 months after ACLR or 4 to 6 months. Women completed less PA and spent more time in sedentary activity than men. Large variation was present in PA levels during the COVID-19 pandemic, suggesting wide-ranging levels of PA during this time.

CLINICAL RELEVANCE: It is unknown how increasing PA from 2 to 4 months but not 4 to 6 months impacts ACLR recovery. Women may require greater monitoring to improve PA after ACLR than men. These analyses did not show an impact of the COVID-19 pandemic on PA levels after ACLR, but its effect on other functional outcomes is unknown.

SPL71

PREDICTORS OF SINGLE-LEG SQUAT PERFORMANCE IN PEOPLE WITH FEMOROACETABULAR IMPINGEMENT SYNDROME

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PURPOSE/HYPOTHESIS: The aim of this study was to determine if dynamic range of motion (ROM), muscle strength, hip morphologic measures, hip pain and hip specific function predict single-leg squat (SLS) performance in people with femoroacetabular impingement syndrome (FAIS). We hypothesized that hip biomechanics, muscle strength, and hip specific function will predict squat performance in people with FAIS.

NUMBER OF SUBJECTS: Thirty-four people with FAIS.

MATERIALS AND METHODS: Three-dimensional kinematic data were collected at 100 Hz using a 20-camera 3-D motion capture system during 3 SLS trials. Isometric muscle strength was tested with a stationary handheld dynamometer in all participants. Squat performance was quantified by squat depth in meters, and the biomechanical variables of dynamic ROM of the pelvis, hip, knee and ankle in all planes were calculated. In people with FAIS, femoral and acetabular morphology were measured using radiographic alpha angles and lateral center edge angles. Hip pain and hip specific function were measured using a visual analog scale for pain (VAS-P), and the Hip Outcome Score Activity of Daily Living Subscale (HOS-ADL), respectively. A hierarchical multiple linear regression (MLR) model was used to determine if biomechanical variables, muscle strength, hip morphology measures, hip pain, and hip-specific function were predictors of squat depth. All statistical analysis was performed using SPSS Version 26.

RESULTS: Hierarchical MLR revealed that dynamic ROM of the hip, knee and pelvis, hip external rotation muscle strength, and femoral alpha angles were all significant predictors of squat performance, and the final MLR model explained 92.4% of the total variance in squat depth in people with FAIS.

CONCLUSIONS: SLS squat performance in people with FAIS is predicted by sagittal plane biomechanics and hip external rotator strength, and less by frontal plane pelvic ROM and hip morphology in people with FAIS.

CLINICAL RELEVANCE: Clinicians should focus treatment on improving dynamic ROM and hip external rotator muscle strength to improve squat performance, however femoral morphology should be also considered in the treatment paradigm. A SLS is useful task to assess functional performance of the hip in people with FAIS since the performance of his task was predicted by factors that are modifiable with rehabilitation.

SPL72

SHORT-TERM EFFECTS OF TRANSCRANIAL DIRECT-CURRENT STIMULATION ON QUADRICEPS PERFORMANCE AND CORTICOSPINAL EXCITABILITY IN ATHLETES AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Quadriceps muscle dysfunction persists after ACL reconstruction (ACLR) despite extensive rehabilitation and is associated with poor functional outcomes. Alterations in corticospinal excitability (CSE) to the quadriceps muscle are present in athletes after ACLR and

these alterations are related to quadriceps performance. Transcranial direct-current stimulation (tDCS) can alter CSE and increase strength, yet only 1 study to our knowledge has examined the use of tDCS in patients recovering from ACLR. Therefore the purpose of this study was to examine the short term effects of tDCS on quadriceps muscle performance and CSE in athletes after ACLR. We hypothesized that a single session of active tDCS would lead to increases in CSE and improvements in quadriceps muscle performance.

NUMBER OF SUBJECTS: Six level I-II athletes (3 male, 3 female) 4 to 6 months from primary ACLR.

MATERIALS AND METHODS: Quadriceps muscle performance (isometric peak torque, rate of torque development) and CSE (active motor threshold, slope of a stimulus response curve) of the vastus medialis were tested pre/post a single session of active tDCS and a single session of sham tDCS. Anodal tDCS was applied to the primary motor cortex contralateral to the surgical limb for 20 minutes as the patient rode a stationary bike. A 2-by-2 (time [pre/post tDCS] by condition [active/sham tDCS]) repeated measures ANOVA was used to determine changes in the surgical limb's quadriceps performance and CSE across time and condition.

RESULTS: There was a significant main effect of time for peak torque (pre active tDCS, 104 ft-lb; pre sham tDCS, 118 ft-lb; post active tDCS, 93 ft-lb; post sham tDCS, 112 ft-lb; $P = .021$). Peak torque decreased pre to post regardless of tDCS condition. There were no other significant main effects and no significant time by condition interactions.

CONCLUSIONS: The addition of a single session of tDCS to stationary bike riding did not lead to increases in CSE and quadriceps performance in this preliminary sample of patients recovering from ACLR. A larger sample size is needed to confirm these findings and recruitment for this study is currently ongoing.

CLINICAL RELEVANCE: Anodal tDCS has the potential to alter CSE and improve quadriceps performance in athletes recovering from ACLR. Future work will determine the effects of multiple tDCS sessions on CSE and quadriceps performance.

SPL73

FIRST-TIME MUSCULOSKELETAL INJURY DOES NOT CHANGE PAIN CATASTROPHIZING, KINESIOPHOBIA, OR FEAR IN COLLEGE SOFTBALL PLAYERS

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PURPOSE/HYPOTHESIS: The fear avoidance model describes the relationship between psychosocial factors and outcomes. When applied to sport injuries, negative psychosocial responses such as pain catastrophizing, kinesiophobia and fear-avoidance beliefs may decrease psychosocial readiness, leading to increased fear avoidance behaviors which can influence return to sport. The purpose of this study was to assess whether pain catastrophizing, kinesiophobia, and fear avoidance beliefs change after suffering a first-time musculoskeletal injury in college softball players.

NUMBER OF SUBJECTS: A prospective cohort of 35 NCAA Division I college softball players (mean $\pm$ SD age, 18.5 $\pm$ 0.9 years; height, 1.7 $\pm$ 0.1 m; weight, 71.9 $\pm$ 8.1 kg; BMI, 25.0 $\pm$ 2.9 kg/m²). These athletes participated in at least 2 consecutive preseason screenings.

MATERIALS AND METHODS: During preseason screening we assessed psychosocial distress using the Fear-Avoidance Beliefs Questionnaire (FABQ), Tampa Scale of Kinesiophobia (TSK-11), and Pain Catastrophizing Scale (PCS). After the first preseason screening encounter, the athletic trainer tracked the occurrence of musculoskeletal overuse injuries resulting in at least 1 missed practice, training, or game occurring during the competitive season. Psychosocial questionnaires were readministered during the next preseason screening (second encounter). A 2-by-2 repeated-measure ANOVA compared the score on psychosocial questionnaires between softball players with and without musculoskeletal injury and over time within encounter.

RESULTS: At the first encounter, softball players demonstrated low levels of psychosocial distress (FABQ score, 7.9 $\pm$ 8.2; TSK-11 score, 13.5 $\pm$ 3.2; and PCS score, 4.8 $\pm$ 6.1). During the season, 9 players suffered a musculoskeletal injury. Seven injuries occurred at lower extremity with an aver-

age time missed of 30 days (range, 1-95); 2 injuries occurred at the spine with an average time missed of 14.5 days (range, 14-15). There were no significant interactions for FABQ ($P = .91$), TSK-11 ($P = .36$), and PCS ($P = .79$) between softball players with and without musculoskeletal injury and over time.

CONCLUSIONS: In college softball players, psychosocial distress does not change following a first-time musculoskeletal injury.

CLINICAL RELEVANCE: College softball players do not appear to alter their psychosocial outlook and may not view their injury as a threat to return to competitive play following a first-time injury exposure. Softball players demonstrate initial low levels of psychosocial distress and are more likely to confront their pain related fear and return to sport following an injury. Unlike other orthopaedic and sports medicine populations, there may be less psychosocial distress following an injury in college softball due to the diminished severity and chronicity of musculoskeletal injuries sustained in this sport.

SPL74

THE INFLUENCE OF STRENGTH AND SPORT EXPOSURE ON PSYCHOLOGICAL READINESS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Griffin Perry Zink, Christin Marie Zwolski, Staci Thomas, Mark Vincent Paterno, Laura C. Schmitt

PURPOSE/HYPOTHESIS: Psychological readiness to return to sport (RTS) has been identified as a significant predictor of a young athlete's return to preinjury level of performance following anterior cruciate ligament reconstruction (ACLR). However, there is limited evidence on the extent to which psychological readiness is influenced by factors beyond the psychological domain, such as strength and exposure to the sport environment. Therefore, the purpose of this study was to test the hypothesis that young athletes with recent sport exposure and higher quadriceps strength would demonstrate higher psychological readiness upon release to unrestricted sports participation after ACLR.

NUMBER OF SUBJECTS: Thirty-eight athletes (median age, 16.9 years; IQR, 16.1-18.8 years) following primary ACLR.

MATERIALS AND METHODS: Within 8 weeks of medical clearance to unrestricted sports participation, all participants completed isometric knee extension strength testing, in addition to the ACL Return to Sport after Injury (ACL-RSI) questionnaire. Psychological response was assessed with ACL-RSI overall score, in addition to each ACL-RSI subscale score (Emotions, Confidence, Risk Appraisal). Athletes who had participated in sports practice or competition between medical clearance and date of study enrollment were categorized as SPORT-YES. Those who had not yet participated in sports were categorized as SPORT-NO. Multiple linear regression analyses were used to determine differences in ACL-RSI scores based on quadriceps strength and sport exposure status, while adjusting for age and sex.

RESULTS: Of the 38 participants, 20 (52.6%) were categorized as SPORT-YES. The regression model for overall ACL-RSI score was significant ($F_{4,33} = 6.732$, $P < .001$, adjusted $R^2 = 0.389$), with age, sex, and exposure status explaining 11.5% ($P = .014$), 10.1% ($P = .02$), and 13.3% ($P = .008$) of the total variance, respectively. In evaluating the ACL-RSI subscales, the regression model for the ACL-RSI Emotions score was significant ($F_{4,33} = 7.434$, $P < .001$, adjusted $R^2 = 0.417$), with age, sex, and exposure status explaining 18.8% ($P = .002$), 11.8% ($P = .011$), and 7.5% ($P = .039$) of the total variance, respectively. The regression model for the ACL-RSI Confidence score was also significant ($F_{4,33} = 5.044$, $P = .003$, adjusted $R^2 = 0.310$), with exposure status explaining 20.0% ($P = .003$) of the total variance. Younger age, male sex, and SPORT-YES status were associated with higher ACL-RSI scores within the respective analyses, while strength was not.

CONCLUSIONS: In partial accordance with our hypothesis, sport exposure was significantly associated with higher psychological readiness among young athletes after ACLR, while quadriceps strength was not. Additionally, males and athletes of younger age demonstrated a more positive psychological response.

CLINICAL RELEVANCE: Reintegration to the sport environment may be necessary for achievement of psychological readiness among young athletes af-

ter ACLR. Implementation of sport-specific or on-field interventions during late-stage rehabilitation may optimize psychological readiness to RTS.

SPL75

FACTORS PERCEIVED TO INFLUENCE PHYSICAL LITERACY AMONG YOUNG ATHLETES AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Christin Marie Zwolski, Mark Vincent Paterno, Timothy Rethorn, Staci Thomas, Catherine Celeste Quatman-Yates, Laura C. Schmitt

PURPOSE/HYPOTHESIS: The synergistic interactions of physical, psychological, and environmental factors within the construct of physical literacy have been promoted as essential components of a physically active lifestyle. Yet, the impact of these mechanisms within a population of young athletes after anterior cruciate ligament reconstruction (ACLR) has not been investigated, despite growing evidence of reduced physical activity engagement after ACLR. The purpose of this study was to explore the perceived impact of ACLR on one's physical literacy in the years following adolescent ACLR.

NUMBER OF SUBJECTS: Ten participants (median age, 20.5 years; 17.5-28.6), were included in this study at a median of 5.9 years (4.3-10.2) after adolescent ACLR.

MATERIALS AND METHODS: Using an interpretive phenomenological methodology, semi-structured interviews with each participant (average, 65 minutes; 51-84) were conducted, recorded, and transcribed verbatim. Data collection focused on participants' lived experiences related to physical literacy and physical activity after ACLR. Thematic analyses were guided by the procedures of the constant comparative method, allowing for identification of themes from open and axial coding. Strategies employed to en-

sure that the methodological rigor of the data collection and analyses produced trustworthy results included triangulation, an audit trail, rich and thick verbatim descriptions, and reflexivity discussions.

RESULTS: Thirteen subthemes were generated from the participants' perspectives, which were categorized into 4 main themes: (1) navigation of barriers, (2) movement motives, (3) movement mindset, and (4) physical literacy recalibration. Participants acknowledged the unique adaptations they make to overcome barriers to engaging in physical activity, including common obstacles to movement and injury-related limitations. These adaptations, along with the participants' internal and external movement motives, were perceived to facilitate engagement in physical activity and enhancement in physical literacy. Underlying these perceived barriers and motives was a movement mindset that was derived from the ACL injury experience itself, along with the participants' lived experiences as young athletes. The participants also emphasized a positive reframing, or recalibration, of perceptions surrounding physical activity participation and their personal physical literacy journeys. Collectively, the factors perceived to influence physical literacy among this cohort spanned all levels of the socioecological framework.

CONCLUSIONS: The themes identified in this study indicate that the adolescent ACLR experience has the potential to significantly influence one's physical literacy into young adulthood. Future research should explore the psychological and environmental factors identified as important to one's physical literacy in the years following adolescent ACLR.

CLINICAL RELEVANCE: Those who provide care for young athletes should consider factors beyond the physical domain when designing clinical and educational interventions to enhance physical activity engagement after adolescent ACLR.

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American Academy of Sports Physical Therapy Poster Presentation Abstracts SPO1-SPO113

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

FUNCTIONAL MUSCLE STRENGTH TEST ASSOCIATIONS WITH BALANCE ERROR SCORING SYSTEM SCORES IN HEALTHY YOUNG ADULTS

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PURPOSE/HYPOTHESIS: The modified Balance Error Scoring System (mBESS) is often used to detect balance impairments in individuals who are post concussion. However, this test has a floor effect and may not be useful in rehabilitation. Functional muscle strength tests (FMSTs) could be used to predict future mBESS performance in younger adults, as previous work has shown that FMSTs were predictors of falls in older adults, which poor balance is associated with falls in this population. The purpose of this study was to examine the associations between FMSTs and the mBESS. We hypothesized that the FMSTs would predict balance errors on the mBESS in healthy young adults.

NUMBER OF SUBJECTS: Eighty-one healthy young adults (47 female; mean $\pm$ SD age, 25.0 $\pm$ 3.4 years).

MATERIALS AND METHODS: We used a cross-sectional design in this laboratory study. After familiarization, participants performed the mBESS on firm and foam surfaces in a randomized order to assess balance performance. Participants performed 2 trials of the lateral step-down test (LSDT), 5-times sit-to-stand (5xSTS), and 30-second chair-stand test (30CST) in a randomized order. We counted the number of completed cycles for the 15-second LSDT and 30CST. For the 5xSTS test, we timed participants' performance (seconds) to complete 5 repetitions. For the LSDT, participants performed 2 versions: (1) touched the floor with their foot flat (standard LSDT) and (2) touched the floor with their heel only (modified LSDT) before returning the foot back to the step. Their nondominant leg remained stationary on a 20-cm step with a hands-on-waist posture. Greater mBESS and 5xSTS scores indicated bad performance, whereas greater 30CST and LSDTs scores indicated good performance. We analyzed data using Pearson correlations and hierarchical multiple linear regressions to determine if the FMSTs were associated with or predicted mBESS errors, controlling for body mass. Significance was set at $P < .05$.

RESULTS: Average total mBESS errors was 20.6 $\pm$ 8.6 (5.8 $\pm$ 4.3 for firm surfaces and 14.7 $\pm$ 5.1 for foam surfaces). Body mass (kilograms) was significantly associated with average total mBESS errors ($r = 0.30$, $P = .002$). Performance on the standard LSDT, modified LSDT, and 30CST were significantly associated with average total mBESS errors ($r = -0.37$, $P =$

.001; $r = -0.37$, $P = .001$; $r = -0.24$, $P = .034$; respectively). Five-times sit-to-stand performance was not significantly associated with average total mBESS errors ($P > .05$). After controlling for body mass, regression analyses showed that none of the FMSTs predicted average total mBESS errors ($P > .05$).

CONCLUSIONS: Our study showed that performance on the standard LSDT, modified LSDT, and 30CST were associated with static balance in young adults, but these measures did not predict balance performance after controlling for body mass.

CLINICAL RELEVANCE: While lower extremity muscle strength is an important factor in balance, these FMSTs had limited utility as a diagnostic marker of balance in young adults. Likely, this is because these tests do not measure other components known to contribute to balance such as sensation, vestibular function, and vision.

SPO2

MOBILITY OUTCOMES FOR PERIACETABULAR OSTEOTOMY IN PERSONS WITH ACETABULAR DYSPLASIA: THE NEED FOR REAL-WORLD MEASUREMENT

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PURPOSE/HYPOTHESIS: Periacetabular osteotomy (PAO) is a surgery for persons with symptomatic acetabular dysplasia (AD) that increases acetabular coverage of the femoral head for improving hip mechanics, pain, and function. Patient-reported outcomes (PROs) are significantly improved following PAO in persons with symptomatic AD, yet little is known regarding mobility-related outcomes. Herein, we synthesized and summarized the evidence regarding PROs and mobility-related outcomes in persons with symptomatic AD following PAO. We further identified important future research directions, chiefly the need for measurement of real-world outcomes that supplement information from PROs.

NUMBER OF SUBJECTS: One thousand four hundred eighty-three total persons with symptomatic AD (1206 females) from the included studies in this review.

MATERIALS AND METHODS: We searched PubMed using predefined search terms. One author reviewed abstracts and full texts. We included studies that: (1) enrolled persons with symptomatic AD undergoing PAO and (2) included PROs and/or mobility-related outcomes. We synthesized and summarized study characteristics and findings, including the study design, sample size, sex distribution, pain levels, function, quality-of-life scores, and/or mobility-related measures.

RESULTS: Fourteen studies were included in this review (9 prospective and 5 retrospective). Of the 14 studies, 9 studies evaluated pain intensity, 11 studies evaluated hip-related function, 6 studies evaluated quality of life, 8 studies evaluated self-reported physical activity, 4 studies evaluated walking speed and cadence, 1 study evaluated laboratory-based functional tasks including sit-to-stand, 4-square-step, and timed stair ascent tests, and 2 studies evaluated physical activity levels using body-worn devices such as accelerometers. Persons with symptomatic AD had significant improvements in PROs (pain, function, quality-of-life, and self-reported physical activity) following PAO, yet walking speed and device-measured physical activity did not change over 1-year following PAO.

CONCLUSIONS: Few studies have evaluated mobility-related outcomes in persons with symptomatic AD following PAO, and these studies were of a low-level research design. Future research might include experience sampling data collection approaches and body-worn devices as free-living, technology-driven methodologies that evaluate mobility-related and other outcomes in persons with symptomatic AD undergoing PAO.

CLINICAL RELEVANCE: Measuring function and physical activity levels during real-world settings for persons with symptomatic AD both before and after PAO, could allow researchers to monitor improvements or decline in activity levels as well as allowing to develop targeted physical activity-related interventions.

SP03

CERVICAL PROPRIOCEPTION IN FEMALE COLLEGIATE ATHLETES WITH VERSUS WITHOUT HISTORIES OF HEAD OR NECK INJURIES

Michelle Ann Schneider, Jon Newbold, Kelli Woods, Quentin Brock Kasten, Sky Daniel Darrah, Christopher Cabral, Joni Goldwasser Barry

PURPOSE/HYPOTHESIS: Athletes with a history of head or neck injury may present with deficits in cervical proprioception similar to impairments noticed in peripheral joints. Cervical proprioception is often measured with the Head Repositioning Accuracy (HRA) test. Repositioning error of $>4.5^\circ$ of error has been used as the criterion for classification of impairment. A nonexperimental study was conducted to explore whether cervical proprioception was compromised in female collegiate athletes with versus without a history of previous injury (>6 months post) to the head or neck. It was hypothesized that those with a self-reported history of head or neck injury versus an uninjured group would have a statistically significant difference in HRA with greater repositioning errors.

NUMBER OF SUBJECTS: A convenience sample consisting of 48 female athletes from 2 universities within a single athletic conference was recruited. The inclusion criteria included females between the ages of 18 and 24 years who competed at the National Collegiate Athletic Association Division II level, including soccer, track, cross country, swimming, diving, and tennis. The exclusion criteria included current cervical pain or diagnosed cervical spine pathology, a concussion within the past 6 months, a history of neck or head surgery, a diagnosed vestibular dysfunction, or diagnosed rheumatic conditions, with each of the conditions having been diagnosed by a physician. For this secondary analysis, participants were grouped into those with ($n = 19$) and without ($n = 29$) a history of head or neck injuries.

MATERIALS AND METHODS: Each participant performed 3 trials of the HRA test in each direction. Error, in degrees, from neutral was read from a cervical range of motion device. Comparisons between athletes with and without a history of concussions and/or cervical injuries were conducted to determine if there were statistically significant differences in absolute error (AE) left and AE right using a Mann-Whitney test (alpha level of $P < .05$).

RESULTS: Descriptive statistics showed that 47.4% (9/19) of the participants with a history of injury and 31% (9/29) of participants without a history of injury demonstrated impaired proprioception. Between groups,

there was a lack of statistical significance for AE left ($P = .57$) and AE right ($P = .07$).

CONCLUSIONS: This study adds to the discussion regarding the potential for impaired cervical proprioception following head or neck injuries. Although a lack of statistical significance was found between groups, a higher percentage of athletes with a history of injury had impaired cervical proprioception overall. Further research with a larger and heterogeneous sample may be beneficial to determine if differences in cervical proprioception between groups exist.

CLINICAL RELEVANCE: Evidence of a potential for impaired proprioception may inform clinicians regarding the utilization of proprioceptive tests for preseason screening, training for injury prevention, and therapeutic intervention in the rehabilitation of cervical injuries in female collegiate athletes. Clinical cutoff values may be useful for the identification of impaired cervical proprioception.

SP04

JOINT EXCURSION, DECELERATION, AND TIMING OF DECELERATION PHASE OF COLLEGIATE BASEBALL PITCHERS

Cody M. Ballay, Blake Lyle Edwards, Cal Haefke, Daniel Richie, James A. Onate, Nathan Edwards, Ajit Mohan Chaudhari

PURPOSE/HYPOTHESIS: Deceleration is the phase in the baseball pitching motion from ball release to maximum dominant shoulder internal rotation which aims to safely decelerate the forward progression of the throwing arm and dissipate the high forces created in the acceleration phase of the pitching motion. As a result, the deceleration phase is associated with high forces and an increased injury risk to overhead athletes. However, while many studies analyze acceleration in the pitching motion, a lack of quantitative data exists in the literature describing the deceleration phase. The purpose of this study was to quantify joint excursion, deceleration, and timing of the deceleration phase of a group of NCAA Division III collegiate baseball pitchers.

NUMBER OF SUBJECTS: Thirteen NCAA Division III collegiate baseball pitchers without current injury or participation limitations.

MATERIALS AND METHODS: Participants threw 5 pitches from their preferred starting position off a standard mound after completing a warm-up, while 3-D kinematics were collected using an optical motion capture system. The trial with the highest dominant index finger velocity, used as a correlate for ball velocity, was analyzed for each participant. Deceleration and timing were analyzed for the pelvis, torso, shoulder internal rotation (IR), shoulder resultant rotation, and elbow extension for the deceleration phase which was defined as maximum angular velocity of the segment to minimum angular velocity or change in direction.

RESULTS: On average, shoulder IR demonstrated the most joint excursion ($54^\circ \pm 15^\circ$) of body segments analyzed. Elbow extension ($61445^\circ/s^2 \pm 20077^\circ/s^2$) and shoulder IR ($42791^\circ/s^2 \pm 36299^\circ/s^2$) demonstrated the highest deceleration values. Additionally, shoulder resultant deceleration motion was found to occur throughout 56.4% of the total time between stride foot contact and end of the follow through, which was the longest duration of any body region analyzed in this study.

CONCLUSIONS: This quantitative description begins to establish normative values for the deceleration phase in collegiate pitchers and allows for comparison between different groups (eg, high/low velocity throwers, college/professional). Additionally, this data illustrates the upper extremity (glenohumeral and elbow joints) undergoing the most joint excursion, the highest deceleration values, and decelerating for the greatest percentage of time of the body segments analyzed which could be a factor in the high risk of injury in the deceleration phase of the pitching motion.

CLINICAL RELEVANCE: Consideration should be given to include glenohumeral deceleration exercises in prevention and rehabilitation approaches due to the high demands on this joint in the deceleration phase.

SP05

SPORT-SPECIFIC PLYOMETRIC PROGRESSION WITH WEARABLE TECHNOLOGY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A CASE REPORT

Katie Ballew, Hannah Dolfuss, Jeffrey B. Taylor

BACKGROUND AND PURPOSE: Return-to-sport protocols after anterior cruciate ligament reconstruction (ACLR) often rely heavily on strengthening activities and limb symmetry measurements. While plyometrics and sport-specific tasks are included in most protocols, clinicians are advised to wait until at least a 70% limb symmetry in strength is achieved. However, plyometric exercises play a crucial role in neuromuscular and movement re-education, simulating sport demands, and when done and progressed safely can help augment strengthening exercises in those that have yet to meet symmetry criteria. The purpose of this case study was to describe the use of wearable technology in progressing plyometric exercise for a slowly progressing patient after ACLR.

CASE DESCRIPTION: The subject was a 21-year-old female collegiate lacrosse player that was 32 weeks removed from an ACLR revision using a quadriceps tendon graft. The patient had a relatively low functional level, including poor quadriceps strength (50% limb symmetry index) and a high level of kinesiophobia (TSK-11, 22/44). A 15-week progressive plyometric program was initiated. The participant wore an inertial measurement unit (IMU) at waist level to help quantify movements and jump counts throughout the treatment sessions.

OUTCOMES: Over the length of the plyometric program, the patient showed a 34% improvement in isokinetic quadriceps strength and a 12.5% and 50% increase in single assessment numeric evaluation (SANE) for daily and sport function respectively. The patient was safely progressed from 0 to 272 jumps in a session over the first 8 weeks with an average weekly increase of 31% per week. Over the subsequent 7 weeks, jump count was reduced by an average of 9% per week as other agility tasks were introduced. Throughout the plyometric program, the patient progressed from assisted jumps to unassisted jumps (40% to 0%) and from double-leg landings to single-leg landings (percentage of single leg landings progressed from 0% to 60.5%). The IMU was clinically useful during treatment sessions, showing a progression from 277 to 1397 movements per session; however, relative to jump count, the IMU did not register data for many of the submaximal jumps, accounting for only 5% to 79% of jumps on any given session.

DISCUSSION: Plyometrics are a crucial part of rehabilitation after ACLR and can be used in patients where strength gains are not progressing. Plyometric progression can include increases in jump counts, transitioning from assisted to unassisted jumps, and changing the base of support (eg, 2-legged to 1-legged), plane of motion, or intensity of the jump. When implemented in a safe, gradual, and calculated manner while being slowly progressed over a longer period of time, plyometrics can positively contribute to both strength and psychological gains. Wearable technology can help clinicians with these safe progressions of exercise if the limitations of the wearable device are known (ie, height threshold for jump count measurement).

SP06

THE LANDING ERROR SCORING SYSTEM-REAL TIME: A VALIDATION STUDY FOR JUMP-LANDING BIOMECHANICS

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PURPOSE/HYPOTHESIS: Anterior cruciate ligament (ACL) injuries are very common in athletes. Factors associated with increased risk of ACL injury include decreased hip and knee flexion, increased knee valgus, and increased GRF, among others. Screening tools are available that attempt to identify movement dysfunction that may increase the risk of injury. One measure that has been proven to be valid and reliable is the LESS.

The LESS-RT requires the same validity and reliability assessment as it is more clinically useful from an efficiency perspective. The purpose of this study was to investigate the ability of the LESS-RT to accurately detect abnormal biomechanics during a jump-landing task to determine its validity by comparing investigator visual scoring with the gold standard of 3-D motion analysis of the lower extremity. Authors hypothesize that the LESS-RT will identify subjects with potentially high risk jump landing biomechanics. And more specifically, poor LESS scores will be associated with decreased hip and knee flexion angles, increased knee valgus angle and moment, increased hip and tibial rotation, and increased ground reaction forces.

NUMBER OF SUBJECTS: Fifty.

MATERIALS AND METHODS: Fifty subjects, including 24 males (mean $\pm$ SD age, 26.5 ± 3.3 years; height, 70.9 ± 2.1 inches; weight, 181.8 ± 27.1 lb) and 26 females (mean $\pm$ SD age, 23.8 ± 0.4 years; height, 65.6 ± 2.6 inches; weight, 154.6 ± 32.4 lb) participated in this study. Subjects performed 4 trials of a jump-landing task from a 30-cm box with simultaneous data collection of 3-D hip and knee motion and LESS-RT visual scoring by 3 raters. Kinematic and kinetic measures from 3-D motion analysis and force-plate data were compared across LESS score quartiles using a series of 1-way ANOVAs; LESS quartiles were compared by sex using a chi-square. Interrater reliability was also computed using ICC_{2k} and SEM calculations.

RESULTS: Subjects with high/poor LESS-RT scores demonstrated significantly different kinematics and kinetics compared to those with low/excellent LESS-RT scores for bilateral hip and knee flexion displacement and bilateral peak hip and knee flexion angles; peak right knee valgus moment; right peak hip adduction and internal rotation moments; and bilateral vertical GRF ($P < .05$). Women had higher/worse LESS-RT scores than men (5.5 versus 3.4). Interrater reliability of the LESS-RT was good at 0.85 and SEM at 0.42.

CONCLUSIONS: The LESS-RT demonstrates preliminary results that support it as a potentially valid tool for identifying high-risk movement patterns during a jump-landing task. Reliability is favorable and similar to what was previously demonstrated in a larger study. A larger sample size is required to confirm these results.

CLINICAL RELEVANCE: Given clinical time constraints, a quick and easy assessment that provides an accurate and valid reflection of lower extremity movement patterns that may result in knee injury provides a useful tool for clinicians to utilize as a basis for exercise programming.

SP07

IMPROVING INTERDISCIPLINARY CONCUSSION CARE THROUGH TELEMENTORING CASE CONFERENCE: A PILOT STUDY

Rebecca Ann Bliss, Michael Mohrland, Michelle Wheeler, Annell Boland

PURPOSE/HYPOTHESIS: Multidisciplinary care in concussion management has been shown to improve outcomes in those suffering from protracted postconcussion symptoms. Shared understanding of roles, increased clinician knowledge, and improved clinical outcomes utilizing tele mentoring has been found effective in complex medical conditions, though no evidence exists specific to concussion. Tele mentoring uses telecommunication and electronic information processing technology to provide individual guidance or direction with the goal of improved clinical care. The purposes of this pilot study is trifold: (1) investigate change in clinician self-efficacy in concussion management (2) examine comfort levels in practice patterns involving interdisciplinary care, and (3) gain insight into effectiveness and satisfaction of tele mentoring among multiple disciplines involved in concussion care at a large university health care system.

NUMBER OF SUBJECTS: Twenty-six health professionals.

MATERIALS AND METHODS: A pre/post prospective cohort study was utilized. Twenty-six medical professionals involved in concussion management were electronically surveyed utilizing Qualtrics platform pre/post

pilot tele mentoring concussion case conference. Survey questions were adapted from the General Self-Efficacy Questionnaire and tailored specific to confidence in current concussion management practice utilizing a 5-point Likert scale. Management questions were divided into 3 construct, evaluation, intervention, and consultation. Content validity was established prior to dissemination and construct validity of our sample was established at $\alpha = .76$. Statistical analysis was performed utilizing SPSS, Version 27 and included descriptive statistics, Cronbach alpha, Shapiro-Wilk, and Wilcoxon signed rank tests with a Bonferroni correction.

RESULTS: A 50% response rate was achieved; 92.3% participants attended 2 or more sessions, 46.1% attended 3 or more. Significant changes were found in the following areas: increased confidence in consultation, $P = .02$ and increased self-efficacy in consulting with multidisciplinary care team, $P = .003$. There was also significant improvement in utilization of medical record data from neuropsychology, $P = .01$; 92.3% of participants increased usage of assessment tools and 69.2% increased discussion with providers outside their specialty. One hundred percent found that case conferences were effective usage of technology, maintained attention during session, and reported it increased their knowledge of concussion care.

CONCLUSIONS: A pilot program utilizing tele mentorship via concussion case conferences was found to be an effective intervention in improving interdisciplinary concussion care. Significant improvement in consultation and understanding of specialties outside one's own discipline to improve concussion outcomes was found. Mutual understanding of interdisciplinary care team's roles and responsibilities have led to improved communication and referrals within the health system specific to concussion management.

CLINICAL RELEVANCE: This pilot program shows potential for improving communication and consultation among health care professionals involved in multidisciplinary concussion care.

SP08

DYNAMIC KNEE JOINT STIFFNESS IS IMPAIRED DURING A DROP VERTICAL JUMP AFTER AN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Benjamin D. Brightwell

PURPOSE/HYPOTHESIS: Impairments in quadriceps muscle function after an Anterior Cruciate Ligament (ACL) reconstruction may result in poor force attenuation at the knee contributing to the risk of future injury and development of posttraumatic osteoarthritis (PTOA). The knee's ability to attenuate force during dynamic tasks can be measured through joint stiffness, which is the ability to store and transmit elastic energy quickly. However, the presence of impaired knee joint stiffness during jumping has not yet been reported 6 months after surgery. Identifying potential relationships between quadriceps muscle function and knee joint stiffness is a critical first step in the development of effective interventions. Therefore, we hypothesized that knee joint stiffness in the ACL reconstructed limb (AL) would be significantly lower than the uninvolved limb (UL) during landing from a jump 6 months after ACL reconstruction. We also hypothesized knee stiffness symmetry would be positively associated with symmetry of quadriceps rate of torque development (RTD) and quadriceps peak torque.

NUMBER OF SUBJECTS: Thirty (13 female) subjects (mean $\pm$ SD age, 20.5 $\pm$ 5.8 years) 6 months post ACL reconstruction.

MATERIALS AND METHODS: Subjects performed 3 instrumented drop-vertical jumps (DVJ) from a 30-cm box onto 2 imbedded force plates. Knee joint stiffness was calculated as the slope of the change in the knee joint moment divided by the change in the knee joint angle during the first 60 milliseconds of landing. RTD is the slope of the first 200 milliseconds of the torque-time curve, and peak torque is the mean of the maximum torque values during 4 5-second maximal isometric contractions per limb on an isokinetic dynamometer. Between limb differences were determined with paired t tests for each outcome. A limb symmetry index (LSI) was determined for each task by dividing the AL by the UL performance. Pearson product-moment correlations were performed to determine the association

between knee stiffness LSI and the LSI of each variable of interest.

RESULTS: Significant differences in knee joint stiffness were present in the first 60 milliseconds of the first landing from a DVJ (AL, 0.02 ± 0.01 Nm/kg/deg; UL, 0.05 ± 0.01 Nm/kg/deg; $P < .0001$). Knee joint stiffness symmetry was a significant positive correlated RTD symmetry ($r = 0.42$, $P = .02$), but not peak torque symmetry ($r = 0.34$, $P = .08$).

CONCLUSIONS: AL knee joint stiffness is significantly lower than the UL during the early phase of the first landing from a jump after ACL reconstruction. Greater knee joint stiffness symmetry was associated with better quadriceps RTD symmetry, but not peak torque symmetry.

CLINICAL RELEVANCE: Impaired knee joint stiffness during the early phase of landing may predispose patients to future injury risk and PTOA development. These results indicate that the rate of quadriceps contraction may be as important as quadriceps strength for restoring optimal jump performance and reducing risk of poor long-term outcomes. Clinicians should consider applying interventions aimed at improving the rate of quadriceps contraction and eccentric loading symmetry at the knee during early phase landings.

SP09

PRESEASON FUNCTIONAL TESTS DISCRIMINATE INJURY RISK IN FEMALE COLLEGIATE VOLLEYBALL PLAYERS

Jason Brumitt, Christopher Scott Patterson, Robert Dudley, Eric Sorenson

PURPOSE/HYPOTHESIS: Volleyball (VB) is played by over 28 000 female athletes at the collegiate level in the United States. The overall injury rate for female VB athletes at the collegiate level is 4.2 per 1000 athletic exposures placing it fourth behind soccer, field hockey, and basketball. Coaches and/or sports medicine professionals may screen athletes during the preseason with a variety of tests in order to identify those who may be at a greater risk for injury. If an athlete can be identified as being at a greater risk for injury, the team's strength coach or sports medicine professional can prescribe an individualized program to address potential deficits. Prior research has reported relationships between preseason functional test (FT) scores and noncontact time-loss injury to the low back and lower extremities in female collegiate level VB athletes. NCAA DIII female VB players were 4 times more likely to experience a noncontact time-loss injury if their preseason standing long jump (SLJ) was $<80\%$ of height, each single-leg hop (SLH) was $<70\%$ of height, and if there was $>10\%$ asymmetry between SLH distances. The purpose of this study was to determine the effectiveness of 1 or more FT to discriminate injury risk in a cohort of female VB players that compete at the collegiate level. It was hypothesized that lower scores on a battery of tests and/or demographic variables would be associated with noncontact time-loss injury to the low back or lower extremities.

NUMBER OF SUBJECTS: One hundred thirty female collegiate level VB players (mean $\pm$ SD age, 19.31 $\pm$ 1.1 years) were recruited from the Portland, OR and Azusa, CA regions. Athletes represented the NCAA DII, DIII, and NAIA levels of competition.

MATERIALS AND METHODS: Testing sessions occurred at the start of the teams' preseason period. Prior to testing, each athlete completed a baseline questionnaire collecting the following information: age, year in school, and prior history of sport injury. Four FT were performed by each athlete in this sequence: Y Balance Test-LQ, SLJ, SLH for distance, and the lower extremity functional test. The operational definition for an injury in this study was any injury to the low back or to the lower extremities that occurred during sport participation (ie, during a practice or a game) that resulted in the athlete not being able to complete that day's event or prevented the athlete from playing in the next practice or game.

RESULTS: Twenty noncontact, time-loss injuries occurred. Athletes considered "at risk" (SLJ $<80\%$ height, bilateral SLH each $<70\%$ height, and who had a prior injury) were 3 times more likely to be injured (OR = 3.0; 95% CI: 1.09, 8.30; $P = .04$). Individual test scores or prior history of injury were not associated with an increase in injury risk.

CONCLUSIONS: This is the second study to demonstrate an association between lower preseason SLJ and SLH scores and injury in female collegiate level VB players.

CLINICAL RELEVANCE: Female collegiate level VB players should be screened during the preseason. Athletes with lower SLJ, SLH, and who have had a prior history of sport injury may benefit from a targeted training program.

SP010

A RETURN-TO-SPORT TEST BATTERY DOES NOT PREDICT REINJURY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Lauren Schlacht Butler, Alexa Rae Martinez, Apeksha Gupta, Kristin Hayden

PURPOSE/HYPOTHESIS: There is mixed evidence on the effectiveness of return to sport (RTS) test batteries and their ability to predict second Anterior Cruciate Ligament (ACL) injury. The majority of tests evaluated include objective measures of strength, hop test distance, knee range of motion and laxity, and measures of psychological readiness to return. Few RTS test batteries have included movement quality assessments. The purpose of this study was to determine the effectiveness of a RTS test battery, including qualitative movement assessments, to predict second ACL injury in adolescent athletes after Anterior Cruciate Ligament Reconstruction (ACLR). **NUMBER OF SUBJECTS:** Seventy-seven adolescent athletes who underwent primary ACLR between 2014 and 2018 (55 male; mean $\pm$ SD age at surgery, 16 ± 2 years; BMI, 25 ± 5 kg/m²).

MATERIALS AND METHODS: A retrospective chart review of was conducted. All athletes completed a RTS test battery consisting of psychological assessment with the Tampa Scale of Kinesiophobia (TSK-11), lateral step down test (LSDT), Tuck jump assessment (TJA), single-leg hop testing (SLHT) including the single, triple, and triple crossover hop for distance, and an evaluation of cutting performance. The LSDT, SLHT's and cutting task were evaluated using a qualitative movement assessment checklist, which awarded a point for each movement fault identified. Athletes passed the RTS test if they scored <19 on the TSK-11, <2 on the LSDT, <3 on all SLHT's with a Limb Symmetry index $\geq 95\%$, ≤ 5 on the TJA and, ≤ 2 on the cutting assessment. All variables were analyzed descriptively. For continuous variables, median and interquartile ranges (IQR) were reported and Wilcoxon rank sum test was used to assess the differences. For categorical variables, frequency and proportion were reported and chi-square or Fisher exact test was used to assess differences between "no second ACL injury" and "second ACL injury" groups.

RESULTS: Overall, 14.2% of athletes ($n = 11$) suffered a second ACL injury (81.8% male). Median Tegner score in both groups was 7 (IQR, 7-9). Median time to RTS clearance was significantly different between the no second ACL injury and second ACL injury groups (10; IQR, 8-12 versus 8; IQR, 8-9 months; $P = .017$). A total of 66.2% of athletes ($n = 51$) passed the RTS test. Of those who suffered a second ACL injury, 63.6% passed the RTS. There was no statistically significant difference between those who passed the RTS test and those that did not on the occurrence of second ACL injury.

CONCLUSIONS: An RTS test battery including qualitative movement assessments does not predict second ACL injury in adolescent athletes after ACLR.

CLINICAL RELEVANCE: RTS test batteries are often used to guide RTS decision making after ACLR. This study shows that more research is needed to determine which tests are predictive of second ACL injury.

SP011

THE RELIABILITY OF 2-DIMENSIONAL KINEMATIC ASSESSMENT OF A 45° SIDESTEP CUT

Lauren Schlacht Butler, Alexa Rae Martinez, Dai Sugimoto, Charles Wyatt, Eryn Keefe Milian, Alex Loewen, Ashley Erdman, Sophia Ulman, Kristin Hayden, Amie DeVerna, Kirsten Tulchin-Francis

PURPOSE/HYPOTHESIS: Up to 70% of all anterior cruciate ligament (ACL) injuries occur via a noncontact mechanism involving deceleration and di-

rection change on a planted foot. Clinical screening tools analyzing movement patterns during a cutting task are reliable and valid. The Expanded Cutting Alignment Scoring Tool (E-CAST) is a reliable tool to qualitatively assess trunk and lower extremity (LE) alignment during a 45° side-step cut (SSC). Previous works found 2-D kinematic analysis more reliable than qualitative assessments when evaluating jumping and squatting movements. However, there is limited evidence on the reliability of 2-D assessments to evaluate SSC tasks. The purpose of this study was to determine if using 2-D kinematic analysis with the E-CAST improves the tool's reliability for evaluating trunk and LE alignment during a 45° SSC. **NUMBER OF SUBJECTS:** Twenty-five healthy females (mean $\pm$ SD age, 13.8 ± 1.4 years; mass, 52.4 ± 9.3 kg; height, 161.7 ± 6.0 cm) who regularly participated in cutting or pivoting sports were included.

MATERIALS AND METHODS: A repeated-measures study design was used. Each subject performed 3 SSC trials with 1 trial randomly selected for analysis. Trials were recorded in the frontal and sagittal planes. Two physical therapist raters independently viewed and scored each video on 2 separate occasions. Videos orders were randomized and a 2-week wash-out period occurred between rounds. The E-CAST evaluates 6 movement variables: trunk lean to the opposite direction of the cut, increased cut width, knee valgus at initial load acceptance, knee valgus throughout the cutting task, decreased knee flexion angle, and decreased plantar flexion angle. The assessment criteria for each variable was adapted to utilize the Dartfish motion analysis application on a smart phone. If a movement variable falls outside of the motion analysis definition, the subject scores a point, therefore a higher score represents poorer technique. Intraclass correlation coefficients (ICCs) and 95% confident intervals (95% CIs) were calculated for the E-CAST total score, and a kappa coefficient was calculated for each variable. Correlations were converted to z scores and compared for significance.

RESULTS: The cumulative intrarater reliability was good (ICC = 0.821; 95% CI: 0.687, 0.898) and the cumulative interrater reliability was moderate (ICC = 0.752; 95% CI: 0.565, 0.859). Intrarater kappa coefficients ranged from moderate to almost perfect for all variables ($\kappa = 0.505$ -0.875) and interrater kappa coefficients ranged from slight to good for all variables ($\kappa = 0.336$ -0.733).

CONCLUSIONS: The use of 2-D kinematic analysis resulted in higher intrarater and interrater reliability compared to the traditional qualitative E-CAST (ICC = 0.77; 95% CI: 0.59, 0.96 and ICC = 0.71; 95% CI: 0.50, 0.91), however, the difference was not significant ($z_{\text{obs}} = -0.46$ and $z_{\text{obs}} = -0.30$).

CLINICAL RELEVANCE: Qualitative assessment tools to identify movement faults during a 45° sidestep cut are just as reliable as 2-D kinematic analysis and likely more time efficient.

SP012

SEX AFFECTS PHYSICAL THERAPY VISIT UTILIZATION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN ADOLESCENT ATHLETES

Lauren Schlacht Butler, Nicholas Gary Giampetruzzi, Elliot M. Greenberg, Meredith A. Link, Victor Valentin Prati, Adam Pierce Weaver, Michael Saper

PURPOSE/HYPOTHESIS: Age and sex have important anterior cruciate ligament (ACL) injury risk implications, with the highest risk in postpubertal and female athletes. However, little is known how age and sex affect the rehabilitation process and return to sport (RTS) outcomes after ACL reconstruction (ACLR). The purpose of this study was to determine the effect of age and sex on physical therapy (PT) visit utilization and hop test performance in adolescent athletes after primary ACLR.

NUMBER OF SUBJECTS: Two hundred eighty-nine patients who underwent primary ACLR between 2013 and 2019 at 5 institutions (57.4% male; mean $\pm$ SD age at surgery, 15.7 ± 1.9 years).

MATERIALS AND METHODS: A retrospective chart review was conducted. All patients completed a RTS test including single-legged hop testing. PT frequency was assessed until the time of the return to sport test. To ac-

count for variability, the average number of weekly visits during the observed time was calculated. The effect of age and sex on the odds of passing hop tests and on the average number of weekly PT visits was assessed using multivariable logistic regression. Passing was defined as achieving a limb symmetry index $\geq 90\%$ on all available tests (single hop, triple hop, crossover hop, and timed hop, if performed). Age was defined as early adolescent (<14 years in females and <16 years in males) and late adolescent (≥ 14 years in females and ≥ 16 years in males).

RESULTS: The most common sport played by participants was soccer (32.9%). Two-tendon hamstring autograft was the most common graft utilized (46.4%). The mean time from surgery to the last RTS test was 7.8 ± 1.7 months (early adolescent) and 8.1 ± 1.9 months (late adolescent, $P = .162$). The average number of weekly PT visits was 1.01 ± 0.37 (early adolescent) and 0.96 ± 0.38 (late adolescent, $P = .321$). Age had no statistically significant effect on the odds of passing hop tests (OR = 1.29; 95% CI: 0.71, 2.35). There was a statistically significant difference in the mean time from surgery to the RTS test between males (7.8 ± 1.5 months) and females (8.2 ± 2.3 months, $P = .048$). There was also a significant difference in the average number weekly PT visits between males (0.94 ± 0.34 visits) and females (1.03 ± 0.41 visits, $P = .047$). Additionally, there was an observed drop in the frequency of weekly PT visits overtime for all subjects. Sex had no statistically significant effect on the odds of passing hop tests (OR = 0.79; 95% CI: 0.43, 1.45).

CONCLUSIONS: Females had a higher weekly frequency of PT and tested later than males. Age had no significant effect on PT visit utilization and age and sex had no significant effect on hop test performance.

CLINICAL RELEVANCE: Female patients may benefit from extended rehabilitation programs and more frequent PT visits after ACLR.

SP013

EFFECTIVENESS OF BLOOD FLOW RESTRICTION TRAINING ON AEROBIC PERFORMANCE DURING CYCLING EXERCISE IN HEALTHY ADULTS

David Calderon, Gian Carlo Cruz, Blake Doughtie, Nicole Hoppe, Jaime Gonzalez, Savannah Nickel, Wesley Okeke, Jovannah Ortiz, Derek Wengert, Jason Winchester

PURPOSE/HYPOTHESIS: To compare aerobic capacity following a cycling exercise protocol with BFR at 60% (BFR-60) versus 80% (BFR-80) occlusion.

NUMBER OF SUBJECTS: Twenty-nine healthy participants (mean $\pm$ SD age, 25 ± 3 years; 14 male, 15 female).

MATERIALS AND METHODS: Subjects were randomly assigned to either: BFR-60 ($n = 10$), BFR-80 ($n = 11$), and control ($n = 8$). Aerobic capacity was measured at baseline, and 3 weeks during a submaximal cycle ergometer protocol on a stationary ergometer connected to a metabolic analyzer for the assessment of peak oxygen consumption (VO_2 peak). Aerobic testing consisted of performing the YMCA protocol which consisted of pedaling at 70 rpm with a load of 25 W. Heart rate (HR) was monitored continuously at the end of the first 3 minutes and used to determine the load increase for the remaining 15 minutes. After the first 15 minutes a 25-W increase occurred every 3 minutes until the participant reached 1 or more of the following criteria: 80% of their predicted HR using the HR reserve formula, or an RER >1.0 . The training program consisted of cycling at 70 rpm for 15 minutes 3 times a week. The BFR group performed the cycling with their respective occlusion in the dominant leg while the control group did not use any occlusion. The variable of interest was VO_2 peak ($ml \cdot kg^{-1} \cdot min^{-1}$). VO_2 values were normally distributed, therefore a 2-by-3 (time by group) repeated-measures ANOVA was used to perform between and within-group comparisons. Statistical significance was at an alpha of .05 for all analyses.

RESULTS: All groups showed baseline homogeneity at baseline for VO_2 peak values. There was no statistically significant difference for the time by group interaction and the between groups factors. However, there was a statistically significant difference for time ($P = .005$) with greater VO_2 peak values at 3 weeks for all groups.

CONCLUSIONS: Blood flow restriction training does not seem to provide any training advantage to aerobic training on a bicycle over training without occlusion.

CLINICAL RELEVANCE: When using an aerobic exercise protocol to increase oxygen consumption, the inclusion of BFR training does not seem to add an additional advantage over the expected physiological adaptations that occur with cycling exercise alone.

SP014

ANTERIOR CRUCIATE LIGAMENT REHABILITATION: IS THERE A GOLD STANDARD FOR RETURN TO SPORT?

Ariana Calderon, Kristen Kelli Waldron, Matthew Brown

THEORY/BODY: Today there are an estimated 200000 anterior cruciate ligament (ACL) injuries per year. ACL reconstruction is a common treatment strategy for this injury, as many patients want to return to competitive sport. With this procedure, about 80% of patients return to some type of sport, but only 65% return to preinjury participation levels, and only 55% return to competitive sport. With this in mind, the sports medicine multidisciplinary team must strive to find the optimal rehabilitation approach to maximize the number of patients achieving their return to sport goals. Strictly time-based rehabilitation protocols are being replaced by criteria-based rehabilitation protocols. The decision to return to sport should take many factors into account. These include concomitant injuries, objective physical examination data, functional testing, psychological readiness, demands of the activity the patient is returning to, and consideration of biological tissue healing. Typically 2 approaches have been used: a conservative 9- to 12-month program and an accelerated 6-month program. In this context, return to sport is defined as "achieving preinjury level of sports participation as defined by the same type, frequency, intensity, and quality of performance as before injury." The aim of a rehabilitation program is to restore prior level of function, strength, range of motion, proprioception, neuromuscular control, and joint stability and decrease kinesiophobia while maintaining the integrity of the graft. In the process of returning to sport, an approach based on criteria rather than a timeline should be adopted. This requires the completion of objective tests and measures before progressing to the next phase. Multiple tests and measures, both qualitative and quantitative, should be used together as a battery to determine readiness for return to participation and ultimately return to sport. Tests shown to be of significance include range of motion, presence of effusion, quadriceps and hamstring strength, joint laxity, limb symmetry index (>90), subjective reports through outcome measures, single-limb hop tests, balance, and a measure of quality of movement. More research is needed to determine the best testing battery. Ideally patients will progress through a structured plan of care that allows them to participate in sport specific activity along a continuum of clearance after completing required milestones. Special considerations must be made for each individual, including physical performance criteria, sport demand, mental readiness, lesion type, surgical technique, genetics, and other factors. A multidisciplinary approach with open communication allows for the surgeon and rehabilitation team to decide on a unique course of action for each patient.

SP015

LONGITUDINAL CHANGES IN KNEE MUSCLE STRENGTH AND HOP DISTANCE IN ADOLESCENT ATHLETES AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: The purpose of this study was to evaluate knee muscle strength and single-leg hop performance at 5 to 13 months after anterior cruciate ligament reconstruction (ACLR). It was hypothesized that normalized quadriceps and hamstrings strength as well as single-leg hop test would improve over time.

NUMBER OF SUBJECTS: Sixty-five subjects (42 female, 23 male; mean $\pm$ SD age, 15.8 ± 1.8 years.; mass, 64.5 ± 13.9 kg; height, 165.8 ± 8.7 cm) with primary ACLR were included. Rehabilitation was not controlled in the current study; however, all subjects received standardized ACLR return to sport testing.

MATERIALS AND METHODS: Isometric knee extensor and flexor strength were measured with a custom set-up using handheld dynamometer, with values for each limb normalized to bodyweight. Single-leg hop testing was performed on each limb, with the 3 best trials averaged and normalized to body height. Subjects were organized into groups based on time post surgery. A 1-way ANOVA was run to compare the differences in knee muscle strength and single-leg hop distance between subjects at 5 to 7 ($n = 17$), 7 to 9 ($n = 26$), 9 to 11 ($n = 8$), and 11 to 13 ($n = 14$) months post surgery. Alpha was set at $P < .05$ for statistical tests. Variables of interest included knee flexion strength (KFI), uninvolved knee flexion strength (KFH), involved knee extension strength (KEI) uninvolved knee extension strength (KEH), involved single-leg hop distance (SLHI), and uninvolved single-leg hop distance (SLHH).

RESULTS: A main effect of time on KFI was observed ($F_{3,40} = 3.8$, $P = .017$). Post hoc testing revealed that the 9 to 11 month group had significantly greater hamstring strength compared to the 5 to 7 and 7 to 9 month groups, but no significant difference compared to the 11 to 13 month group.

CONCLUSIONS: Knee flexor strength was the only variable to demonstrate statistically significant differences. While not statistically significant, all variables including KEI, KEH, SLHI, and SLHH demonstrated a trend of improvement over time.

CLINICAL RELEVANCE: Isometric strength testing and single leg hop testing are feasible to conduct in a clinical setting and are commonly used in return to sport decision making. The results of this study establish normalized ranges for knee muscle strength and single leg hop test performance for the adolescent population at multiple post-op time intervals. Clinicians can utilize these reference values to gauge rehabilitation progress and target intervention to adequately prepare patients with ACLR in safe return to sports.

SP016

ALTERNATIVE MECHANICAL DIAGNOSIS AND THERAPY-MCKENZIE APPROACH TO MANAGING HIP PAIN IN AN ADOLESCENT RUNNER

Dmitry Chan, Nicholas Keith Purcell

BACKGROUND AND PURPOSE: Hip/groin pains in adolescent runners are not as prevalent as knee or shin injuries. Accurately diagnosing and treating hip pain can be challenging. Among common diagnoses are FAI, athletic pubalgia, IT band syndrome. The success of conservative management varies. This case presents an alternative approach to managing hip pain in an adolescent runner for whom initial physical therapy (PT) was not successful.

CASE DESCRIPTION: A 17-year-old male track runner complained of right hip pain possibly due to sit-ups was seen in the sports medicine department. The original diagnosis was sports hernia. He reported pain up to 7/10, worse with coughing, sneezing, sitting up from bed, and running. The patient demonstrated painful and limited flexion and internal rotation of right hip. Following 2 months of PT patient was getting worse even with basic ROM exercises. The diagnostic US ruled out sports hernia and the patient was referred to a hip orthopaedic specialist.

OUTCOMES: MRI revealed: chondrolabral and intralabral tearing involving the anterior labrum extending to posterosuperior labrum of the right hip. The patient was referred to PT for 3 more months to fail conservative management in order to obtain authorization for surgery. On reassessment, the patient continued to have painful Flexion, IR ROM, hip flexion strength was 41 lb right with pain versus 48 lb left based on handheld dynamometry, positive FADIR, and LEFS 20/80. The new episode of care lasted 6 months during which in addition to classical phys-

ical therapy, Movement diagnosis and treatment approach was used. The patient had a decrease in pain with repetitive hip extension with IR bias. The pain subsided to 3/10 on average, mostly with getting up from bed and running. Hip flexion strength improved to 89 lb right and 68 lb left pain free. He passed the Lower Quarter Y Balance Test LQYBT at 105% composite score and symmetrical all directions. Patient LEFS improved to 73/80 and he was able to run varsity state level through some pain. Due to the patient's intention to run competitively in college, he opted to have surgery during which only minimal labrum tear was observed and required no repair. However, the patient was found to have CAM FAI pathology which was surgically managed. Following 3.5 months accelerated post of rehabilitation patient was discharged with full pain-free hip ROM, passing LQYBT at 110% composite score, demonstrating 99% symmetry on x1, x3, and crossover hop tests, and returning to run and 5 min/mi pace.

DISCUSSION: Managing hip pain can be challenging at times. Correct diagnosis might not always be achieved even with advanced imaging. Whenever a patient does not progress as expected it is critical to explore options and think outside of the box. MDT principles of repetitive movement and directional preference allowed the patient to run competitively his senior year and improve functional level from 20 to 73/80 based on LEFS. However, structural impairment of CAM FAI pathology still caused some level of pain not acceptable to the patient. We believe fast postop recovery must be in part attributed to extensive preop rehabilitation.

SP017

A REVIEW OF THE EFFECTS OF FUNCTIONAL KNEE BRACES ON STABILITY OF THE ANTERIOR CRUCIATE LIGAMENT-DEFICIENT KNEE

Derek Bradley Charles, Jeffrey Jordan Goetz, Bradley Tyler Jones, Jordan Mingo, Michal Zienkiewicz

THEORY/BODY: Anterior cruciate ligament (ACL) deficiency due to injury can result in increased tibial translation and rotation, diminished joint proprioception, and increased tibiofemoral joint loading. These impairments can advance the progression of articular cartilage changes, meniscal tears, and other ligamentous injuries. Functional knee bracing (FKB) is commonly utilized for those who do not undergo an ACL reconstruction surgery and consists of a rigid or semi-rigid shell secured by straps at the calf and thigh that are connected by rigid bars with hinges on either side of the knee. FKB is designed to limit accessory motion in the frontal, sagittal, and transverse planes, while facilitating recruitment of the hamstrings, quadriceps, and gastrocnemius. Although FKB has been referenced in the literature since the 1980s, evidence for its efficacy remains inconclusive despite its wide use in athletics. Therefore, the purpose of this review was to assess the effects of functional knee bracing on stability of the ACL deficient-knee. The databases PubMed, ScienceDirect, Google Scholar, and EBSCOhost were searched using the Preferred Reporting Items for Systematic Review and Meta Analyses (PRISMA) guidelines and a combination of the terms anterior cruciate ligament, deficiency, and functional knee brace. Inclusion criteria were English language, peer-reviewed journals; subjects with a unilateral ACL-deficient knee; a quantifiable outcomes measure such as kinematic, kinetic, or electromyography (EMG) data; and the use of FKB. Exclusion criteria were cadaver studies; bilateral knee involvement; history of knee surgery, osteoarthritis, or meniscal pathology; additional knee ligament injuries; and studies without sufficient information to evaluate methodology. Twelve articles met all criteria and were evaluated using the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) scale to rate the overall quality based on study limitations, inconsistency, indirectness, imprecision, and publication bias. The scale uses a standardized format that provides a level of confidence that the true effect is the same as the estimated effect. Article methodology quality ranged from very low ($n = 1$), low ($n =$

10), and moderate ($n = 1$). There was low evidence supporting FNB in limiting anterior tibial translation, weak to moderate evidence for limiting tibial abduction and rotation, and overall low evidence to support FKB for increased muscle activity around the tibiofemoral during functional activities. Factors related to inconsistencies included a wide variety of functional braces reported, variability in the brace's model or design description, lack of subject randomization, and inconsistent use of control groups. Despite the proposed effects of providing stability to the unstable knee, FKB has intrinsic flaws that diminish its efficacy and it does not provide significant mechanical stability during functional movement and rehabilitative exercises. Studies with stronger methodologies are needed before FKB can be recommended in rehabilitation of chronically unstable knees.

SP018

IDENTIFICATION OF HIGH-RISK BONE STRESS INJURIES IN THE ATHLETE: HOW TO ADVOCATE FOR YOUR PATIENT

Kaitlyn Colgan

BACKGROUND AND PURPOSE: Bone Stress Injuries (BSI) are described as the inability of bone to withstand submaximal mechanical forces caused by repetitive activities such as running. High-risk areas include those with low blood flow and high load, such as the femoral neck. Femoral neck BSI are relatively rare, accounting for only 3% of all sports-related stress fractures, but can be devastating if left untreated and operative care is necessitated. High clinical suspicion for stress injuries, particularly those at high-risk areas, is imperative to ensure optimal care. The purpose of this case report is to increase advocacy for the running athlete by emphasizing careful examination, conservative referral for imaging, activity modification, and comprehensive treatment techniques.

CASE DESCRIPTION: This case describes a 25-year-old man who recently increased his running volume due to gym closures secondary to COVID-19. Initially thought to be experiencing hip pain secondary to a labral tear, he was referred to physical therapy with the assumption that he would progress to surgical management. On evaluation, his physical therapist became suspicious of a stress injury and advocated for imaging which demonstrated a compression-sided stress injury of the posterior medial femoral neck. A comprehensive treatment strategy was implemented including neuromuscular control activities, gluteal and core strengthening and flexibility work, progressing towards more impact and sports-specific activities near end of care.

OUTCOMES: Progress was assessed using strength measures via handheld dynamometry, a timed lateral step down test and hop testing battery. Following 8 weeks of activity modification in accordance with bone-healing norms, the patient was able to demonstrate 95% limb symmetry index (LSI) with triple hop and crossover hop, and 102% with forward single leg hop. Strength testing revealed 119% LSI peak Hamstring strength at 60°, 108% peak quadriceps strength, and 95% peak gluteus medius strength. He was able to perform a timed lateral step down to 2 minutes with no compensations bilaterally. Eventually, he worked through a walk-jog progression and was able to return to skiing, running and weight lifting without symptoms.

DISCUSSION: If untreated, a progression from a femoral neck stress reaction to a fracture can advance to avascular necrosis of the femoral head and necessitate early total hip arthroplasty. While typically described in a female athlete with RED-S, BSI can affect those who do not fit this typical profile as well such as the male patient presented above. A physical therapist must be diligent with examination, with a low threshold for recommendation of imaging if the patient presents with symptoms and factors at risk for BSI. Physical therapists should consider taking a global approach to these patients and individualizing treatment to encompass all contributing factors for optimization of function and reduction of re-injury risk.

SP019

EFFECT OF BLOOD FLOW RESTRICTION COMPARED WITH HIGH-INTENSITY INTERVAL TRAINING ON MUSCLE POWER AND LACTATE THRESHOLD

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PURPOSE/HYPOTHESIS: Blood flow restriction (BFR) training as a rehabilitation modality has gained lots of attention in the last decade due to its potential to minimize joint load while improving muscle function. Yet, BFR training is but 1 exercise modality available to rehabilitate musculoskeletal injuries. Thus, we aimed to compare the effect on hamstring and quadriceps muscle power, and lactate threshold (LT) of 3 rehabilitation regimens: 80% 1RM squats (CON), High-Intensity Interval Training (HIIT) body weight squats, and body weight squats using BFR (BFR).

NUMBER OF SUBJECTS: Twenty healthy subjects (65% female; mean $\pm$ SD age, 26.3 ± 5.3 years; BMI, 24.3 ± 4.0 kg/m²).

MATERIALS AND METHODS: Subjects were randomized to receive BFR, HIIT, or CON over 12 weeks (3 d/wk). Muscle power was tested on an isokinetic dynamometer at 60°/s, 180°/s, and 300°/s, and LT was assessed pre/post exercise completion in each group at baseline (T0), 6-week (T1), and 12-week (T2) follow-up. CON ($n = 4$) performed 3 sets of 5 repetitions at 80% of 1RM squats. HIIT ($n = 8$) performed 20-second squats followed by 10-second rest for 8 sets. BFR ($n = 8$) performed 30/15/15/15 squats with 30-second rest between sets (a metronome set to 60 bpm with each repetition for 2 seconds was used). BFR cuffs were placed on the proximal thighs bilaterally and inflated to 250 mmHg. Due to the small sample size, Kruskal-Wallis analyses were performed to evaluate differences pre-post training within groups for each outcome and to identify differences between groups.

RESULTS: T0-T1: HIIT improved hamstring power at 180°/s ($P = .016$); BFR improved quadriceps power at 60°/s ($P = .008$). There were no significant differences in muscle power in CON or between groups. T0-T2: HIIT improved quadriceps power at 300°/s ($P = .039$); BFR improved quadriceps power at 60°/s ($P = .008$). There were no significant differences in muscle power in CON or between groups. At T0 LT increased after HIIT protocol ($P = .008$), but not after BFR or CON; HIIT led to higher LT than BFR ($P = .004$). There were no significant differences in LT between HIIT-CON or BFR-CON. At T1 LT increased after HIIT protocol ($P = .008$) and BFR ($P = .014$), but not after CON; HIIT led to higher LT than BFR ($P = .016$); there were no significant differences in LT between HIIT-CON or BFR-CON. At T2 LT increased after HIIT protocol ($P = .008$) and BFR ($P = .023$), but not after CON; HIIT led to higher LT than BFR ($P = .002$). There were no significant differences in LT between HIIT-CON or BFR-CON.

CONCLUSIONS: Our preliminary data suggest that both HIIT and BFR can improve muscle power in healthy subjects. HIIT might be superior to BFR in improving muscle power at higher speeds of contraction. LT is elevated after BFR and HIIT training, however, LT is much higher after HIIT. A larger study is needed to validate our findings.

CLINICAL RELEVANCE: BFR and HIIT performed using low resistance improved muscle power in healthy individuals. These interventions may be beneficial for those who cannot tolerate exercises using heavy loads. Moreover, lower LT after BFR training as compared to HIIT indicates that such training may prevent muscle soreness related to lactate buildup.

SP020

RETURNING TO SPORT FOLLOWING FEMOROACETABULAR IMPINGEMENT SURGERY: CONSIDERATIONS FOR A COLLEGIATE AMERICAN FOOTBALL KICKER

Logan J. Couce, Caitlin Joy Miller, Misha Bradford, John Shelton Magel

BACKGROUND AND PURPOSE: The prevalence of cam or mixed type femoroacetabular impingement (FAI) among adult athletes is estimated at 66%

and 57% respectively. Research indicates high levels of return to sport following arthroscopic surgical management of FAI. Significant variability exists regarding postoperative protocols, and the authors are aware of no evidence-based return to sport protocols for American football. The purpose of this case study is to describe the physical therapy (PT) return to sport management after surgery for a college football kicker.

CASE DESCRIPTION: The patient was a 21-year-old male college student who self-referred to PT 4.5 months following a right hip osteochondroplasty and labral repair. Baseline impairments included anterior hip pain with hip flexion, particularly during deep squatting, and pain during a resisted straight leg raise (SLR). He was additionally fearful of returning to rigorous sports-specific training. Stage 1 of rehabilitation addressed lumbopelvic strength, endurance, and motor control for anticipated training movements, with progression criteria to stage 2 including a pain-free maximum voluntary isometric contraction (MVIC) SLR. Stage 2 introduced sport specific and rate of force development training including plyometric exercises and progression to reintroduction of kicking activities. Progression criteria to stage 3 included performance of half the patient's preinjury kicking volume without reactive soreness, swelling, or other symptoms. Stage 3 continued progression of kicking while increasing frequency, intensity, and number of kicks as tolerated.

OUTCOMES: The patient successfully progressed through stages 1 and 2 over 11 weeks. During stage 3, the patient felt a "pop" with immediate onset of anterior hip pain during a routine kicking session at a frequency and intensity previously well tolerated. This setback was initially managed with therapeutic exercise, manual therapy, and dry needling to quadriceps musculature. A Medrol dose pack and corticosteroid injection were trialed by the patient's surgeon without any effect. An MRI revealed an anterosuperior capsular defect. The patient and surgeon agreed that revision surgery was necessary, and a dermal allograft was utilized for the capsular repair.

DISCUSSION: This case describes the postoperative rehabilitation of a young male seeking to return to sport. Despite the use of a criterion-based rehabilitation program, this patient ultimately experienced a significant reinjury and revision surgery. Two potential contributing factors were identified. First, this patient underwent an accelerated return to activity prior to PT involvement, including a return to running 5 days after surgery. Second, recent evidence suggests that a subset of hip capsules may not remain closed following arthroscopic surgery. Given this, activities requiring forceful end range hip extension may present an inherently higher risk of reinjury. The outcome of this case emphasizes the need for further development of evidence-based return to sport criteria.

SP021

ISOMETRIC KNEE EXTENSION RATE OF TORQUE DEVELOPMENT DEFICITS 3.5 MONTHS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Adam Michael Culiver, David Bennion, Colton Thomas Kellogg, Bryan Riemann, Laura C. Schmitt

PURPOSE/HYPOTHESIS: Quadriceps muscle strength deficits are well documented following anterior cruciate ligament (ACL) reconstruction (ACLR). Rate of torque development (RTD) is an aspect of quadriceps muscle function which has been linked to poor gait mechanics and rate of knee extension loading during single leg landing. Return to jumping and running is considered safe by 12 weeks post ACLR, yet understanding of RTD around this time point is lacking. The purpose of this study was to determine whether isometric knee extension RTD would differ between individuals after ACLR and healthy control participants. We hypothesized RTD would be significantly lower at 100 milliseconds and 250 milliseconds in the ACLR limb compared to the healthy control group.

NUMBER OF SUBJECTS: Twenty participants, 10 following ACLR (3.56 ± 0.73 months after surgery; 8 patellar tendon, 1 hamstring, 1 quad tendon graft) and 10 healthy active individuals were included. The control group was

significantly older than the ACLR group (27.70 ± 3.41 versus 17.15 ± 6.70 years old, $P < .01$) and significantly taller (175.87 ± 3.62 versus 180.87 ± 4.26 cm, $P = .01$) but there were no significant differences in weight or sex.

MATERIALS AND METHODS: Participants performed isometric knee extension strength testing using a dynamometer locked at 60° of knee flexion. Participants completed 3 total repetitions of maximal effort knee extension, lasting 5 seconds, followed by a 15 second rest interval and a 5 second maximal effort knee flexion trial. Participants were verbally encouraged during the trials and were allowed real time visual feedback on peak torque performance. RTD onset was defined as the first 10 milliseconds where RTD increased consecutively for 100 milliseconds. Knee extension peak torque, RTD onset to 100 milliseconds (RTD100), and RTD onset to 250 milliseconds (RTD250) were separately averaged across all 3 trials and used for analysis. Independent-samples t tests analyzed group differences on the variables of interest.

RESULTS: The ACLR limb had a significantly lower RTD100 compared to the healthy control group (2.34 ± 1.34 versus 4.75 ± 2.06 ft-lb/lb-s, $P = .01$), RTD250 compared to the healthy control group (1.33 ± 0.60 versus 2.57 ± 0.535 ft-lb/lb-s, $P < .01$) and body weight normalized peak torque compared to the control group (0.71 ± 0.18 ft-lb/kg versus 0.91 ± 0.17 ft-lb/kg, $P = .02$).

CONCLUSIONS: Early phase RTD (100 milliseconds) and late phase RTD (250 milliseconds) are significantly reduced compared to healthy control individuals. RTD within the early phase has been previously associated with neurologic factors such as motor unit recruitment and motor neuron firing rate, whereas late phase RTD is associated with physiologic muscle properties. This report would further support the framework that systemic neuromuscular changes occur after ACLR.

CLINICAL RELEVANCE: RTD, in addition to knee extension peak torque, should be evaluated in individuals after ACLR. Clinicians should exercise caution when returning individuals to running and jumping 3.5 months following ACLR due to RTD deficits which are associated with detrimental knee extension loading during landings.

SP022

ANGLE COUPLING VARIABILITY AND PATIENT-REPORTED FUNCTION 2 YEARS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Adam Michael Culiver, Sanjiv Ajit Dhodapkar, Jennifer Perry, Laura C. Schmitt

PURPOSE/HYPOTHESIS: Greater angle coupling variability (ACV) during gait exists in an anterior cruciate ligament reconstruction (ACLR) population compared to healthy controls. ACV measures the coordinated angular relationship between 2 joints and coordination asymmetries during stair descent and single leg landing are present in an ACLR population. These changes in ACV highlight kinematic differences from time of return to sport up to 20 years following ACLR. However, these results currently lack an association with patient reported function. The Knee Injury and Osteoarthritis Outcome Score (KOOS) is frequently used to determine patient reported function in individuals 2 years after ACLR. Therefore, the purpose of this investigation was to determine the association among knee and ankle sagittal plane ACV during gait and patient reported function. We hypothesized increased knee and ankle sagittal plane ACV would predict worse KOOS Symptoms and KOOS Quality of Life (QoL) scores.

NUMBER OF SUBJECTS: Sixteen participants (mean $\pm$ SD age, 22.91 ± 3.98 years; 7 female) following primary ACLR (all hamstring grafts) were tested 2.26 ± 0.28 years after surgery.

MATERIALS AND METHODS: Three-dimensional kinematic data at the hip, knee, and ankle were collected during over ground gait. Data were analyzed from initial contact, defined as vertical ground reaction force (vGRF) exceeding 20 N until the local minima vGRF in the mid-stance phase. Data were time normalized and angle coupling was calculated at the knee and ankle in the sagittal plane. Angle coupling was then averaged for each of the 5 gait trials, standard deviation was calculated and

used for subsequent analysis. Participants additionally completed KOOS Symptoms, ADL, Sport and QoL subscales (each subscale scored 0-100, 100 indicating high function) within 1 week of the testing session. Simple linear regressions were performed to determine if ACV at the knee and ankle of the ACLR limb predicted KOOS scores.

RESULTS: No significant associations were noted among knee and ankle sagittal plane ACV and KOOS Symptoms ($P = .140$, $R^2 = 0.088$), KOOS ADL ($P = .941$, $R^2 = -0.071$), KOOS Sport ($P = .951$, $R^2 = -0.071$), or KOOS Quality of Life ($P = .557$, $R^2 = -0.045$).

CONCLUSIONS: ACV at the knee and ankle during gait does not predict patient reported function, as measured by the KOOS, in individuals 2 years after ACLR. Although prior research has identified changes in gait ACV at the knee and ankle relative to healthy controls, this specific angle coupling may not be a predictive measure.

CLINICAL RELEVANCE: Sagittal plane knee and ankle angle coupling during gait does not influence patient reported function in individuals 2 years after ACLR. ACV of more dynamic tasks should be investigated in the future to determine their influence on patient reported function.

SP023

SCREENING FACTORS THAT PREDICT INJURY RISK IN COLLEGIATE FEMALE ATHLETES

Dylan Davies, Madison Wengel, Justin Rodriguez, Sabrina Martineau, Jennifer Christie Kish, Laura Spivey Kabiri, Alexis Ortiz

PURPOSE/HYPOTHESIS: To identify screening factors related to female athlete low energy availability, menstrual dysfunction, and bone mineral density and to determine the association between these factors and injuries throughout the season.

NUMBER OF SUBJECTS: Collegiate female athletes from the University of the Incarnate Word ($n = 42$) participated in this study.

MATERIALS AND METHODS: An online questionnaire, adapted from the Female Athlete Triad Coalition's recommended screening questions was emailed to female athletes during the Spring athletic season. Additional survey items included athlete demographics, vitamin deficiency status, hours of training/week, and number of injuries during the season. Responses were recorded anonymously in an electronic spreadsheet. Descriptive statistics in terms of average, standard deviations, and frequencies were summarized for the numerical and categorical variables respectively. Hours of training, worry about weight, limited food intake, and a diagnosed eating disorder or Vitamin D deficiency were used as predictors in 2 separate binary logistic regressions to explore their associations with stress fracture history and number of musculoskeletal injuries during the season.

RESULTS: Binary logistic regression revealed that athletes who worry about their weight and limit their amount of food are 5 and 10 times more likely, respectively, to have a soft tissue musculoskeletal injury during the season. However, no association was found between predictors and stress fractures.

CONCLUSIONS: Disordered eating behaviors such as limiting amount of food intake and worrying about weight gain appear to be significant contributors to musculoskeletal injuries in Division I collegiate female athletes.

CLINICAL RELEVANCE: Physical therapists can play a vital role in musculoskeletal injury risk assessment as part on a multiprofessional NCAA sports medicine team. Screening across an athletic season and including returning athletes for injury predictors in female athletes is indicated.

SP024

CARBOHYDRATE INGESTION ATTENUATES COGNITIVE DYSFUNCTION FOLLOWING LONG-DURATION EXERCISE IN THE HEAT IN HUMANS

Nate Joshua Deming, Jennifer C. Richards, Frank A. Dinunno

PURPOSE/HYPOTHESIS: To determine if electrolyte or carbohydrate supplementation versus water would limit the magnitude of dehydration and

decline in cognitive function in humans following long-duration hyperthermic exercise.

NUMBER OF SUBJECTS: Twenty-four subjects.

MATERIALS AND METHODS: Subjects performed 3 visits of 2 h walking (3 mph/7% grade) in an environmental chamber ($33^{\circ}\text{C}/10\%$ relative humidity). In random order, subjects consumed water (W), electrolytes (Gatorade Zero; E), or electrolytes plus carbohydrates (Gatorade; E+C). Throughout exercise (EX), subjects carried a 23-kg pack and drank ad libitum. Pre-and post-EX, body mass (BM) and plasma osmolality (pOsm) were measured. Physiological Strain Index (PSI) and core temperature (TC) were recorded every 15 minutes. Plasma glucose (GLU) was measured every 30 minutes. Cognitive processing (SCWT) was measured post EX and compared to baseline (BL). A subset of 8 subjects performed a normothermic (N) protocol (21°C /ambient humidity) to ascertain how the exercise stimulus influenced hydration status and cognition without heat.

RESULTS: There were no significant differences between fluid conditions (W, E, E+C) for BM loss (change: 2.5 ± 0.2 , 2.5 ± 0.2 , 2.3 ± 0.2 kg), fluid consumption (1.9 ± 0.2 , 1.9 ± 0.2 , 1.8 ± 0.2 L), pOsm (change: 1.5 ± 2.7 , 2.2 ± 2.4 , 2.0 ± 1.5 mmol/L), peak-PSI (7.5 ± 0.4 , 7.0 ± 0.6 , 7.9 ± 0.5), and peak-TC ($38.7^{\circ}\text{C} \pm 0.1^{\circ}\text{C}$, $38.6^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$, $38.8^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$). GLU decreased significantly in W and E, whereas it increased above BL in E+C at 60, 90, and 120 minutes ($P < .05$). Compared to BL values (43.6 ± 26 milliseconds), SCWT performance significantly decreased in all conditions (463 ± 93 , 422 ± 83 , 140 ± 52 milliseconds; $P < .05$). Importantly, compared to W and E, the impairment in SCWT was significantly attenuated in E+C ($P < .05$). As expected, when compared to the heat-stress protocol (W, E, E+C), N resulted in lower BM loss, fluid consumption, and peak-PSI (1.1 ± 0.1 kg, 1.2 ± 0.7 L, 4.8, respectively), and improved SCWT performance.

CONCLUSIONS: Compared to water and fluids supplemented with only electrolytes, fluids supplemented with carbohydrates significantly blunts this decrease in cognitive function.

CLINICAL RELEVANCE: These data are the first to suggest that, independent of supplementation variety, cognitive processing significantly decreases immediately following long-duration exercise in the heat in healthy humans.

SP025

MULTIMODAL PHYSICAL THERAPY FOR A BALLET DANCER WITH CHRONIC CERVICALGIA

Heather Lynn Disney-Polman, Sarah Rebecca Brown

BACKGROUND AND PURPOSE: The purpose of this case report was to examine how a multimodal treatment program was used to increase upper quarter stability, improve posture, and reduce pain in a patient with chronic cervicalgia. The interventions of this program focused on soft tissue mobilization, neuromuscular re-education, and axioscapular strengthening to reduce the patient's pain, and help her return to her prior level of function.

CASE DESCRIPTION: The patient was a 19-year-old female ballet dancer referred to physical therapy, reporting chronic neck and upper back pain for the previous 4 years. This patient's primary impairments included decreased strength of her bilateral shoulder musculature, and decreased cervical range of motion. Secondary impairments for this patient included increased pain with cervical and shoulder movements. The patient received physical therapy treatment twice a week for 6 weeks. Interventions included soft tissue mobilization to facilitate increased efficacy of stretching targeted muscles, neuromuscular re-education to facilitate increased upper quarter stability, postural training and education, therapeutic activity, therapeutic exercises to strengthen key postural muscles, and modalities to compliment pain relief and lengthening of tight muscles.

OUTCOMES: Since the beginning of treatment, the patient's pain decreased from 6/10 to 3/10 at the worst level, and 2/10 to 1/10 at the best level. The MCID for the NPRS is 1 point. The patient had improved her UEFS score by 10 points from 67/80 (83.75%) to 77/80 (96.25%), with the MDC for the UEFS being 8.1 points. Values for B shoulder flexor, abductor, and in-

ternal/external rotator strength and cervical extension, and R lateral flexion ROM improved since the start of care, in conjunction with decreased cervical pain with movement.

DISCUSSION: After physical therapy treatment, the patient reported improved quality of life, which was demonstrated by increased shoulder strength, increased cervical ROM, and decreased pain with movements. The patient's progress took place over 6 weeks, and her physical therapy program had shown effectiveness in the treatment of chronic upper thoracic and cervical pain.

SP026

EFFECTIVENESS OF 2 DIFFERENT BLOOD FLOW RESTRICTION TRAINING PRESSURES ON ISOKINETIC MUSCLE STRENGTH OF THE QUADRICEPS

Blake Doughtie, David Calderon, Gian Carlo Cruz, Nicole Hoppe, Jaime Gonzalez, Jason Winchester

PURPOSE/HYPOTHESIS: To examine the effectiveness of blood flow restriction (BFR) training while using 2 different cuff pressures on the isokinetic strength of the quadriceps muscle group after 3 weeks of cycling training for 15 minutes.

NUMBER OF SUBJECTS: Twenty-seven healthy participants (mean $\pm$ SD age, 25 ± 3 years; 12 male, 15 female).

MATERIALS AND METHODS: Participants were randomly assigned to a group of BFR training with 60% occlusion ($n = 8$), BFR with 80% occlusion ($n = 11$), or control ($n = 8$). The training protocol consisted of cycling on a stationary ergometer for 15 minutes at 70 rpm, 25 W of resistance with the BFR cuff inflated to their assigned occlusion percentage for the BFR group on the dominant leg and no occlusion for the control group. The stationary cycling training was performed 3 times a week for 3 weeks at 70 repetitions per minute. Muscle strength of the knee extensors in the dominant leg was measured at baseline and at 3 weeks using an isokinetic dynamometer at speeds of 60°/s, 180°/s, and 300°/s using a standardized knee extension protocol. Given the normally distributed data for torque and work of the knee extensors, a 2-by-3 (time by group) repeated-measures ANOVA was used to perform between and within-group comparisons with post hoc tests if appropriate. Statistical significance was at an alpha of .05 for all analyses with appropriate post hoc analysis.

RESULTS: The ANOVA time by group interaction was not statistically significant. However, the time main effect was statistically significant with improvements over time, while the between-group main effect was not statistically significant. Torque at 180°/s ($P < .001$) and 300°/s ($P = .01$) and work at 180°/s ($P < .001$) were the variables improving over time, in all groups.

CONCLUSIONS: It appears there are no differences between the 2 different BFR occlusion pressures between groups and a control group, indicating that BFR training is not superior to a control condition.

CLINICAL RELEVANCE: Aerobic exercise on a cycle ergometer appears to be sufficient to create an increase the strength of the quadriceps muscles during a 3-week period. The addition of BFR cuffs during cycling does not appear to provide an additional strengthening effect to the quadriceps musculature when compared to a standardized aerobic protocol.

SP027

VENOUS ABNORMALITY WITH SUPRASCAPULAR NERVE ENTRAPMENT IN A COLLEGIATE BASEBALL PITCHER

Alexander Nathaniel Durland, Christopher Tyler Ricks, Zac Womack, Chris Urbanek

BACKGROUND AND PURPOSE: Suprascapular nerve palsy accounts for 1% to 2% of all shoulder pathologies. Early diagnosis is critical to prevent the development of infraspinatus wasting, otherwise known as infraspinatus syndrome. Traction or compression of the nerve, as well as rotator cuff diseases, can result in damage and subsequent neuropathy. Other causes include bone tumors and cysts after capsular injury or labral tears. There is limited literature on suprascapular vein malformation associated with

nerve compression highlighting 6 cases only 1 in a college aged individual. In the overhead athlete, damage to the suprascapular nerve is often due to repetitive tightening of the spinoglenoid ligament while the shoulder is in the overhead throwing position. Following a suprascapular nerve palsy diagnosis, conservative treatment is often used initially with arthroscopic decompression, the gold standard, being used secondarily. The purpose of this case report is to describe diagnosis and treatment of a collegiate baseball pitcher with suprascapular nerve entrapment with suprascapular vein as a potential contributing factor.

CASE DESCRIPTION: A 20-year-old male right-handed collegiate baseball pitcher was used for this case study with clinical presentation of right anterior shoulder pain, external rotation weakness (4-/5), positive O'Brien's test, and infraspinatus syndrome. Negative special tests of the shoulder included drop arm, Speeds, and Jobe's empty can. An MRI was ordered and showed evidence of a mild subchondral cyst on the posterolateral surface of the humeral head along with fatty infiltration of the infraspinatus. An EMG was completed and revealed suprascapular nerve injury with denervation and impaired recruitment of the infraspinatus. An ultrasound of the shoulder revealed venous malformation of the suprascapular vein as compared to the uninvolved limb, which was believed to be contributing to the suprascapular nerve injury.

OUTCOMES: After 2 months of physical therapy focused on rotator cuff and periscapular strengthening as well as neuromuscular reeducation, the patient presented with continued shoulder pain while throwing. Venous sclerotherapy was discussed versus surgical consultation. The patient elected to undergo an arthroscopic SARS procedure for suprascapular nerve decompression by release of the spinoglenoid. The patient resumed rehab postoperatively and was able to return to throwing. He did however, develop recurrent anterior shoulder pain with crepitus while throwing along with increased pain with activities of daily living (ADLs), and continued external rotation weakness and was unable to return to competition or prior level of performance.

DISCUSSION: Despite months of intensive rehabilitation and arthroscopic decompression surgery, the patient was unable to return to in-game competition at his prior level of performance without continued shoulder pain and weakness. The involvement of venous malformation on suprascapular nerve entrapment is a unique anatomical abnormality and should be taken into account as part of a comprehensive treatment plan.

SP028

STABILITY OF LOWER EXTREMITY MOVEMENT QUALITY OVER A DIVISION I COLLEGIATE WOMEN'S SOCCER SEASON

Timothy George Eckard, Elena D'Argenio, Barnett Frank, William Edward Prentice, Darin Padua

PURPOSE/HYPOTHESIS: Anterior Cruciate Ligament (ACL) injuries have been recognized as one of the most common and devastating injuries in women's soccer. The Landing Error Scoring System (LESS) is a valid and reliable clinical screening tool of lower extremity movement quality used to assess ACL injury risk. Currently, there is a dearth of evidence regarding how performance on the LESS may change over a women's soccer season in response to training and match loads and how prior ACL injury status may influence the direction and magnitude of any changes.

NUMBER OF SUBJECTS: Twenty-eight.

MATERIALS AND METHODS: Varsity women's soccer athletes from 1 NCAA Division I institution completed the LESS prior to the start of the preseason (week 0) and postseason (week 15). Prior ACL injury status data were collected at the start of the preseason. Mean LESS change scores from pre to postseason were compared between those with and without a history of ACL injury utilizing an independent t test. A 2-by-2 mixed-model ANOVA was utilized to compare LESS scores between the 2 time points of the season between those with and without a history of ACL injury.

RESULTS: There was no significant difference in overall mean LESS scores from pre to postseason ($P = .19$). A total of 9 (32.1%) participants re-

ported a history of ACL injury. The mean change score from pre to post-season was $+1.17 \pm 1.94$ points in those with a history of ACL injury and -0.60 ± 1.35 points in those without. In univariable analysis, this difference was statistically significant ($P = .03$). In multivariable analysis, there was a significant interaction between ACL injury history and time in season ($P = .03$), as well as a significant main effect for ACL injury history ($P = .03$).

CONCLUSIONS: Lower extremity movement quality appears to degrade in women's collegiate soccer players with a history of ACL injury over the course of a competitive season, a trend not observed in those without a history of ACL injury.

CLINICAL RELEVANCE: The divergent pattern in lower extremity movement quality observed in this study suggests that women's collegiate soccer players with a history of ACL injury may benefit from ongoing performance of corrective exercises focused on maintaining movement quality to avoid deterioration in movement quality over a competitive season.

SPO29

DIFFERENCES IN DECELERATION-PHASE KINEMATICS BETWEEN HIGH-VELOCITY AND LOW-VELOCITY COLLEGIATE BASEBALL PITCHERS

Blake Lyle Edwards, Cody M. Ballay, Cal Haefke, Nathan Edwards, Daniel Richie, James A. Onate, Ajit Chaudhari

PURPOSE/HYPOTHESIS: Deceleration is the phase in the baseball pitching motion from ball release to maximum dominant shoulder internal rotation. Past studies have established pitching velocity as a risk factor for injury in pitchers. In addition, limitations in hip mobility have been correlated with shoulder and elbow injury in pitchers. There is a lack of research on biomechanics of the deceleration phase, differences in high-velocity versus low-velocity pitchers, and kinematics of proximal and lower extremity segments of the kinetic chain in the pitching motion. The objective of this study was to compare deceleration kinematics between 2 groups of NCAA Division III collegiate baseball pitchers based on pitching velocity.

NUMBER OF SUBJECTS: Thirteen NCAA Division III collegiate baseball pitchers without current injury or participation limitations.

MATERIALS AND METHODS: After a warm-up, participants threw 5 pitches from their preferred starting position off a standard mound while 3-D kinematics were captured using an optical motion capture system. The trial with the highest dominant index finger velocity was analyzed for each subject. Angular velocity and timing were analyzed for the pelvis, torso, shoulder internal rotation (IR), shoulder resultant, and elbow extension for the deceleration phase; defined as maximum angular velocity of the segment to minimum angular velocity or change in direction. The pitchers were divided into 2 groups based on finger velocity with 4 pitchers in the high-velocity group and 9 in the low-velocity group. Student's t tests were used to compare parameters between groups ($\alpha = .05$).

RESULTS: The high velocity group executed the deceleration phase of the pelvis ($21^\circ \pm 7^\circ$ versus $36^\circ \pm 8^\circ$, $P = .03$), trunk ($11^\circ \pm 5^\circ$ versus $20^\circ \pm 5^\circ$, $P = .02$), and throwing shoulder IR ($9^\circ \pm 1^\circ$ versus $17^\circ \pm 9^\circ$, $P = .03$) in a significantly shorter percentage of the pitching motion than the low velocity group. The high velocity group demonstrated a significantly higher joint excursion of shoulder IR ($69^\circ \pm 9^\circ$ versus $47^\circ \pm 12^\circ$, $P = .01$). The high-velocity group also demonstrated significantly greater deceleration than the low-velocity group in shoulder IR ($104162^\circ/\text{s} \pm 13077^\circ/\text{s}$ versus $38158^\circ/\text{s} \pm 22060^\circ/\text{s}$, $P = .0001$), shoulder resultant ($15474^\circ/\text{s} \pm 4727^\circ/\text{s}$ versus $7288^\circ/\text{s} \pm 2919^\circ/\text{s}$, $P = .05$), and elbow extension ($88456^\circ/\text{s} \pm 13293^\circ/\text{s}$ versus $55286^\circ/\text{s} \pm 12850^\circ/\text{s}$, $P = .01$) segments.

CONCLUSIONS: Overall, the high-velocity group demonstrated more deceleration at each segment than the low-velocity group. The most significant result was shoulder IR which demonstrated a significantly greater joint excursion and change in velocity over a significantly shorter amount of time in high-velocity pitchers.

CLINICAL RELEVANCE: This study indicates that there are higher demands on the decelerating muscles of the throwing shoulder in higher velocity pitchers, potentially explaining the correlation between high velocity and injury. Clinicians should keep in mind the high stresses that all segments in the kinetic chain undergo during deceleration, especially the throwing shoulder, as they design rehabilitation programs meant to simulate these in-game demands.

SPO30

EFFECT OF BLOOD FLOW RESTRICTION TRAINING ON MUSCULAR STRENGTH IN FEMALE RUNNERS WITH PATELLOFEMORAL PAIN

Lauren Nicole Erickson, Christopher S. Fry, Cale A. Jacobs, Michael Samaan, Brian W. Noehren

PURPOSE/HYPOTHESIS: Patellofemoral pain (PFP) is associated with quadriceps and gluteal weakness, especially in females. High-load strength training, which is typically required to improve muscular strength, can often cause pain and symptoms to flare. Blood flow restriction training (BFRT) is an alternative training method that uses low-load strength training to improve muscular strength; however, minimal research has assessed the effects of BFRT in individuals with PFP. Therefore, the purpose of this study was to determine if low-load strength training with BFRT would lead to greater improvements in quadriceps and gluteal strength than low-load strength training without BFRT in females with PFP.

NUMBER OF SUBJECTS: Twenty female recreational runners with PFP: 10 in the BFRT group (mean $\pm$ SD age, 31.2 ± 9.1 years; symptom duration, 26.3 ± 31.6 months), 10 in the standard of care (SOC) group (mean $\pm$ SD age, 27.9 ± 7.5 years; symptom duration, 27.9 ± 43.9 months).

MATERIALS AND METHODS: Subjects were randomly allocated to either low-load strength training with BFRT (BFRT group) or low-load strength training with sham BFRT (SOC group) over a 10-week intervention period. Quadriceps strength was assessed with a Biodex dynamometer and gluteal strength was assessed with a handheld dynamometer at preintervention and postintervention. Variables of interest included peak isometric quadriceps strength, hip external rotation strength, and hip abduction strength. Change scores were calculated as: postintervention value – preintervention value. Independent t tests were used to compare differences between groups in change scores. Pearson product moment correlations were used to assess the relationship between strength outcomes ($\alpha < .05$).

RESULTS: There were no significant differences between groups in change scores for quadriceps strength (BFRT, 0.2 ± 0.3 Nm/kg; SOC, 0.2 ± 0.4 Nm/kg; $P = .83$), or for hip external rotation (BFRT, 1.4 ± 1.3 Nm/kg; SOC, 1.4 ± 0.8 Nm/kg; $P = .83$) and hip abduction (BFRT, 4.0 ± 3.9 Nm/kg; SOC, 4.4 ± 2.0 Nm/kg; $P = .82$) strength. Improvements in quadriceps strength ranged from 8% to 10%, and improvements in hip external rotation and hip abduction strength ranged from 23% to 32% in both groups. In the BFRT group, change scores for quadriceps strength were strongly significantly associated with change scores for hip external rotation ($r = 0.72$, $P = .02$) and hip abduction ($r = 0.75$, $P = .01$) strength.

CONCLUSIONS: Low-load strength training with BFRT was equally effective as low-load strength training without BFRT for improving quadriceps and gluteal strength. In the BFRT group, subjects that demonstrated minimal change in quadriceps strength also demonstrated minimal change in gluteal strength, indicating that some individuals may respond better to BFRT than others.

CLINICAL RELEVANCE: Low-load strength training with or without BFRT can be used as an alternative to high-load strength training to address quadriceps and gluteal strength deficits in female runners with PFP. Further studies are needed to help elucidate what characteristics/factors may lead to a more favorable response to BFRT. Thus, enabling clinicians to design the most effective rehabilitation program for individuals with PFP.

SP031

RETURN TO RUNNING AFTER A TRANSFEMORAL AMPUTATION USING AN ANTIGRAVITY TREADMILL

Vanessa Jean Everett, Valerie Jane Williams Hogan, Samuel Moisenko, Megan Wiley, John Russell Belcher

BACKGROUND AND PURPOSE: Return to recreational running is a common goal of young healthy individuals after transfemoral amputation (TFA). A comprehensive rehab approach addressing prosthetic adaptations, physical impairments, running biomechanics, and patient preferences and confidence, ensures return to running is safe and energy efficient. De-weighting devices can be useful to decrease vertical ground reaction forces while maintaining horizontal forces, to increase weight-bearing tolerance through a prosthetic limb. The AlterG antigravity treadmill is one such device, but previous research of its use after TFA is limited. The purpose of this case report is to describe a return-to-running program using the AlterG in an individual with a TFA.

CASE DESCRIPTION: The patient was a 35-year-old woman with a diagnosis of right TFA due to necrotizing fasciitis. She was hospitalized in late August 2019 due to insidious onset of severe right lower extremity pain and underwent a TFA the next day. She stayed in the acute care hospital for 17 days, followed by 3 weeks of post acute care and rehabilitation at a skilled nursing facility. She was discharged to home, with her husband and children, and participated in outpatient physical therapy from October 2019 to February 2021. The patient had a long-term goal to be independent in a recreational running program. Use of the AlterG was initiated in December 2020. The initial 3 sessions (over 6 weeks) were made in conjunction with the prosthetist to facilitate appropriate fit and adjustment of the running prosthesis. Initial video analysis revealed decreased weight bearing through the prosthetic limb resulting in a shortened step length on the other limb, decreased cadence, and excessive circumduction of the right limb in swing phase. The return to running intervention included 4 months of interval training with selected parameters for speed (walking, 2.2-2.8 mph; running, 4-4.8 mph), body weight support (85%-20% unweighted), and running interval duration (2-4 minutes). The final 3 running sessions (once a week for 3 weeks) were used to make the transition to independent running outside on uneven ground (June 2021). Qualitative assessments of her running mechanics via video analysis, heart rate, and RPE were collected each session.

OUTCOMES: Gait analyses revealed improvements in cadence, speed, alignment, and step length while in the AlterG. Duration of exercise increased to 35 minutes, top running speed increased to 4.8 mph max, and weight-bearing assistance decreased to 20% unweighted, ultimately achieving full weight bearing running outside of the AlterG.

DISCUSSION: Use of an antigravity treadmill with an interval training program assisted this individual in achieving full weight bearing through a running prosthesis and returning to independent recreational running. Benefits of using the AlterG included increased comfort and confidence for the patient, ease of working on natural gait, and real time biomechanics biofeedback provided by video cameras. The therapist was unable to provide tactile cues in this device.

SP032

COMPARISON OF SELECTED UPPER EXTREMITY PHYSICAL PERFORMANCE MEASURES IN YOUNG, COMPETITIVE GYMNASTS

Danielle Farzanegan, Nicole Melfi, Emily Francione

PURPOSE/HYPOTHESIS: There is minimal research on how healthy, young gymnasts perform on standardized upper extremity (UE) physical performance tests. Clinically, it seems possible that there could be a difference based on sex due to the different physical demands of male and female gymnastics events; however, this has not been demonstrated in the literature. Overall, there is a need for normative data in this population to assist clinicians treating injured gymnasts, screening those at risk for injury, and for comparing athletes across different competitive sports. The

purpose of this study was to describe and compare performance on standardized measures by sex. This study hypothesizes there will be a significant difference in upper extremity physical performance between the sexes in young, competitive gymnasts.

NUMBER OF SUBJECTS: Thirty-one subjects.

MATERIALS AND METHODS: Thirty-one female gymnasts were recruited to participate in this study. All participants reported no current injury affecting the spine or upper extremity. Participants completed the Upper Quarter Y Balance Test (UQYBT). Measurements for medial, inferolateral, and superolateral as well as unilateral composite scores were calculated. Participants also completed the closed kinetic chain upper extremity stability test (CKCUEST). The data were analyzed in SPSS using comparative *t* tests with an alpha level set at .05.

RESULTS: The average $\pm$ SD age of the sample was 12.8 ± 2.2 years (range, 9-18 years) with 12 males and 19 females. The average BMI was 19.3 kg/m^2 for males and 17.3 kg/m^2 for females. The average competitive gymnastics level was 9.0 for males and 7 for females. There were no significant differences between the sexes for any of the 3 UQYBT directions, but there were significant differences between the sexes for the composite scores, $P \leq .025$. Males had right and left UQYBT composite scores of 94.1 ± 8.0 and 94.0 ± 9.2 , and females had right and left UQYBT composite scores of 84.1 ± 8.6 and 84.7 ± 10.3 . There was no difference found on the CKCUEST with males having an average score of 24.8 ± 4.2 and 24.1 ± 3.8 for females, $P = .655$.

CONCLUSIONS: This study found no evidence of asymmetric performance on the UQYBT test in youths participating in competitive gymnastics. However, there was a significant difference between the sexes on the composite UQYBT for the UE.

CLINICAL RELEVANCE: It is suggested that future studies continue to gather normative values for these UE performance measures. These normative sets would be valuable for the clinicians in order to set appropriate goals and identify athletes that may be at risk for UE injury and loss of participation time.

SP033

VALIDATION OF THE ISOMETRIC MID-THIGH PULL AS A TOTAL BODY MEASURE OF STRENGTH

Richard A. Ferraro, Andrew David Lynch, Arjun K. Patel

PURPOSE/HYPOTHESIS: To describe the isometric mid-thigh pull (IMTP) as a measure of total body strength in healthy adults and to compare results to other commonly used measures.

NUMBER OF SUBJECTS: Thirty-three active, healthy adults (10 females) participated. Average $\pm$ SD age was 25.8 ± 3.2 years (range, 22-37 years). Average $\pm$ SD BMI was $24.6 \pm 2.7 \text{ kg/m}^2$ (range, 18.8-29.5 kg/m^2). Recruitment and data collection continue (target $n = 80$).

MATERIALS AND METHODS: Participants performed the IMTP and 4 standardized tests including grip strength, 30-second chair rise, 5-times sit-to-stand, and standing broad jump. Maximum force output for 3 IMTP trials was recorded with a digital strain gauge and normalized to body weight. Grip strength was compared to age, sex, and body size predictions. Normalized IMTP results were compared to other tests with simple correlations.

RESULTS: On average, participants produced $18.8 \pm 4.0 \text{ N/kg}$ of body weight with the IMTP. Male participants produced $20.8 \pm 2.6 \text{ N/kg}$ of body weight compared to $14.3 \pm 2.5 \text{ N/kg}$ body weight for female participants ($P < .0001$). IMTP force outputs were lower than published outputs in athletic populations but are consistent with reported values in recreationally trained adults and adults completing rehabilitation for low back pain. Average grip strength for the dominant hand was $49.2 \pm 12.9 \text{ kg}$ of force which was $15.7 \pm 7.3 \text{ kg}$ of force greater than predicted from age, sex, height, and weight. IMTP and normalized grip strength were moderately correlated ($r = 0.56$, $P < .001$). Participants completed 26.6 ± 4.3 sit-to-stand repetitions in 30 seconds. IMTP demonstrated a fair correlation

with 30-second chair rise performance ($r = 0.48$, $P < .005$). Participants completed 5 ± 1.0 sit-to-stand repetitions in 5.9 seconds, which had a fair correlation with IMTP ($r = -0.38$, $P = .03$). Participants broad jumped 6.9 ± 1.1 cm of horizontal distance per cm of body height, which was very strongly correlated with IMTP ($r = 0.84$, $P < .0005$).

CONCLUSIONS: IMTP demonstrated stronger correlations with measures of maximum force and power production compared to measures of endurance used in the clinic. Male participants produced greater normalized force than females, indicating a need for gender based normative data. Participants had greater grip strength than a general age matched cohort, however participants produced less force in the IMTP than in trained athletes. Continued data collection will produce a more representative sample for clinical comparisons.

CLINICAL RELEVANCE: To date, there are few valid measures of total body strength used consistently in nonathletic populations. The IMTP has potential as a total body measure of strength that is accurate, cost-effective, and feasible outside of the athletic population. Comparison to existing measures and creating normative data are the first steps in validating the IMTP for use with patients. These results will be used as a comparison when using IMTP in individuals with musculoskeletal (low back pain, osteoarthritis, etc) and neurological conditions (Multiple Sclerosis, Parkinson's Disease, etc).

SP034

BLOOD FLOW RESTRICTION EXTENDS TIME TO RECOVERY FOLLOWING FATIGUING UPPER EXTREMITY EXERCISE

Patrick James Grabowski, Cody Michael Carlstrom, Malcolm Richard Driessen, Benjamin Michael Thornton, Alex Burton

PURPOSE/HYPOTHESIS: Blood flow restriction (BFR) training uses a pneumatic cuff to occlude extremity blood flow during exercise. Many responses to BFR are well-researched, and the emergence of BFR in clinical settings is becoming more prevalent, however, the understanding of various uses of BFR remains limited. For example, BFR elicits fatigue more quickly than traditional strength training during an acute bout of exercise, which makes it an ideal tool for creating conditions of fatigue in a clinical setting. However, the effect of maintained occlusion during recovery post exercise is not well understood and may have clinical relevance for functional training under fatigued conditions. This study explored feasibility and effectiveness of inducing a prolonged fatigued state of the upper extremity (UE) using BFR at different occlusion pressures (0%, 50% and 75%).

NUMBER OF SUBJECTS: Fifteen healthy individuals (7 female; age, 22-35 years).

MATERIALS AND METHODS: Baseline 1-arm seated shot-put throws with a 6lb medicine ball were measured by tape. Participants then completed a fatigue protocol of 2 sets of overhead dumbbell shoulder press with a Delfi tourniquet system (Delfi Medical Innovations, Inc, Vancouver, Canada) on the proximal humerus inflated to 60% occlusion, until 3-repetition reserve was met. Immediately following, participants threw maximally every 30 seconds, with the cuff set to 0%, 50%, or 75% occlusion until 95% of the initial throw distance was reached (ie, "recovery") or 10 cycles max. After resting, the protocol was repeated for the other levels of occlusion. Conditions were randomized and balanced. Participants and data collectors were blinded to the occlusion condition. Statistics were calculated with repeated measures ANOVA and Bonferroni-corrected post hoc tests.

RESULTS: At 0% occlusion, recovery time averaged 2.6 ± 1.9 minutes (95% CI: 1.5, 3.7), for 50% occlusion 4.6 ± 3.5 minutes (95% CI: 2.6, 6.5), and at 75% occlusion 7.2 ± 3.2 minutes (95% CI: 5.4, 9.0). Mean differences were statistically significant between 0% and 50% ($P < .05$, $d = 0.7$), 0% and 75% ($P < .05$, $d = 1.7$), and 50% and 75% occlusion ($P < .05$, $d = 0.8$). The average discomfort rating (0%: mean $\pm$ SD, 1.7 ± 1.5 ; 95% CI: 0.4, 1.8; 50%: mean $\pm$ SD, 4.1 ± 1.5 ; 95% CI: 3.2, 4.9; 75%: mean $\pm$ SD, 6.8 ± 1.3 ; 95% CI: 6.1, 7.5) increased with each pressure.

CONCLUSIONS: BFR can be used to fatigue the UE and maintain that fatigue for a prolonged period. A trade-off between longer fatigue period and discomfort level was found as higher occlusion pressures produced significantly more discomfort. More research is needed to determine the optimal occlusion and upper limit of recovery time as a majority (9/15) of participants did not meet the 95% threshold within 10 trials at 75% occlusion, meaning recovery time is longer than reported or unattainable.

CLINICAL RELEVANCE: BFR for UE functional training under fatigued conditions may be valuable for athletes returning to competitive activities. This study demonstrates fatigued conditions can be reached quickly and sustained long enough to complete skill training with tolerable occlusion pressures.

SP035

BLOOD FLOW RESTRICTION EXTENDS TIME TO RECOVERY FOLLOWING FATIGUING LOWER EXTREMITY EXERCISE

Patrick James Grabowski, Grace Elizabeth Gaugert, Taylor Nicole Gesch, Mackenzie Elyse Torgerson, Alex Burton

PURPOSE/HYPOTHESIS: Blood flow restriction (BFR) training uses a pneumatic cuff to occlude extremity blood flow during exercise. Most research on BFR relates to long-term impacts on muscle morphology and function, or acute exercise response. For example, BFR elicits fatigue more quickly than traditional strength training during an acute bout of exercise. However, the effect of maintained occlusion during recovery post exercise is not well understood and may have clinical relevance for functional training under fatigued conditions. This study compared the effect of maintained occlusion pressure on recovery time after fatiguing lower extremity (LE) exercise.

NUMBER OF SUBJECTS: Twelve healthy individuals (8 female; age, 22-27 years).

MATERIALS AND METHODS: Baseline maximal single-leg (SL) hop height was measured with a force plate and The Motion Monitor software (Innovative Sports Training, Inc, Chicago, IL). Participants then completed a fatigue protocol of 3 sets of SL squats with a Delfi tourniquet system (Delfi Medical Innovations, Inc, Vancouver, Canada) on the proximal thigh inflated to 65% occlusion, until 3-repetition reserve was met. Immediately following squats, participants hopped maximally once every 30 seconds, with the cuff set to 0%, 50%, or 65% occlusion until 80% of the initial hop height was reached (ie, "recovery") or 5 minutes max. After resting, the protocol was repeated for the other levels of occlusion. Conditions were randomized and balanced. Participants and data collectors were blinded to the occlusion condition. Statistics were calculated with repeated-measures ANOVA and Bonferroni-corrected post hoc tests.

RESULTS: At 0% occlusion, recovery time averaged 0.95 ± 0.79 minutes (95% CI: 0.51, 1.4), for 50% occlusion 2.75 ± 1.67 minutes (95% CI: 1.80, 3.70), and at 65% occlusion 4.30 ± 1.27 minutes (95% CI: 3.58, 5.00). Mean differences were statistically significant between 0% and 50% ($P < .05$, $d = 3.0$), 0% and 65% ($P < .05$, $d = 3.3$), and 50% and 65% occlusion ($P < .05$, $d = 1.1$). The number of squats completed during fatigue protocols decreased as conditions progressed, from 23.4 in the first to 17.5 in the last. When grouped by sex or self-reported activity level recovery time did not differ.

CONCLUSIONS: Maintaining 65% occlusion elicited the longest fatigue effect: 56% longer than 50% and 350% longer than the 0% control condition. However, 8/12 participants were stopped after 5 minutes in the 65% condition, indicating actual recovery time would be longer or unattainable. Participants rated discomfort at an average 6.7/10 during the fatigue protocol, and generally tolerated the study well. Of note, 2 male participants with prehypertensive blood pressures experienced presyncopal events during the first trial and did not complete the study.

CLINICAL RELEVANCE: BFR for LE functional training under fatigued conditions may be valuable for athletes returning to competitive activities. This study demonstrates fatigued conditions can be reached quickly and

sustained long enough to complete skill training with tolerable occlusion pressures.

SP036

THE PREVALENCE OF PSYCHOSOCIAL FACTORS AMONG ATHLETES WITH NONSPECIFIC LOW BACK PAIN: A SYSTEMATIC REVIEW

Taylor Graham, Samuel Gisselman, Sean Daniel Rundell

PURPOSE/HYPOTHESIS: Systematically review studies on prevalence of psychosocial factors in adult athletes with nonspecific low back pain (LBP), defined as LBP not explained by radicular, stenotic, or other specific diagnoses. We hypothesized that athletes may present with a low prevalence of pain avoidance behavior.

NUMBER OF SUBJECTS: Five studies of competitive or recreational adult athletes (>18 years old) with current nonspecific LBP.

MATERIALS AND METHODS: A search of the literature was conducted using the PubMed, Embase, CINAHL, and PsycINFO databases with search terms relating to LBP, psychosocial factors, and outcome measures regarding pain and disability. Additional inclusion criteria: cross-sectional or cohort studies and outcome measures addressing psychosocial aspects of pain or disability. Exclusion criteria: specific diagnosis of LBP. Two researchers independently reviewed each title and abstract to determine which studies were included for full-text review. Full-text review was performed by 2 researchers, and data from all included studies was extracted and compiled into a table for analysis. Each study was assessed for bias using the risk of bias assessment developed by Hoy et al 2012.

RESULTS: A total of 741 studies were identified, with 18 selected for full text review, and 5 meeting the criteria for inclusion. Four studies assessed pain responses based on the Avoidance-Endurance Model as a predictor of chronicity and intensity for LBP, while the fifth study focused on aspects of quality of life and LBP beliefs. Two studies of elite German athletes reported endurance responses were the most prevalent (67.1% and 72.4% of subjects), while an avoidance response was least prevalent (9.8% and 13.3% of subjects). Two studies also reported that average endurance subscale scores and pain-related thought suppression were greater than help-hopelessness subscale scores. In 1 study of Italian runners, 54.1% of those with LBP reported a correlation of onset of LBP with high stress periods in school, family, or work, while 45.9% did not. Furthermore, 66% of those with LBP reported not changing their training regimen. Risk of bias was found to be "low" for all 5 studies.

CONCLUSIONS: Few studies assess the prevalence of psychosocial factors in athletes with LBP. The included studies showed that an endurance response was common in athletes with LBP, and that maladaptive pain responses were more prevalent than an adaptive response. However, future studies need to include a nonathlete comparison and survey athletes in the United States, as 4 of 5 studies used German athlete data.

CLINICAL RELEVANCE: These findings may help physical therapists screen and tailor individual treatment regimens for athletes with LBP. Future studies should focus on clinical approaches for athletes exhibiting maladaptive endurance responses to LBP.

SP037

QUADRICEPS STRENGTH AND RATE OF TORQUE DEVELOPMENT ASYMMETRIES ARE ASSOCIATED WITH ALTERED JUMPING BIOMECHANICS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Megan Claire Graham

PURPOSE/HYPOTHESIS: Return to sport rates following anterior cruciate ligament reconstruction (ACLR) are low, with less than half of athletes returning to their preinjury level of play. Athletes who fail to reach preinjury levels of competition often have persistent quadriceps weakness and significant deficits in rate of torque development (RTD). To date, it is unclear how deficits in quadriceps function affect an athlete's ability to generate knee joint power during explosive movements. If an athlete is unable to produce adequate power, their athletic performance will suffer and

they will be less likely to return to their preinjury level of competition. We hypothesized that ACL reconstructed limbs would exhibit reduced knee joint power, impulse, and velocity during a drop vertical jump (DVJ) compared to noninjured limbs. In addition, we hypothesized that biomechanical jumping asymmetries would be associated with asymmetries in quadriceps strength and RTD.

NUMBER OF SUBJECTS: Forty-one athletes 6 months post ACLR (mean $\pm$ SD age, 20.5 ± 5.5 years; BMI, 23.6 ± 2.6 kg/m²; 17 female).

MATERIALS AND METHODS: Three DVJs were recorded for each subject using instrumented 3-D motion analysis. Knee joint power, impulse, and velocity were calculated for each limb during the concentric (CON) phase of the DVJ using custom computer code. Peak torque (PT) and RTD were obtained from the subject's maximal voluntary isometric knee extension strength using an isokinetic dynamometer. The limb symmetry index (LSI) was calculated by comparing the injured to noninjured side. Paired-samples *t* tests were used to compare the involved and noninvolved limbs and associations between variables were determined with Pearson product-moment correlation coefficients.

RESULTS: There were significant differences ($P < .01$) between involved (INV) and noninvolved (NON) limbs in knee power (INV, 3.6 ± 1.5 W/kg; NON, 6.7 ± 2.0 W/kg), impulse (INV, 0.22 ± 0.08 Nm·s/kg; NON, 0.45 ± 2.0 Nm·s/kg), and velocity (INV, $729.9^\circ/\text{s} \pm 142.6^\circ/\text{s}$; NON, $828.9^\circ/\text{s} \pm 140.2^\circ/\text{s}$). PT LSI was significantly correlated with power LSI ($r = 0.67$, $P < .01$) and impulse LSI ($r = 0.47$, $P = .005$), while RTD LSI was significantly correlated to power LSI ($r = 0.39$, $P = .014$), impulse LSI ($r = 0.45$, $P = .004$), and velocity LSI ($r = 0.36$, $P = .026$).

CONCLUSIONS: ACL reconstructed limbs exhibited significant deficits in knee joint power, velocity, and impulse compared to noninjured limbs. PT LSI was associated with power and impulse LSI, while RTD LSI was associated with LSI of all variables. These findings highlight the importance of restoring PT and RTD symmetry to optimize athletic performance and improve return-to-sport outcomes.

CLINICAL RELEVANCE: While most athletes begin jumping progressions around 4 to 6 months postop, significant deficits in quadriceps function continue to persist for most athletes. Clinicians should prioritize the restoration of PT and RTD symmetry in order to normalize jumping mechanics, improve athletic performance, and increase the likelihood of return to sport.

SP038

HIGH INJURY RISK IN A MULTISPORT ATHLETE DISCHARGED FROM CARE AT 6 MONTHS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Adam Christopher Grannan

BACKGROUND AND PURPOSE: One of the most common ligament injuries in American football is a tear of the anterior cruciate ligament (ACL). Currently, there is insufficient evidence to support a uniform return to sport (RTS) protocol for football players following an ACL reconstruction. The tests that do exist are not consistently used to inform RTS decisions, indicating that RTS for athletes is determined by the overseeing medical professional. The objective of this study is to describe a RTS protocol for a male American football player with a history of an ACL reconstruction from a quad tendon graft and determine readiness to RTS within a 6 to 9-month range. This study will also describe whether the current suggested timeline for RTS is appropriate based on the time of discharge of this patient from usual care.

CASE DESCRIPTION: A 16-year-old multisport male athlete (height, 5 ft 10 inches; weight, 185 lb; BMI, 26.5 kg/m²) sustained an ACL rupture in an American football game. MRI confirmation of the injury occurred 2 weeks following the date of injury, and surgical reconstruction of the ACL and medial meniscus occurred 1 month following the injury. The patient received standard physical therapy care for 6 months postoperatively at a local outpatient clinic. The patient's goal was to return to previous level of

function, which includes unrestricted competition in American football and baseball at the high school level.

OUTCOMES: The participant was discharged from physical therapy by his surgeon at 6 months after reconstruction. Seven outcomes were intended to be tested on the athlete including Selective Functional Movement Assessment (SFMA), Functional Movement Screen (FMS), lower quarter Y Balance Test (YBT-LQ), drop landing jump, tuck jump, hop testing, and Tampa Scale of Kinesiophobia (TSK-11). Testing occurred 1 week after physician discharge. The SFMA results showed all movements patterns were Dysfunctional Nonpainful except for bilateral upper extremity pattern 2. The FMS composite score was 9/21, with a score of 0 noted on the right inline lunge, and scores of 1 noted for the deep squat, bilateral hurdle step and left straight leg raise. The YBT-LQ score showed a 14 cm asymmetry in the posterolateral direction. Drop Landing jump was attempted but terminated due to safety concerns. The participant's TSK-11 score was 41/68.

DISCUSSION: Substantial deficits in all tests were noted, indicating the athlete is a high risk for reinjury based on the following cut scores: FMS >14 composite and no 0's or 1's in any individual category, YBT-LQ posterolateral reach <6 cm, and TSK-11 <19. Athletes are returning to sport far before their bodies and minds are ready. This report indicates that athletes continue to be discharged from rehabilitation by medical professionals based upon a timeline rather than objective readiness for sport, leaving athletes vulnerable to future injury. This gap in education and communication must be addressed to ensure all athletes are receiving appropriate care to return to their sport safely.

SP039

ALTERATION IN TRAINING INTENSITY CORRELATES WITH RUNNING-RELATED INJURIES IN LONG-DISTANCE RUNNERS

Ryan Anthony Griffith

PURPOSE/HYPOTHESIS: Few studies have examined the risk factors for injury occurrence among long distance runners. This research is being proposed to examine if there is a relationship between aerobic and anaerobic exercise training intensity and injury risk in long distance runners. There has not been conclusive research performed in this area, and this question addresses interests of health care professionals that work with long distance runners. The purpose of this study is to determine the relationship between training intensity, measured with Rating of Perceived Exertion (RPE), and running related injuries.

NUMBER OF SUBJECTS: One hundred thirty-one.

MATERIALS AND METHODS: One hundred thirty-one self-reported runners completed electronic original surveys distributed through social media platforms and running communities. The outcome of interest was a running-related injury, defined as any musculoskeletal complaint of the lower extremity or back caused by running that restricted the amount of running (volume, duration, pace, or frequency) for at least 1 week. Groups were separated into Noninjured ($n = 74$) and Injured ($n = 57$) based on self-reported questions. Based on responses comparison data using a 2-sample t test assuming unequal variances was utilized.

RESULTS: The results of this study showed correlations between training intensity and running related injuries. Results showed that history of a prior injury was the most predictive of suffering another running related injury (95% CI, $P < .01$). Other statistical analysis showed that those who ran less frequently (95% CI, $P = .02$) and those who rested more frequently per week (95% CI, $P = .04$) had a higher correlation in suffering a running related injury in this sample population. The primary aim of this study was to determine the correlation between running intensity, measured via RPE, and running related injuries. While approaching statistical significance, this did not show statistical significance (95% CI, $P = .079$).

CONCLUSIONS: This study confirms the need for additional research to investigate the correlation between training parameters and running related injuries in long distance runners. Several factors such as number of

rest days and frequency of runs in this sample size elucidated correlations between running related injuries and training routines.

CLINICAL RELEVANCE: With the increasing popularity of long-distance running, it is imperative that we as clinicians best educate our patients on how to effectively rehabilitate and train to reduce the likelihood of running related injuries. Research findings in this study show that runners who ran less frequently per week and incorporated more rest days per week had an increased risk of suffering of a running related injury. This information can allow better discharge and training plans to our patients and community to try and reduce the risk of running-related injuries.

SP040

MEN AND WOMEN WALK WITH ASYMMETRICAL QUADRICEPS NEUROMUSCULAR FUNCTION 6 MONTHS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Sarah Hall, Naoaki Ito, Jacob J. Capin, Karin Gravare Silbernagel, Thomas S. Buchanan, Lynn Snyder-Mackler

PURPOSE/HYPOTHESIS: Gait asymmetries after anterior cruciate ligament (ACL) reconstruction (ACLR) are associated with post traumatic knee osteoarthritis (PTOA) development. Women are more likely to present with asymmetrical movement patterns after ACLR, which may subsequently contribute to higher rates of PTOA in women compared to men. Sex differences in movement patterns may be mediated by quadriceps weakness and inhibition. The quadriceps play a key role in controlling the knee during the weight acceptance phase of gait, and altered timing of peak quadriceps activity relative to peak external knee flexion moment (pKFM), or extensor latency, may reflect neuromuscular deficits after ACLR. The purpose of this study was to investigate sex differences in symmetry of extensor latency during the weight acceptance phase of gait in athletes 6 months after ACLR.

NUMBER OF SUBJECTS: Sixty-nine athletes (37 men, 32 women; mean $\pm$ SD age, 21.1 ± 8.1 years; height, 170 ± 10 cm; weight, 77.7 ± 14.6 kg) 5.6 $\pm$ 1.9 months after ACLR.

MATERIALS AND METHODS: Gait kinematics, kinetics, and electromyography (EMG) of the vastus medial (VM), lateralis (VL), and rectus femoris (RF) were recorded as participants walked at self-selected speeds. EMG data were high-pass filtered (second order Butterworth, 30 Hz), rectified, low-pass filtered (6 Hz), and normalized to maximum voluntary isometric contractions. Quadriceps muscle activation as a single extensor muscle group (QUAD) was estimated using previously described methodology. VM, VL, RF, and QUAD latencies were calculated by measuring the time between time (milliseconds) of peak EMG activity of each extensor muscle and time of pKFM. A 2-by-2 (limb by sex) repeated-measures ANOVA was performed for the 4 latencies ($\alpha = .05$).

RESULTS: Main effects of limb were observed for QUAD (involved, 79.5 ± 20.8 milliseconds; uninvolved, 73.5 ± 23.2 milliseconds; $P = .04$) and RF (involved, 76.1 ± 23.2 milliseconds; uninvolved, 68.3 ± 21.1 milliseconds; $P = .02$) latencies characterized by longer latencies in the involved versus uninvolved limbs. No main effects of limb were observed for VM ($P = .14$) and VL ($P = .06$) latencies. No sex-by-limb interactions ($P = .21-.93$), or main effects of sex ($P = .44-.94$) were observed for all 4 latencies.

CONCLUSIONS: Prolonged extensor latencies were observed in the involved versus uninvolved limbs in both male and female athletes 6 months after ACLR. Sex differences in latencies, however, were not observed. The findings suggest diminished quadriceps neuromuscular function are present in athletes even after initial symptom resolution regardless of sex. Altered extensor latency during gait may contribute to aberrant gait mechanics associated with the development of PTOA. Future research should investigate latencies at different time points and between other demographic factors following ACLR to understand the implications of prolonged extensor latencies during gait and the associations with PTOA.

CLINICAL RELEVANCE: Both men and women walk with asymmetrical quadriceps neuromuscular function 6 months after ACLR. Early tar-

geted neuromuscular gait training may be critical to prevent PTOA in men and women.

SP041

MANUAL THERAPY AND A MULTIMODAL APPROACH TO RECALCITRANT CERVICAL RADICULOPATHY IN A COLLEGIATE GYMNAST

Chase Mykel Hamilton, Derek L. Vraa, Adrian Noel Marrero, Tisha D. Sutton

BACKGROUND AND PURPOSE: Radicular pain and paresthesia are common symptoms associated with cervical radiculopathy and often a result of disc derangement or space occupying lesion that inflames or pinches the nerve root. There is only 1 clinical prediction rule (CPR) to predict short-term outcomes with multimodal care for cervical radiculopathy and scarce research on outcomes for recalcitrant symptoms. The purpose of this case study was to demonstrate the inclusion of manual therapy to a multimodal approach to treat recalcitrant cervical radiculopathy symptoms in an athlete.

CASE DESCRIPTION: The patient was a 20-year-old female collegiate gymnast who presented with a 3-month history of left-sided cervical and shoulder pain, numbness and tingling on the dorsal side of the arm, elbow, forearm, thumb, and fourth to fifth digits with no mechanism of injury. MRI revealed C3-T1 spondylitic changes and C4-5 small disc protrusion. Bilateral cervical rotation reproduced symptoms, positive central C6-7 spring's test, trigger points to cervical and periscapular musculature, triceps weakness, and paresthesia to ulnar and median palmar digital branches on the fourth to fifth digits. Findings revealed 2/4 predictors for cervical radiculopathy with 21% posttest probability (PTP) although this CPR has not been validated. Numeric pain-rating scale (NPRS) was 1/10 and increased to 6-7/10 with sport training. Patient met 3/4 treatment CPR predictors suggesting 85.4% PTP success with multimodal care. Previous care consisted of nerve glides, rotator cuff exercises, and modalities by the Athletic Trainer with no improvements. Mobilization and manipulation to the thoracic spine were initiated with pain neuroscience education (PNE) and trigger point dry needling (DN) to the left upper extremity and left cervical spine. Over the next 2 sessions, impairments in the cervicothoracic spine were addressed with orthopaedic manual physical therapy (OMPT) to the left C6 cervical multifidus followed by deep neck flexor and scapular motor control exercises. By session 3, her only symptom was neck stiffness and a graded return to sport training was initiated with the Athletic Trainer. Over the next 7 sessions, motor control exercises were progressed with upper quarter strengthening and injury prevention screening.

OUTCOMES: All symptoms except reports of neck tightness and triceps fatigue following training were resolved by session 10. The patient reported a +6 on the Global Rating of Change scale, Quick Disabilities of Arm Shoulder and Hand improved from 22.72% to 9% and NPRS improved to 0/10.

DISCUSSION: This athlete was successfully treated with a multimodal plan that reduced subjective neurological complaints and pain and paralleled identified predictors for successful short-term results. The outcomes of this case are not generalizable and require further large-scale investigation for collegiate and elite athletes. Results suggest that when combined as a comprehensive rehabilitative care, OMPT including DN and PNE can be a viable tool to reduce recalcitrant radicular symptoms in athletes.

SP042

RELATIONSHIP BETWEEN AGE AND FRONTAL AND TRANSVERSE PLANE RUNNING KINEMATICS IN FEMALE RUNNERS

Heather McConchie Hamilton, Rumit Singh Kakar

PURPOSE/HYPOTHESIS: Female runners demonstrate increased motion in the frontal and transverse planes at the hip and knee compared to males. In addition to sex-specific differences in running biomechanics, there are differences associated with increased age. Aging runners demonstrate de-

creased lower extremity joint motion during running, which has been hypothesized to be associated with age-related physiological changes, such as decreased muscle strength, power, and tendon capacities. These age-related kinematic differences have primarily been studied in the sagittal plane. Females experience a unique aging process due to menopause and the associated hormonal changes that affect musculoskeletal physiology. For the reasons mentioned above, it is important to consider both aging and sex effects when studying running biomechanics. The purpose of this study was to determine the relationship between age and frontal and transverse plane running kinematics specifically in female runners at 2 different speeds. Running at faster speeds places greater demand on the musculoskeletal system and may be more sensitive to age-related changes in running biomechanics.

NUMBER OF SUBJECTS: Forty-six female runners aged 18 to 65 years (mean $\pm$ SD age, 37.5 ± 13.5 years).

MATERIALS AND METHODS: Participants ran at self-selected jogging (JOG, 2.66 ± 0.30 m/s) and maximal (MAX, 3.78 ± 0.61 m/s) running speeds on a treadmill. Three-dimensional joint angular kinematics of the ankle, knee, and hip of the right limb were calculated (Vicon Nexus 2.9.0 and Visual3D). Multiple linear regression was used to determine the relationship between age and the following dependent variables: peak frontal and transverse plane ankle, knee, and hip angles during the stance phase of running. Running speed was controlled via inclusion in the first regression block.

RESULTS: There was a significant negative relationship between age and peak eversion for JOG ($R^2 = 0.20$, $P = .008$) and MAX ($R^2 = 0.20$, $P = .011$), age and peak knee external rotation for JOG ($R^2 = 0.15$, $P = .032$) and MAX ($R^2 = 0.21$, $P = .009$), and age and peak hip adduction for JOG ($R^2 = 0.14$, $P = .044$). No other significant relationships were found ($P > .109$).

CONCLUSIONS: Older female runners demonstrated decreased peak eversion, peak knee external rotation, and peak hip adduction compared to the younger runners. These results are consistent with studies reporting decreased lower extremity joint motion in aging runners. Greater peak eversion may be associated with increased risk of lower leg and/or ankle running-related injury, so aging runners may limit their motion as a protective adaptation or to improve stability during running.

CLINICAL RELEVANCE: Running is a convenient and popular form of exercise that is related to decreased risk of mortality. However, running injuries are common and both increased age and female sex are risk factors for running-related injury. Due to the unique aging process that females experience, it is important to understand running biomechanics specifically in aging female runners to develop training and rehabilitation programs to reduce risk of injury and maximize performance in this population.

SP043

COMPARISON OF DRY-NEEDLING APPROACHES FOR THE QUADRATUS PLANTAE

Mary C. Hannah, Randall Scott Lazicki, Monica Jon Zimmerman, Austin Moore, Luguang Wei, Janet Cope

PURPOSE/HYPOTHESIS: Dry needling involves the insertion of a thin monofilament needle into targeted tissue to treat neuromuscular pain and movement impairments. Plantar heel pain is 1 of the 3 most common musculoskeletal complaints in runners. Plantar heel pain has been linked to trigger points in the quadratus plantae muscle (QP) and dry needling is 1 treatments that can be useful within a management plan. This novel observational study provides insight to dry needling procedures when targeting the QP. The recommended approaches are a posterior-anterior (PA), a proximal medial-lateral (Prox-ML), and distal medial-lateral (Dist-ML) approach. The purpose of this anatomical-dissection study was to establish the accuracy of 3 different dry needling placements in the QP muscle of embalmed human donors.

NUMBER OF SUBJECTS: Ten feet of 8 human donors were used for dissection with a total of 30 needle placements.

MATERIALS AND METHODS: An experienced clinician placed 3 needles in each plantar foot, aimed at QP attachment at the plantar calcaneal tubercle. PA, 3 cm distal to plantar calcaneal tubercle and perpendicular to calcaneus Prox-ML, 1.5 cm inferior to base of navicular tuberosity Dist-ML, 1.5 cm distal and 1.5 cm inferior from navicular tuberosity After placing 3 needles in each foot, the plantar musculature distal to the calcaneal tubercle was dissected to determine which structures were penetrated by the needle, including its terminal location. An anthropologist and experienced anatomy instructor made the determination of which plantar structures each needle pierced.

RESULTS: The PA needle approach terminated in the QP muscle in 90% (9/10) of trials; this approach did not pierce the medial neurovascular bundle at all, and pierced the lateral plantar neurovascular bundle in 30% (3/10) of trials. The Prox-ML needle approach terminated in the QP in 70% (7/10) of trials; this approach pierced the medial neurovascular bundle in 10% (1/10) of trials, and pierced the lateral neurovascular bundle in 30% (3/10) of trials. The Dist-ML approach terminated in the QP in 90% (9/10) of trials; this needle pierced the medial neurovascular bundle in 50% (5/10) of trials; and the lateral neurovascular bundle in 50% (5/10) of trials.

CONCLUSIONS: The PA approach and the Dist-ML method were equally accurate approaches to target the QP muscle; however, the PA approach presented with the least risk with just 3 trials piercing the medial neurovascular bundle while the Dist-ML presented with the highest risk of piercing both neurovascular bundles. The Prox-ML approach was least accurate with moderate risk of piercing the neurovascular bundles.

CLINICAL RELEVANCE: When treating a patient with plantar heel pain and targeting the quadratus plantae muscle with dry needling, a PA approach is most accurate and least risk to piercing neurovascular structures when compared to a Prox-ML and Dist-ML approaches. Clinicians should consider the benefits of treating the QP while understanding the risks of penetrating neurovascular structures.

SP044

LIMB DOMINANCE AFFECTS RESTORATION OF LOADING DURING GAIT FOLLOWING PRIMARY ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Joseph Patrick Hannon, Shiho Goto, Steve B. Singleton, Lindsey Dietrich, Craig Craig Garrison

PURPOSE/HYPOTHESIS: Changes in knee joint loading during gait have been found in individuals following ACL-R. These changes persist long after individuals return to normal activity and are hypothesized to contribute to the development of posttraumatic osteoarthritis. Recent literature suggests that limb dominance may affect loading strategies. It is unknown how limb dominance may affect joint loading during walking. Therefore, the purpose of this study was to assess if there were difference present in knee joint loading in individuals who injured their dominant limb ACL (DOM-ACL) versus nondominant limb ACL (NonDOM-ACL) during walking at 3 months post surgery.

NUMBER OF SUBJECTS: Thirty-one participants following unilateral ACL-R were enrolled in this study. Participants were divided into 2 groups; those who injured their DOM-ACL ($n = 13$; mean $\pm$ SD age, 15.54 ± 1.2 years; height, 173.04 ± 7.0 cm; weight, 73.9 ± 14.1 kg) and those who injured their NonDOM-ACL ($n = 18$; mean $\pm$ SD age, 16.17 ± 1.8 years; height, 166.86 ± 8.1 cm; weight, 71.9 ± 13.2 kg).

MATERIALS AND METHODS: A 10-camera Motion Capture System (Qualisys AB, Göteborg, Sweden) with a sampling rate of 120 Hz and 2 force plates capturing at 1200 Hz (Advanced Mechanical Technology, Inc, Watertown, M) were used to capture joint motions during gait. Participants walked approximately 10-m runway at a self-selected walking speed until 3 acceptable trials were collected from each limb. The gait cycle was divided into 2 phases (P1: heel strike to 50% of stance phase; P2: 50% of stance phase to toe-off). For the purposes of this investigation only P1 was analyzed. Variables of interest included average peak knee extension moment

(KEM), average KEM impulse (KEMi). Two separate (surgical and non-surgical) independent t tests were used to assess for between group differences in peak knee extension moment and peak knee extension impulse with an alpha level set at $P = .05$.

RESULTS: Results of the independent t tests demonstrated significant differences on both the involved and uninvolved limb between groups in all variables of interest. At P1, KEM on the surgical limb of the DOM-ACL group (0.021 ± 0.009) was significantly greater than the NonDOM-ACL (-0.003 ± 0.008 , $P < .001$). However, this was reversed on the non-surgical limb (DOM-ACL, -0.001 ± 0.007 ; NonDOM-ACL, -0.037 ± 0.012 ; $P < .001$). At P1, KEMi on the surgical limb of the DOM-ACL group (-0.003 ± 0.001) was significantly greater than the NonDOM-ACL (-0.00006 ± 0.0008 , $P < .001$). Again, this was reversed on the non-surgical limb (DOM-ACL, -0.00009 ± 0.001 ; NonDOM-ACL, -0.006 ± 0.002 ; $P < .001$).

CONCLUSIONS: Side of injury may influence restoration of loading following ACL-R.

CLINICAL RELEVANCE: The results of this study indicate that individuals who injure their DOM-ACL demonstrate greater KEM and KEMi than those who injure their NonDOM-ACL on their surgical limb. However, on the nonsurgical limbs both KEM and KEMi were greater in the NonDOM-ACL group. These findings are relevant discussing restoration of knee loading as decreased knee extension moments have been associated with less favorable short- and long-term outcomes.

SP045

COMPARISON OF DOUBLE-LEG SQUAT MECHANICS BETWEEN INDIVIDUALS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION AND CONTROLS

Joseph Patrick Hannon, Shiho Goto, Steve B. Singleton, Lindsey Dietrich, Craig Craig Garrison, Caitlin Anne Nadolny

PURPOSE/HYPOTHESIS: Assessing movement impairments in patients following anterior cruciate ligament reconstruction (ACL-R) is a critical part of rehabilitation. Three-dimensional motion analysis is the gold standard for assessing movement impairments, but this technology is not readily accessible. There is a need for clinician friendly measurements validated against 3-D technology to improve movement assessment. The purpose of this study was to examine joint motions in 3 planes including frontal plane projection angle (FPPA), max sagittal plane knee displacement (DSP), and ground reaction force (GRF) LSI between athletes following ACL-R and matched controls performing a double leg squat (DLS).

NUMBER OF SUBJECTS: One hundred sixty participants were included; 80 following ACL-R and 80 healthy age-, gender-, height-, weight-, and limb-matched controls.

MATERIALS AND METHODS: A 10-camera Motion Capture System (Qualisys AB, Göteborg, Sweden) with a sampling rate of 120 Hz and 2 force plates capturing at 1200 Hz (Advanced Mechanical Technology, Inc, Watertown, M) were used to capture joint motions in all 3 planes during a DLS. Variables of interest included max frontal plane projection angle (FPPA), max sagittal plane knee displacement (DSP), and ground reaction force (GRF) LSI. These variables were included as they are relatively easily identifiable to clinicians. To assess for differences between ACL-R and healthy controls an independent t test with Bonferroni correction was used with an adjusted a level was set at .01.

RESULTS: Results of the independent t tests revealed that the ACL-R demonstrates significantly less max FPPA displacement on their involved limb compared to the control group (ACL, 3.87 ± 2.47 ; control, 5.65 ± 3.87 ; $P < .001$). There was no difference in FPPA on the uninvolved limb (ACL, 4.60 ± 2.81 ; control, 5.76 ± 3.99 ; $P = .037$). There were no differences in knee sagittal plane max displacement between groups on either the involved ($P = .941$) or uninvolved ($P = .182$) limb. However, GRF LSI was significantly less in the ACL-R group compared to controls (ACL-R, 82.48 ± 28.7 ; control, 102.24 ± 31.1 ; $P < .001$).

CONCLUSIONS: Following ACL-R, individuals can improve both sagittal and frontal plane movements to be similar (DSP) or better (FPPA) than controls. However, GRF LSI, which may be more difficult to assess clinically, remains worse than controls.

CLINICAL RELEVANCE: FPPA, DSP, and GRF LSI were chosen as variables of interest, because they can more readily be assessed in 2 dimensions without additional equipment. DLS was chosen as a fundamental task for daily function completed numerous times during rehabilitation. The implications of these findings are that improvements are more likely to be made in movements that clinicians can more readily assess without additional equipment. However, in less clinician friendly measurements, critical impairments remain. Researchers and clinicians alike need to work toward improving the ease of measurability of these more difficult to assess, yet extremely important variables.

SPO46

THE INFLUENCE OF RUNNING HABITS AND INJURY ON ATHLETIC IDENTITY ACROSS THE FEMALE RUNNER LIFE SPAN

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PURPOSE/HYPOTHESIS: Athletic identity (AI) is a key component of an athlete's self-perception and can impact training and rehabilitation decisions however little is known about AI and female runners. This study aims to investigate athletic identity in female runners across the lifespan as well as explore variables that influence a female runner's AI.

NUMBER OF SUBJECTS: Six hundred seventy-five females who self-identified as a runner aged ≥ 18 years were included.

MATERIALS AND METHODS: Participants were administered an online Qualtrics survey, which included Athletic Identity Measurement Score (AIMS), OSTRC overuse injury questionnaire, weekly run mileage, demographics, and information about running habits during COVID. Participants self-selected into lifespan groups (collegiate, recreational [aged 18-34 years and not within the other groups], pregnant, postpartum [≤ 3 years], and masters [age, ≥ 35 years]). Recruitment was performed via electronic online platforms. Prior to analyses, missing data were assessed. Missing data were low (AIMS, 0%; age, <1%; mileage, <1%), thus complete case analyses were performed. An a priori power analysis was performed. With a $\beta = 0.80$, $\alpha = .05$, and a sample size of ≥ 70 per group, and 5 groups, an effect size of 0.19 could be observed. A series of analyses of variance and analyses of covariance were performed. Analysis controlled for age, weekly running mileage, OSTRC score, and the impact of COVID-19 on running habits. Tukey post hoc analyses were performed to understand group differences.

RESULTS: Adjusted analyses observed significant differences between AIMS scores ($P < .001$) and group to group differences (collegiate-recreational, 3.1; 95% CI: 0.2, 6.0; $P < .039$; collegiate-postpartum, 3.8; 95% CI: 0.5, 7.1; $P = .025$; collegiate-masters, 4.9; 95% CI: 0.6, 9.1; $P = .024$). Weekly running mileage (-0.2 ; 95% CI: -0.3 , -0.2 ; $P < .001$) and OSTRC Score (-0.1 ; 95% CI: -0.2 , -0.01 ; $P < .001$) were factors significantly associated with decreased AI.

CONCLUSIONS: After adjusting for confounding variables, collegiate female runners had significantly lower AI compared to recreational, postpartum, and master runners. This may be clinically meaningful, but currently there is no minimum clinically important difference to aid interpretation. Mileage and OSTRC were influential in mediating the relationship between AI across the lifespan. More severe overuse injuries (OSTRC), and higher mileage were associated with lower AI.

CLINICAL RELEVANCE: Previous research shows overuse injuries negatively affect AI in collegiate athletes, but the relationship between increased running mileage and decreased AI in female runners is novel. Clinicians treating overuse injuries in female runners should consider that high mileage does not translate to high AI as seen in the collegiate group.

Understanding that injury and high run mileage are related to loss of AI can help clinicians consider the psychosocial elements of recovery by providing rehabilitation with meaningful sport participation and alternatives to high mileage running.

SPO47

EFFECTIVENESS OF 2 DIFFERENT BLOOD FLOW RESTRICTION CUFF PRESSURES ON SINGLE-LEG BALANCE

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PURPOSE/HYPOTHESIS: To assess the effects of 2 different blood flow restriction (BFR) cuff pressures after 3 weeks of cycling training on single-leg balance in healthy adults.

NUMBER OF SUBJECTS: Twenty-nine healthy subjects (mean $\pm$ SD age, 25 $\pm$ 3 years; 14 male, 15 female).

MATERIALS AND METHODS: Subjects were randomly assigned to a group of BFR with 60% occlusion ($n = 10$), a group of BFR with 80% occlusion ($n = 11$), and a control group ($n = 8$). The exercise protocol consisted of cycling on a cycle ergometer for 15 minutes at 25 W and 70 rpm, 3 times a week for 3 weeks. Groups assigned to the BFR training group cycle with their respective occlusion in their dominant leg while the control group cycle without any occlusion. Single-leg balance was assessed bilaterally on a balance system platform, measuring the amount of sway in 20 seconds within the following conditions: eyes open (EO) and eyes closed (EC), at baseline and 3 weeks after. Each balance condition was performed only once for a length of 20 seconds with a standardized foot position identified in the platform. Both groups were homogenous in physical activity levels, height, and weight at baseline. Most data were normally distributed; therefore, a 2-by-3 (time by group) repeated-measures ANOVA was used to compare balance results across time and between groups. post hoc analyses were conducted were appropriate. Statistical significance was at an alpha of .05 for all analyses with appropriate post hoc analysis.

RESULTS: The ANOVA showed no statistically significant differences between groups for the time by group interaction, changes across time, or differences between groups.

CONCLUSIONS: Data suggests BFR training during aerobic cycling exercise does not significantly alter balance measures in a 3-week training period. Also, it appears that there are no differences between occlusion pressures for balance outcomes.

CLINICAL RELEVANCE: When it comes to balance training, the inclusion of BFR does not seem to add any advantage over adaptations that are already occurring.

SPO48

PREVENTION DELIVERY MODES AMONG RUNNERS WITH AND WITHOUT A HISTORY OF RECENT RUNNING-RELATED INJURY

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PURPOSE/HYPOTHESIS: Running is a popular, cost affordable way to achieve recommended physical activity health guidelines. Unfortunately, annually reported incidence for running related injuries (RRIs) ranges from 19% to 92%. An initial RRI correlates with future injury, therefore, it is essential to identify and create effective primary and tertiary prevention programs. The purpose of this study was to identify preferred modes of prevention programs in runners with, and without, a RRI within the past 5 years. Identifying the preferred modes of these target populations may lead to more effective prevention protocols.

NUMBER OF SUBJECTS: Two hundred seventy-eight runners (mean $\pm$ SD age, 37.9 $\pm$ 13.6 years; BMI, 24.1 $\pm$ 3.9 kg/m²; 65.2% female) participated in an online survey. Of respondents, 69.5% reported a RRI within the last 5 years ($n = 194$; mean $\pm$ SD age, 39.6 $\pm$ 14.0 years; BMI, 23.9 $\pm$ 3.6 kg/m²;

60.82% female), while the remaining respondents reported no RRI within the last 5 years ($n = 85$; mean $\pm$ SD age, 34.0 ± 11.8 years; BMI, 24.7 ± 4.6 kg/m²; 75.3% female).

MATERIALS AND METHODS: An electronic questionnaire consisting of history of injury, running experience, mileage, age, gender, and use of various modes of RRI prevention programs was marketed and sent to runners via social media, flyers, and various running clubs.

RESULTS: Two-sample t test and Pearson chi-square test were used to identify differences in intrinsic factors and running experience. Runners with no 5-year history of injury were significantly younger ($P < .016$), included more females ($P < .02$), ran less miles per week ($P < .043$), and reported fewer years of running ($P < .017$). RRI prevention was not reportedly used in 12.8% of the 278 respondents. Commonly used modes of prevention were physical therapy (22.1%), other health care professionals (15.1%), websites (14.6%), and running stores (13.4%), while less frequently used modes were running magazines (5.4%) and mobile applications (4.5%). Runners with a previous RRI consulted physical therapists (51.8%), other health care professionals (38.3%), and websites (32.6%) most frequently, while runners with no RRI within the past 5 years consulted trainers (20.0%), running stores (15.3%), and physical therapists (14.1%) most frequently.

CONCLUSIONS: Beginner to middle experienced female runners may be a target population for RRI primary prevention programs. Runners without recent injury preferred prevention through trainers and running stores versus health professionals, however, physical therapists were collectively used more than other health care professionals. Runners with past injury largely consulted physical therapists and other health care professionals for prevention.

CLINICAL RELEVANCE: Healthcare professionals seeking to advance primary prevention of RRIs may best target runners without recent RRI by communicating with local running specialists to provide and promote these programs. Physical therapists are the most commonly consulted health care professionals for RRI prevention in runners with a prior history of injury, lending to a need to develop more effective tertiary prevention programs.

SP049

EFFECTS OF CHEWING CAFFEINE-CONTAINING GUM ON PHYSIOLOGY, EXERTION, AND RUNNING PERFORMANCE

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PURPOSE/HYPOTHESIS: Studies have shown positive endurance exercise performance effect with pre-exercise ingestion of caffeine at a dosage of 4 to 6 mg caffeine/kg body weight, but running is not the typical investigated exercise mode. Running is a popular endurance exercise and a high caffeine dosage can be realistically obtained through gum ingestion. The purpose of this study was to assess the effect chewing 4 to 6 mg caffeine/kg containing gum on physiological response, exertion, and maximal running time in healthy, recreationally active adult runners.

NUMBER OF SUBJECTS: Eight injury free adult subjects (50% female; mean age, 26.9 years; height, 167.3 cm; weight, 63.5 kg; BMI, 22.8 kg/m²) with at least a 3-month history of regular running (mean run frequency/week, 4.07 days) and were typical consumers of caffeine (at least weekly) provided consent to participate.

MATERIALS AND METHODS: VO₂ peak (mean, 48.9 mL O₂/kg/min) was measured by indirect calorimetry and HR was determined via electronic sensor during a progressive treadmill running protocol. At each workload blood pressure (auscultation) and Borg RPE (ratio scale) were recorded. Two performance-running trials followed at least 1 week apart. Caffeinated gum (mean, 4.16 mg caffeine/kg) or a similar tasting placebo gum was administered in a double-blind fashion. Subjects ran at a treadmill speed corresponding to 70% of VO₂ peak for 30 minutes and then

the treadmill speed was increased to 90% of VO₂ peak until volitional fatigue. Performance time was recorded. At 10 minutes into the run subjects chewed placebo or caffeinated gum for 5 minutes. Oxygen uptake was taken throughout the protocol except during gum ingestion. HR, BP, and RPE were taken every 5 minutes. Blood lactate levels were taken prior to the performance trials, at 10 minutes, and at volitional fatigue.

RESULTS: No significant differences ($P < .05$) were found in average VO₂ peak, METs, HR, lactate, SBP, and RPE. Mean performance run time to volitional fatigue (P , 559 seconds; C , 596 seconds) was not significantly different.

CONCLUSIONS: Chewing caffeinated gum did not yield differences in performance time, exertion, metabolic, or cardiovascular function in recreational adult runners performing at 70% and 90% of VO₂ peak, although.

CLINICAL RELEVANCE: Current evidence does not support advising healthy adult runners to acutely ingest caffeine-containing gum as a means to improve performance time at high exertion levels. Future study with a larger subject number and in a population of more highly trained athletes is indicated.

SP050

OLYMPIC-CLASS SAILORS HIKING RISK FOR KNEE PAIN DOESN'T DISCRIMINATE BETWEEN DOMINANT AND NONDOMINANT LIMBS

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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 and trunk activity to control a boat. Knee pain has the potential to impact competitive performance. Our previous studies found hiking exposure's association with 3 to 4 times increased knee pain over the course of competition and the impact of training on reducing incidence. The purpose of this study was to examine if the hiking risk effect differs in dominant versus nondominant limb's development of knee pain.

NUMBER OF SUBJECTS: One hundred seventy-seven (59 female).

MATERIALS AND METHODS: A convenience sample of sailors having finished competition was collected after the same 5-day Olympic class regatta for 3 separate 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 23.9 ± 4.6 years (range, 18-43 years), Body mass index of 23.55 ± 4.4 kg/m² (range, 19.2-32.8 kg/m²), years of competitive sailing experience of 10.8 ± 4.6 (range, 1-32), and years of current sailing class experience of 5 ± 3.4 (range, 1-16). Among the sailors surveyed, 86 (49%) were hikers and 91 (51%) were nonhikers. Sailors with incident knee pain over course of the regatta also reported dominant lower extremity and side of knee pain. Summary statistic and chi-square analysis of injury side and dominance was generated via SAS 9.4.

RESULTS: Twenty-three incident cases (27%) of knee pain were reported by the 86 hikers. Twenty-one (93%) reported right knee dominance and 2 left (7%). Thirteen cases (62%) of right knee pain and 1 case (50%) of left knee pain were reported on the dominant side. Chi-square revealed no significant difference in these case rates ($P = .75$). Further statistical measures of association were examined due to low cell count, possibly effecting chi-square result. Nonsignificant Fisher exact test ($P = .498$) and Cramer's V ($P = .0687$) further indicate low association between injury side and dominant limb.

CONCLUSIONS: Knee pain from hiking is common in Olympic class sailors, but limb dominance and pain do not appear related. This is possibly due to the simultaneous bilateral demands intrinsic the activity of hiking. More research is needed in this topic.

CLINICAL RELEVANCE: Training to prevent knee pain in hiking does not appear to need limb dominance considerations.

SP051

CASE SERIES: USING A MARKERLESS MOTION-CAPTURE SYSTEM FOR DETERMINING RETURN TO SPORT AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION*Debi Lynn Jones, Andrew Pearle*

BACKGROUND AND PURPOSE: The appropriate tests for determining safe return to sport after anterior cruciate ligament reconstruction (ACLR) have not been determined. It has been proposed that return-to-sport (RTS) testing include movement analysis. The current gold standard for movement analysis is marked motion capture; however, a markerless system may provide a cheaper and more efficient method of analyzing movement with objective measures. The purpose of this case series is to describe the RTS testing in 3 subjects using a markerless motion capture system.

CASE DESCRIPTION: Three subjects were evaluated for RTS after ACLR between 6 and 12 months postoperatively. Each subject underwent a battery of tests including measures of quadriceps strength limb symmetry index (LSI) using a handheld dynamometer, the lower quarter Y Balance Test (YBT) LSI and the single-hop test distance LSI. Additionally, each subject underwent movement analysis using the DARI Motion system to determine knee valgus angle during a single-leg squat, double-leg squat, and vertical jump as well as maximal weight bearing asymmetry during the double-leg squat. Knee valgus angle was measured in the frontal plane as a unit vector from the hip joint to the knee joint, and a unit vector from the knee joint to the ankle joint.

OUTCOMES: Subject 1 is a 45-year-old male squash player 7 months post ACLR with hamstring autograft. He demonstrated 70% quadriceps strength LSI, 102% YBT LSI and 70% single-leg hop LSI. During the markerless motion capture, he demonstrated 23.8° knee valgus during the single-leg squat, 7.4° during double-leg squat, and 15.1° during vertical jump landing. Additionally, he demonstrated a 18.1% maximal asymmetry of weight bearing during the double-leg squat. Subject 2 is an 18-year-old female basketball player 8 months post ACLR with bone-tendon-bone autograft. She demonstrated 97% quadriceps strength LSI, 98% YBT LSI and 99% single-leg hop LSI. During the markerless motion capture, she demonstrated 44.1° knee valgus during the single-leg squat, 5.8° during double-leg squat and 2.3° during vertical jump landing. Additionally, she demonstrated a 8.6% maximal asymmetry of weight bearing during the double-leg squat. Subject 3 is a 15-year-old female skier 10 months post ACLR with hamstring autograft. She demonstrated 135% quadriceps strength LSI, 100% YBT LSI, and 94% single-leg hop LSI. During the markerless motion capture, she demonstrated 50.2° knee valgus during the single-leg squat, 8.7° during double-leg squat and 1° during vertical jump landing. Additionally, she demonstrated a 3.2% maximal asymmetry of weight bearing during the double-leg squat.

DISCUSSION: Subject 1 was not cleared for return, while subjects 2 and 3 were given the recommendation to work on movement patterns prior to RTS. Markerless motion capture has been used as part of a battery of tests to determine readiness for RTS. These objective measures would allow for multiple testing sessions throughout the rehab process to provide definitive cutoff scores and track improvement. Further research is needed to determine if this testing is valid and reliable for RTS testing after ACLR.

SP052

RELIABILITY AND AGREEMENT OF REAL-TIME VISUAL ASSESSMENT OF KNEE MOVEMENT DURING A DROP VERTICAL JUMP*Michael Wesley Kennedy, Elizabeth S. Norris, Matthew Parker Dye, Paige N. Harris, Kinsy H. Shofner, Nicholas M. Smith*

PURPOSE/HYPOTHESIS: To assess the interrater reliability of real-time visual assessment of knee movement during a drop vertical jump and to examine the association between real-time visual assessment and single-camera 3-D motion analysis of knee movement.

NUMBER OF SUBJECTS: Twenty-five healthy subjects (48% females) aged 24.5 ± 3 years participated in the study.

MATERIALS AND METHODS: Participants performed 6 trials of the DVJ from a 30-cm box while visual ratings and 3-D motion analysis of knee movement were conducted simultaneously. Two physical therapy students who were trained in visual analysis procedures performed all visual analysis ratings. Visual analysis procedures were based on criteria established by Rabin et al (2018) which consisted of rating frontal and sagittal plane knee movement as good, moderate or poor. Visual analysis of knee movement was conducted for 3 trials in both the frontal and sagittal planes during the first landing of the DVJ. Quantitative measures of knee valgus and knee flexion were acquired simultaneous to visual ratings using the VSTPro, a portable single-camera motion analysis system that utilizes infrared technology to conduct 3-D kinematic measurements. All visual analysis were conducted in real time in which both raters were present but were blinded to each other's ratings and were blinded to measures from the VSTPro system. Percentage agreement and weighted kappa coefficients were used as estimates of interrater reliability of visual ratings. An independent-groups ANOVA was used to compare 3-D knee flexion measures between participants with good, moderate or poor sagittal plane visual ratings. Due to the low number of participants with a poor rating in the frontal plane, 3-D knee valgus measures were compared between participants with good or moderate/poor frontal plane visual ratings using independent *t* tests.

RESULTS: Percentage agreement (weighted kappa) for the interrater reliability was 84% ($\kappa = 0.724$, $P = .001$) for visually rated frontal plane knee movement and 64% ($\kappa = 0.508$, $P = .001$) for visually rated sagittal plane movement. Participants with a good visual rating of frontal-plane knee movement had significantly less knee valgus than participants with poor-moderate visual rating ($P < .044$). The analysis of VSTPro knee flexion measures were significantly different between visual rating groups ($P < .011$). Post hoc tests indicated that participants with a poor visual rating had significantly less knee flexion during landing than participants with moderate ($P < .007$) or good ratings ($P < .001$) and no difference between participants with good and moderate ratings ($P < .377$).

CONCLUSIONS: The interrater reliability of real-time visual assessment of frontal and sagittal plane knee movement was good and moderate, respectively. Participants with different visual ratings of frontal and sagittal plane knee movement presented with statistically different 3-D measurements.

CLINICAL RELEVANCE: Study findings suggest that trained, novice student raters can produce reliability real-time visual ratings of knee movement during a DVJ. Visual rating groups obtained differed in knee valgus and knees flexion measures.

SP053

TREATMENT OF VESTIBULAR DISTURBANCE POST COVID-19 INFECTION IN AN ELITE FIGURE SKATER*Samuel T. Kim, Airelle Onnolee Giordano*

BACKGROUND AND PURPOSE: The World Health Organization (WHO) declared Coronavirus-19 (COVID-19), caused by the SARS-CoV-2 virus, as a pandemic in March 2020. Since the origin of the disease, experts have made it a mission to understand the pathophysiology, clinical presentation, and management of the disease. Although respiratory symptoms have been the hallmark complication related to the COVID-19 infection, vestibular-related symptoms have been reported in certain individuals.

CASE DESCRIPTION: A 16-year-old female figure skater presented with difficulty maintaining her orientation with jumps and spins that began after a COVID-19 infection. She was evaluated 4 weeks post diagnosis after noticing a lack of body awareness during triple loop and double axel jumps that she described as "being lost in the air" leading to an inability to land these jumps. Dizziness Handicap Inventory (DHI) and Activity-specific Balance Confidence (ABC) Scale revealed no disability with activities of daily living (ADLs), suggesting that her complaints were only related to higher level figure skating jumps. Vestibulo-ocular testing revealed positive smooth

pursuit and saccade testing, vestibulo-ocular Reflex (VOR), VOR cancellation, and head thrust test although all testing was asymptomatic. Seven weeks post diagnosis, she received vestibular function testing that revealed slightly decreased function in the right vestibular system. Treatments (7 visits/6 weeks) consisted of traditional gaze stabilization exercises such as VORx1, VORx2, and sports-specific functional habituation exercises such as high-speed stationary spins utilizing a harness system. Further assessment of postural stability revealed deficits with BESS testing and positive symptom reproduction when combining multiplanar head movements on a trampoline. Thus, training of jump spins off of a trampoline and running jump spins that combined these head movements commenced.

OUTCOMES: Patient's rehabilitation focused on vestibulo-ocular training, habituation, and progression of spinning and jumping movements that were gradually reincorporated during figure skating practices so that she could land them successfully. Her NDI and ABC Scale were still 0% and 100% (no disability for both) and Patient-Specific Functional Scale (0-10 scale, 10 is function before symptom onset) improved from a 7 at initial evaluation to a 9 at discharge related to her figure skating jumps. BESS test was reassessed at discharge which were improved from 20 errors to 5 errors total. Saccades and smooth pursuit testing were still positive.

DISCUSSION: Although vestibular-related impairments secondary to COVID-19 infection have been reported, this area requires further research to fully understand the range of symptoms that may result. The outcomes of this case suggest that an impairment-based approach by combining provocative signs with complaint-specific activities will promote habituation and success in these activities even in return to high level athletics.

SP054

ANTERIOR CRUCIATE LIGAMENT INJURY IN YOUNG FEMALE ATHLETES: PERSPECTIVES OF PARENTS AND ATHLETES

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PURPOSE/HYPOTHESIS: Female athletes, due to their biomechanical deficit profiles and increased risk of valgus collapse, are more susceptible to both contact and noncontact ACL injury. While evidence based ACL injury prevention programs exist, parent and athlete awareness of the need for such programs is less clear. The purpose of this study was to determine awareness of ACL injury risk in female athletes among both parents and athletes.

NUMBER OF SUBJECTS: Participants included 67 parents of female athletes and 29 female athletes. The parents were between the ages of 39 and 62 (mean age, 46.6 years). The athletes were between the ages of 13 and 16 years (mean, 14.6 years).

MATERIALS AND METHODS: Parents of female athletes, and female athletes between the ages of 12 and 16 years, were recruited via social media platforms to participate in an online survey. The survey was administered via Qualtrics and consisted of 27 questions for parents, and 17 questions for athletes. Survey questions included basic demographic information, and questions specific to ACL awareness individualized for each group of participants.

RESULTS: The majority of parents had a college education (67% of participants), and indicated that their child had never sustained an ACL injury (93% of participants). Most parents indicated that they were aware of the prevalence (75% of participants), and risk (76% of participants) of ACL injury, although only 50% of participants were aware of the increased risk in females specifically. While parents were aware of ACL injury risk, only 32% were interested in a free educational program related to ACL injury prevention, and 19% indicated they would be willing to pay for their child to participate in a program. Specific to the female athlete participants, 18% had a history of ACL injury, and 82% knew at least 1 person who had an ACL injury. Seventy-four percent were aware that ACL injuries can be

prevented, while 62% were aware that females are at higher risk for an ACL injury compared to males. The majority of athletes indicated that they had seen content related to ACL injury/prevention on a social media platform (55% of athletes). Forty-one percent of the female athletes indicated that they would be willing to participate in a weekly injury prevention program. The most common barrier to participation in a weekly program reported by the female athletes was lack of time.

CONCLUSIONS: Results of this study suggested that both parents and female athletes were aware of ACL injury risk. While awareness was noted in both groups, far fewer participants were interested in either participating, or having their child participate in, an injury prevention program. These results suggest that individuals working with female athletes need to provide education related to the efficacy of injury prevention programs. **CLINICAL RELEVANCE:** Physical therapists have a unique role in the development and implementation of health promotion efforts related to injury prevention. These findings should be considered as evidence-based ACL prevention programs are created and marketed to parents and athletes. Specific strategies to encourage participation in programs that minimize risk should be a priority.

SP055

QUADRICEPS STRENGTH IS ASSOCIATED WITH 2-DIMENSIONAL KINEMATICS AND MOVEMENT VARIABILITY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Jamie Kronenberg, Laura C. Schmitt, Kevin R. Ford, Staci Thomas, Christin Marie Zwolski, Mark Vincent Paterno

PURPOSE/HYPOTHESIS: Residual functional impairments often persist at the time of return to sport (RTS) after ACL reconstruction (ACLR). Prior work has identified the importance of sufficient quadriceps femoris (QF) strength for high-quality movement at the time of RTS. The purpose of this study was to test the hypothesis that significant correlation exists between isometric QF strength and 2-D landing kinematics among athletes at time of RTS following ACLR.

NUMBER OF SUBJECTS: Twenty-nine young athletes (22 female, 7 male; mean $\pm$ SD age, 17.8 ± 3.2 years) following primary unilateral ACLR were recruited for this study.

MATERIALS AND METHODS: All participants completed a laboratory-based assessment within 8 weeks of medical release to RTS. The assessment included isometric QF strength testing and 2-D biomechanical analysis of a drop vertical jump (DVJ). Two-dimensional frontal and sagittal plane videos of the DVJ were collected. Kinematic variables of interest included trunk flexion, knee flexion and knee valgus angles at initial contact (IC) and lowest center of mass (LCOM). Joint angle averages and standard deviations (variability) for all variables of interest were calculated over the three DVJ trials. Pearson product correlations were calculated to determine the relationships between QF strength and kinematic data. QF strength limb symmetry index (LSI) was used to split the sample into those who met LSI $\geq 90\%$ (High QF) and those who did not (Low QF). One-way ANOVA was used to determine kinematic differences between groups.

RESULTS: When comparing strength to average kinematic variables, involved limb QF strength significantly correlated with involved ($r = 0.389$, $P = .041$) and uninvolved ($r = 0.576$, $P = .001$) knee valgus angle at IC, and uninvolved knee flexion angle at IC ($r = 0.403$, $P = .045$). There was a trend towards a significant correlation between involved limb QF strength and involved knee flexion angle at IC ($r = 0.325$, $P = .091$). When comparing strength to movement variability, involved limb QF strength significantly correlated with involved knee flexion angle variability at IC ($r = 0.378$, $P = .048$) and involved knee valgus angle variability at LCOM ($r = 0.381$, $P = .045$). Finally, a between-group difference in trunk flexion angle variability was found between participants with QF LSI ≥ 90 (variability, 2.97 ± 1.54) and those with LSI < 90 , (variability, 6.15 ± 5.26 ; $P = .02$).

CONCLUSIONS: Previously reported high-risk 2-D biomechanical variables including trunk flexion, knee flexion and knee valgus, during a DVJ had

low to moderate correlations with involved limb isometric QF strength at the time of RTS. Additionally, achieving QF strength with LSI ≥ 90 was related to decreased movement variability during a DVJ.

CLINICAL RELEVANCE: ACL injuries are the result of a single traumatic event. While joint angle averages during a DVJ provide an overview of the patient's mechanics, assessment of variability may allow clinicians to identify the between-trial differences in motion that may contribute to ACL injury risk. Isometric QF strength may assist in identification of excessive movement variability.

SP056

FEAR OF REINJURY WORSENS IN HALF OF PATIENTS THE FIRST 10 WEEKS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Julianne Justine Lane, Kathleen Helen Cummer, Cristine E. Agresta

PURPOSE/HYPOTHESIS: Impaired psychological readiness to return-to-sport (RTS) after anterior cruciate ligament reconstruction (ACLR) can lead to reduced self-reported knee function, poor rehab outcomes, and prevent return to previous activities. Psychological readiness must be included in RTS testing; however, a common metric or single construct is not currently agreed upon, because how psychological readiness changes during rehab is not well understood. An understanding of the patient's development of psychological readiness is needed to determine the best assessment methods. Therefore, the purpose of this study is to characterize changes in fear of reinjury and perceived knee function during the early phase (2-10 weeks) after ACLR.

NUMBER OF SUBJECTS: Sixteen participants (mean $\pm$ SD age, 35.55 $\pm$ 12.3 years; 12 female; preinjury Tegner Activity Score, 6.73 $\pm$ 1.28) underwent an isolated unilateral ACLR.

MATERIALS AND METHODS: Subjects completed online questionnaires at 2 time points (T1, 2.86 $\pm$ 0.8 weeks; T2, 9.12 $\pm$ 2.83 weeks) after ACLR for fear of reinjury: Tampa Scale of Kinesiophobia (TSK-11), Anterior Cruciate Ligament-Return to Sport after Injury (ACL-RSI); and knee function: International Knee Documentation Committee (IKDC), Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADLS), and the Global Rating Scale (GRS). Descriptive statistics and paired t tests were used to assess within-subject change. Pearson correlation coefficients were used to assess the relation between demographics (age, gender, preinjury Tegner Activity Score, and athletic identity) within-subject change (T2-T1) of outcome measures. ACL-RSI scores were compared to published RTS threshold scores of ≥ 56 .

RESULTS: ACL-RSI scores worsened from T1 to T2 for 50% (8/16) of patients. At T2, 8 subjects scored ≥ 56 on the ACL-RSI and 8 subjects scored < 56 (11.67-54.17). No significant correlations were found between changes in ACL-RSI and select demographics. Significant improvements for mean scores were observed from T1 to T2 for the TSK-11 ($P = .008$), IKDC ($P < .001$), KOS-ADLS ($P < .001$), and GRS ($P < .001$). Mean ACL-RSI scores did not improve from T1 to T2 ($P = .32$).

CONCLUSIONS: These findings indicate that the ACL-RSI does not progress in-step with other self-reported measures early after ACLR. A decline in ACL-RSI scores for 50% of participants suggests individual perceptions of psychological readiness are evolving in early phases of rehab. Fifty percent of participants met or exceeded the ACL-RSI threshold for RTS, as early as 6.43 weeks after surgery before higher level activities were initiated. No variables were found to relate to the decline in ACL-RSI scores and more research is needed to identify potential influential factors.

CLINICAL RELEVANCE: There is a large intersubject variation in psychological scores. Individuals may be shifting their perception of psychological readiness to RTS early in rehab and the ACL-RSI may capture those changes. It is important for clinicians to assess and monitor patient-specific psychological readiness early in rehab, even before higher level activities are introduced.

SP057

SUBJECTIVE AND OBJECTIVE OUTCOME MEASURES AFTER CONCUSSION DO NOT IDENTIFY DIFFERENCES IN LOWER EXTREMITY KINEMATICS

Bobby Jean Sanders Lee, Shiho Goto, Joseph Patrick Hannon, Craig Craig Garrison, Kalyssa Creed, Damond Blueitt

PURPOSE/HYPOTHESIS: A relationship between a positive history of sport-related concussion (SRC) and lower extremity (LE) injury has been well established. The purpose of this study was to determine if scores on the Post-Concussion Symptom Scale (PCSS) and the Vestibular-Ocular Motor Screen (VOMS) at the time of initial evaluation after concussive injury could differentiate between athletes who would present with altered kinematic movement patterns during a double-limb drop landing (DLJ) at the time of return to play (RTP).

NUMBER OF SUBJECTS: A total of 24 athletes after SRC (mean $\pm$ SD age, 14.2 $\pm$ 1.5 years; height, 162.5 $\pm$ 18.8 cm; mass, 68.0 $\pm$ 28.3 kg) were included in the study. Participants were grouped according to scoring on the PCSS (> 36 , $n = 12$; ≤ 36 , $n = 12$) and according to scoring on the objective VOMS (> 4 domains, $n = 12$; ≤ 4 domains, $n = 12$).

MATERIALS AND METHODS: Performance during DLJ was assessed using an 8-camera Qualisys Motion Capture System and 2 AMTI force plates. The average of 3 consecutive trials was used to calculate LE joint kinematics. Joint angles were identified in the sagittal plane at initial contact (IC) and for total sagittal plane displacement (TD) for both limbs (DOM, NonDOM). A median split was used to determine the cutoff values for grouping athletes based on PCSS score and the number of involved VOMS domains. Independent t tests were calculated to examine differences in IC and TD for both limbs. Alpha level was set at $P < .05$ for all statistical analyses.

RESULTS: No differences were found in IC between VL and VH groups for the DOM (VLDOM, 21.1 $\pm$ 6.2; VHDOM, 16.7 $\pm$ 8.2; $t_{21} = 1.44$, $P = .16$) and NonDOM limbs (VLNonDOM, 20.5 $\pm$ 7.1; VHNonDOM, 18.5 $\pm$ 7.5; $t_{22} = 0.66$, $P = .52$). Further, no differences were found in IC between PL and PH groups for the DOM (PLDOM, 19.6 $\pm$ 7.9; PHDOM, 18.3 $\pm$ 7.1; $t_{21} = 0.41$, $P = .69$) and NonDOM limbs (PLNonDOM, 20.0 $\pm$ 7.5; PHNonDOM, 19.0 $\pm$ 7.2; $t_{22} = 0.34$, $P = .74$). Similarly, no differences were found in TD between VL and VH groups for the DOM (VLDOM, 72.7 $\pm$ 14.3; VHDOM, 71.5 $\pm$ 17.2; $t_{21} = 0.18$, $P = .86$) and NonDOM limbs (VLNonDOM, 74.9 $\pm$ 14.0; VHNonDOM, 72.6 $\pm$ 18.3; $t_{22} = 0.35$, $P = .73$). No differences were found in TD between PL and PH groups for the DOM (PLDOM, 75.8 $\pm$ 16.4; PHDOM, 68.0 $\pm$ 13.9; $t_{21} = 1.23$, $P = .23$) and NonDOM limbs (PLNonDOM, 76.9 $\pm$ 17.2; PHNonDOM, 70.7 $\pm$ 14.8; $t_{22} = 0.95$, $P = .35$).

CONCLUSIONS: Common subjective and objective measurements used at the time of initial evaluation after SRC cannot identify differences in LE kinematics at the time of return to sport based on scoring severity.

CLINICAL RELEVANCE: Athletes with prior history of SRC demonstrate kinematic movement patterns that may be related to future risk of LE injury. Using objective and subjective measurements at the time of initial evaluation does not indicate differences in prognosis for kinematics at the time of return to sport.

SP058

BILATERAL DIFFERENCES IN ULNAR COLLATERAL LIGAMENT QUANTITATIVE AND QUALITATIVE MEASURES IN COLLEGIATE PITCHERS

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PURPOSE/HYPOTHESIS: In baseball pitchers, the ulnar collateral ligament (UCL) is at risk for injury as it stabilizes the medial elbow against a large valgus stress during pitching. Increased ulnohumeral joint gap distance, UCL thickness and presence of hypoechoic foci and calcifications have been observed during preseason in the dominant compared to nondominant elbow in professional, but not high school pitchers. Defining UCL characteristics in collegiate pitchers will enable the understanding of when UCL quantitative and qualitative changes occur.

NUMBER OF SUBJECTS: NCAA Division I collegiate pitchers ($n = 24$; mean $\pm$ SD age, 20.0 ± 1.4 years).

MATERIALS AND METHODS: Bilateral ultrasound (US) images were collected of the medial elbow at 90° elbow flexion at rest and with a 2.5-kg valgus load. US-based calipers measured the ulnohumeral joint between the medial humeral trochlea and ulnar coronoid process. UCL thickness was measured at the proximal and distal UCL attachments. The UCL was rated on characteristics of degeneration (0 is normal, 1 is hypoechogenic foci, 2 is anechoic foci, 3 is full thickness fiber discontinuity) and presence of calcifications, enthesopathy, and joint effusion. Bilateral differences were assessed using independent t tests for quantitative measures, and Wilcoxon ranked-sum and chi-square tests for qualitative appearance. Linear regression analyses assessed the relationship between qualitative and quantitative measures.

RESULTS: The dominant arm had a greater prevalence of enthesopathy (29.2% versus 4.2%, $P = .02$), degenerative rating (0.83 versus 0.21, $P < .01$) and a thicker distal UCL (MD, 0.21 mm; 95% CI: 0.05, 0.37; $P = .01$) versus the nondominant. There were no significant differences in proximal UCL thickness or ulnohumeral joint gap at rest or with applied force. The linear regression model including both degenerative and enthesopathy scores significantly predicted UCL thickness ($R^2 = 0.20$, $P < .05$), but only the intercept was significant ($P < .01$). Degenerative score ($P = .31$) and enthesopathy ($P = .16$) were not due to multicollinearity. When modeled individually, both enthesopathy ($R^2 = 0.19$, $P = .02$) and degeneration ($R^2 = 0.15$, $P = .04$) were significant predictors of UCL distal thickness.

CONCLUSIONS: Healthy collegiate pitchers had greater distal thickness, and prevalence of degenerative changes (50% with ratings 1-3) and enthesopathy (29.2%) on the dominant UCL. But, there was no difference in ulnohumeral joint gap. Increased UCL thickness, degeneration and enthesopathy may represent a transition period in elbow health between high school and professional pitchers where some negative changes have occurred but medial stability has not yet been affected. The positive relationship between both enthesopathy and degenerative grade and UCL thickness also indicates greater thickening occurs in the presence of degenerative changes in UCL quality.

CLINICAL RELEVANCE: These findings suggest the UCL is thicker distally, with associated qualitative changes in the ligament. Considering greater ulnohumeral gapping has been previously associated with UCL injury, the lack of gapping in this study indicates that collegiate pitchers may have a lower risk for UCL injury compared to professional pitchers.

SP059

SYSTEMATIC REVIEW: PERTURBATION TRAINING WITH ANTERIOR CRUCIATE LIGAMENT-INJURED ATHLETES IMPROVES SELF-REPORTED FUNCTION WITH INCONSISTENT CHANGES IN PERFORMANCE

Andrew David Lynch, Roshni Makim, Arjun K. Patel, Cristina Estremera, Carlos Komlan Donou, Shane Morales

PURPOSE/HYPOTHESIS: Early reconstruction is the standard of care for acute ACL injury in athletes who want to return to sport. However, delayed operative management has similar 5-year outcomes to early surgery. Neuromuscular training is effective in improving outcomes, therefore we conducted a systematic review to answer the question "What effect does perturbation training have on clinical outcomes in patients with acute ACL deficiency?"

NUMBER OF SUBJECTS: Across the 5 observational studies, 314 participants underwent perturbation training. The randomized control trial included 26 total participants: 12 in the perturbation training group and 14 in the standard group.

MATERIALS AND METHODS: A search of MEDLINE, CINAHL and Web of Science using "ACL, (or) anterior cruciate ligament", (and) "injury (or) deficiency, (or) tear, (or) sprain" (and) "perturbation training (or) balance training (or) neuromuscular training." Studies had to include pre and post perturbation training outcomes for individuals with ACL injury includ-

ing patient reported outcomes (PROs) or functional test outcomes (hop tests). Preliminary results yielded 1085 results. Five observational studies and 1 randomized control trial were included in this review.

RESULTS: Five studies assessed the change in global rating scale (GRS), 5 of 5 studies reported statistically significant changes, 4 of which also exceeded the minimal detectable change (MDC) score (6.5 points). Four of 5 studies found a statistically significant improvement in the Knee Outcome Survey-Activities of Daily Living Scale after perturbation training, however only 1 exceeded the MDC of 8.9. A significant improvement in the International Knee Documentation Committee Subjective Knee Form was found in 3 of 4 studies, however, the change only exceeded the MDC of 9 in 1 study. Limb symmetry index (LSI) in the single hop for distance and triple hop for distance improved significantly in all 3 studies that reported results; however, only 1 of 3 reported exceeding the respective MDC values of 8.09% and 10.02%. LSI in the 6 m timed hop improved significantly in 3 of 4 studies but did not exceed the MDC value of 12.96%. LSI in the triple crossover hop improved significantly in 2 of 4 studies with only 1 exceeding the MDC value of 12.25%. Each study had minor to moderate threats to validity when assessed with JBI Critical Appraisal tools. In all studies, perturbation training was completed at the same time as strength and agility training, therefore it is difficult to isolate the effects perturbation training.

CONCLUSIONS: Perturbation enhanced rehabilitation after isolated ACL tears consistently improved patient self-report as measured by the GRS. Improvements in other knee-specific PROs and hop tests were inconsistent.

CLINICAL RELEVANCE: Perturbation training after ACL injury appears to produce superior clinical outcomes compared to standard rehabilitation and is a viable option. Further research is needed.

SP060

PHYSICAL THERAPY TREATMENT OF GROIN INJURY IN A MALE DIVISION I ATHLETE: A CASE REPORT

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BACKGROUND AND PURPOSE: Hip and groin injuries are common in sports involving quick changes of direction. Within these sports, men are shown to have a higher incidence rate than women and tend to be more serious when they do occur. Of sports involving rapid changes of direction, lacrosse is the fastest-growing in the United States, seeing a 227% increase in participation since 2001. Further, it is expected that as popularity of the sport increases, hip and groin injuries will also rise. This case study examines a 21-year-old male Division I lacrosse player, treated successfully with Dry Needling (DN) and Pain Neuroscience Education (PNE), after failing to improve with standard care provided by team Athletic Trainers (ATC) and Sports Medicine Physicians.

CASE DESCRIPTION: Prior to data collection, subject had been treated approximately 11 months utilizing a combination of massage, stretching, strengthening, and both Platelet-Rich Plasma (PRP) and intra-articular injections, all without measurable short-term relief. Notable exam findings included painful active range of motion and manual muscle testing on the affected side in hip flexion, adduction, and internal rotation. Furthermore, palpation of the pectineus and adductor magnus reproduced the patient's symptoms at the anteromedial hip and groin. Measures of psychosocial factors were taken based on the Zurich, 2018 hip-related pain consensus recommendations. Following a 2-week baseline data collection, the patient was then introduced to a combination of DN and PNE, using the *Why You Hurt: Pain Neuroscience Education System*, in twice-weekly sessions. The patient completed quizzes included with the Why You Hurt cards to gauge understanding. DN techniques included trigger point DN to pectineus and adductor magnus. In addition, homeostatic DN to the iliotibial band, saphenous nerve, and deep fibular nerve, as well as systemic DN to adductor magnus were utilized. Data were collected at weeks 1, 2, 3, 4, and 5, as well as at 2 and 3 months.

OUTCOMES: Patient-Reported Outcomes (PRO) including the Lower Extremity Functional Scale (LEFS), Fear-Avoidance Beliefs Questionnaire (FAB-Q), Pain Catastrophizing Scale (PCS-EN), numeric pain-rating scale (NPRS), and Single Assessment Numeric Evaluation (SANE) were recorded weekly. The subject demonstrated improvement in all PROs by week 5, meeting MCIDs for all measures. The FABQ-PA and FABQ-W improved 19 and 33 points, respectively. PCS improved from 13 to 0, and LEFS improved from 68/80 to 80/80. Patient gradually returned to practice without restriction by the fifth week. Improvements were maintained at 2 and 3 months. Patient had zero missed days of full-participation practice related to injury after the 5 week mark.

DISCUSSION: In this subject, DN and PNE appear effective in the treatment of a male lacrosse player with a longstanding groin injury. It is evident that more research is needed to examine incorporation of dry needling and PNE as a treatment for groin injury, both in isolation and in combination.

SPO61

A FIELD-EXPEDIENT ARM-CARE SCREENING TOOL CAN IDENTIFY MUSCULOSKELETAL RISK FACTORS IN BASEBALL PLAYERS

Kyle A. Matsel, Matthew C. Hoch, Robert John Butler, Philip M. Westgate, Terry Malone, Timothy Lee Uhl

PURPOSE/HYPOTHESIS: To investigate the discriminant validity of the new and efficient Arm Care Screen (ACS) to identify the presence of musculoskeletal injury risk factors in baseball players. It was hypothesized that poor performance on the ACS subtests would be highly sensitive at detecting the presence of at least 1 associated MSK risk factor in youth, high school, and college baseball players.

NUMBER OF SUBJECTS: One hundred ten male baseball players aged 11 to 22 years.

MATERIALS AND METHODS: Youth, high school, and college level baseball players were independently scored on the ACS. The ACS consisted of 3 components performed bilaterally: reciprocal shoulder mobility screen, standing 90/90 total body rotation screen, and lower body diagonal reach screen. Each participant was evaluated for mobility impairments following standard physical therapy measures of shoulder, trunk, and hip rotation deficits and balance limitations with the Y Balance Test. The validity of the ACS was determined by comparing live screen performance as pass or fail with the reference standard of mobility or balance deficits using 3 separate 2-by-2 contingency tables dichotomizing musculoskeletal risk factors above or below a predetermined cutoff value from the literature.

RESULTS: Chi-square tests showed significant associations for the 2-by-2 contingency tables created for each ACS subtest ($P < .001$) across all age levels. Each ACS subtest demonstrated higher sensitivity ranging from 0.84 to 0.90 compared to specificity which ranged from 0.56 to 0.71. The sensitivity of the reciprocal shoulder mobility, 90/90 total body rotation, and lower body diagonal reach screens were 0.90 (95% CI: 0.82, 0.95), 0.85 (95% CI: 0.77, 0.91), and 0.84 (95% CI: 0.76, 0.90), respectively. Musculoskeletal risk factors were 2 to 3 times more likely to be present in those who tested positive on the reciprocal shoulder mobility screen (+LR = 2.03; 95% CI: 1.44, 2.87), 90/90 total body rotation screen (+LR = 3.09; 95% CI: 1.70, 5.61), or the lower body diagonal reach (+LR = 2.95; 95% CI: 1.49, 5.84).

CONCLUSIONS: The ACS components demonstrated high sensitivity for identifying musculoskeletal risk factors common in baseball players. The ACS may be feasible screening tool which coaches and health care providers can administer to discriminate between youth, high school, and college level baseball players who possess musculoskeletal risk factors.

CLINICAL RELEVANCE: This field expedient screening tool which can be completed in under 3 minutes would provide coaches or clinicians with the ability to easily screen for common musculoskeletal risk factors that often develop throughout a season. Time efficient recognition of risk fac-

tors could aid in design of more targeted interventions which address individual athlete's needs.

SPO62

THE RELIABILITY OF AN ARM-CARE SCREENING TOOL IN HIGH SCHOOL BASEBALL COACHES

Kyle A. Matsel, Stephanie N. Brown, Matthew C. Hoch, Robert John Butler, Philip M. Westgate, Terry Malone, Timothy Lee Uhl

PURPOSE/HYPOTHESIS: Limited resources and time demanding testing procedures prevent high school coaches from accurately performing frequent movement screens on their players. The purpose of this study was to establish the intrarater and interrater reliability of a field expedient arm care screening tool in high school baseball coaches. It was hypothesized that a novel Arm Care Screen (ACS) will demonstrate moderate intrarater and interrater reliability with a Cohen's kappa value >0.40 when administered by high school baseball coaches.

NUMBER OF SUBJECTS: Thirty-one male high school baseball players (mean $\pm$ SD age, 15.9 ± 1.06 years).

MATERIALS AND METHODS: All baseball players were independently scored on the arm care screen (ACS) by 3 examiners in real time and again 7 days later by reviewing video recordings of each players' initial screening performance. Two high school coaches were trained by a physical therapist with greater than 10 years of experience performing movement screening. Both coaches received 1 hour of ACS scoring instruction and passed a competency exam prior to performing the screens. Results from each blinded examiner were compared within and between raters using Cohen's kappa and percent absolute agreement for determining reliability.

RESULTS: Substantial to excellent intrarater and interrater reliability were established among all raters for each component of the ACS. The mean Cohen's kappa coefficient for intrarater reliability was 0.76 (95% confidence interval: 0.54, 0.95) and percent absolute agreement ranged from 0.82 to 0.94 among all raters. Interrater reliability between the 2 coaches and the experienced rater demonstrated a mean Cohen's kappa value of 0.89 (95% confidence interval: 0.77, 0.99) while percent absolute agreement between raters ranged from 0.81 to 1.00. Intrarater and interrater reliability did not differ between raters with various movement screening experience ($P < .05$).

CONCLUSIONS: High school baseball coaches with 1 hour of training using the ACS screening movement can reliably score all 3 components of the ACS in less than 3 minutes.

CLINICAL RELEVANCE: Introduces a simplified movement screen based on the principles of the Function Movement Systems which requires no equipment and minimal training. The demonstrated reliability of the ACS enables high school baseball coaches to perform movement screening on their players in a time efficient manner and on regions of the body which commonly contribute to injury in baseball.

SPO63

THE LATERAL STEP-DOWN TEST AS A PREDICTOR OF GAIT MECHANICS CHANGES IN FATIGUED RUNNERS

Danny McAndrew, Nelson Glover, Jackson Corbisello, Ajit Chaudhari

PURPOSE/HYPOTHESIS: The primary purpose was to determine the correlation between pre-fatigue lateral step down test (LSDT) scores and changes in vertical ground reaction forces (vGRF) and peak knee flexion angles (PKFA) when fatigued. It is hypothesized that greater LSDT scores correlate to greater vGRF and PKFA increases. Secondary purpose was to determine if pre-fatigue LSDT scores can predict runners with increased vGRF and PKFA. It is hypothesized that higher movement quality assessed by LSDT would result in smaller vGRF and PKFA increases.

NUMBER OF SUBJECTS: Ten participants (6 female) with average $\pm$ SD age of 25.1 ± 5.8 years self-reported running 3.8 ± 1.3 times a week. Age require-

ments were 18 to 55 years, and participants had to self-report running 5 to 25 mi/wk. Active pregnancy resulted in study exclusion.

MATERIALS AND METHODS: Movement data were calculated using visual tracking markers placed on various body segments and processed using motion capture software (Motion Monitor, Chicago, IL; Vicon, Oxford Metrics, UK). Force dynamometry data collected on a Bertec Instrumented treadmill (Bertec, Columbus, OH). A repeated-measures ANOVA test (pre/post vGRF and PKFA), paired 2-samples *t* tests (LSDT score changes, LSDT scores versus post fatigue vGRF and PKFA), and Pearson correlation tests (LSDT score changes with the means vGRF and PKFA changes) were run using IBM SPSS. After completing eligibility and consent paperwork and giving informed consent, participants were given as much time as they needed for warming up. Before running, participants performed the LSDT on each side using a 20-cm step. Participants then ran at a speed 10% to 15% slower than their self-reported 5K time for 30 minutes, or until volitional fatigued was achieved, and then repeated the LSDT on each limb. The first and last 10 stride cycles collected during the running portion were used to calculate vGRF and PKFA.

RESULTS: A strong correlation (0.705) existed between LSDT changes and mean vGRF changes. vGRF increased by 2.6% body weight (prefatigue, 2.47 ± 0.05 ; $P < .001$), PKFA decreased $1.0^\circ \pm 0.2^\circ$ ($P < .001$), and PKFA was $1.3^\circ \pm 0.2^\circ$ less on the left lower extremities ($P < .001$). Post fatigue LSDT scores increased significantly when participants' lower extremity scores were summed (4.5 ± 2.4 to 5.4 ± 2.5 , $P < .05$) and on their left lower extremity (2.1 ± 1.2 to 2.9 ± 1.2 , $P = .02$), but not on the right side (2.4 ± 1.4 to 2.5 ± 1.5 , $P = .34$).

CONCLUSIONS: Quality of movement and running kinematics in recreational runners changed significantly following volitional fatigue running protocol. LSDT changes correlated to vGRF changes but not PKFA, suggesting the LSDT could be used to detect those who may benefit from vGRF alterations. The lack of significance in right LSDT scores could be attributed to lower extremity dominance, seeing as most participants were right lower extremity dominant. Further research is needed to determine if the LSDT can help detect running mechanics that could predispose runners to patellofemoral pain (PFP).

CLINICAL RELEVANCE: The LSDT is a valid tool to utilize to analyze movement quality in those with PFP, and it may help detect individuals that exhibit predisposing factors to PFP.

SP064

USE OF VIDEO ANALYSIS SOFTWARE TO ASSESS THE OUTCOME OF AN ANTERIOR CRUCIATE LIGAMENT INJURY PREVENTION PROGRAM

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PURPOSE/HYPOTHESIS: Female athletes are more susceptible to ACL injury between the ages of 12 and 16 due to genetic predisposition, hormone levels, and biomechanics during landing and cutting. The purpose of this study was to examine the impact of participation in a 6-week exercise program on knee biomechanics via video analysis software in young female athletes.

NUMBER OF SUBJECTS: Ten female athletes between the ages of 12 and 14 (mean age, 12.83 years) completed pretesting, while 6 of these athletes completed both pre/post testing (mean age, 13.11 years).

MATERIALS AND METHODS: Female athletes between the ages of 12 and 16 were recruited to participate in a 6-week exercise program. Each athlete received step-by-step instructions on how to record video submissions of knee biomechanics at both pretest (before the start of the program) and posttest (following completion of the 6-week program). Participants were assessed by video during countermovement jumps (hands on waist) during landing phase of the jump from initial foot contact to lowest point during descent. Participants had tracking markers at the ASIS, center of the patella, and center of the ankle on both legs. Pre-post video submissions

were analyzed using Kinovea Software (Joan Charmant, developer; GPL Version 2 license). The 6-week exercise program included pre-recorded exercise videos to be performed 3 times per week developed from evidence-based literature in ACL injury prevention. Exercises targeted improvement of hamstring and quadricep strength ratio, balance, and proprioception via plyometrics to simulate sport like activities.

RESULTS: Pre and posttest videos were analyzed using Kinovea Software. Specific variables assessed included, Q-angle (LandR), medial-lateral maximum displacement of the knee normalized to leg length, medial-lateral maximum rate of knee displacement normalized to leg length and observed medial-lateral knee displacement variability. All participants displayed Q-angles in the expected range. At pretest 8/10 participants (80%) displayed some degree of medial knee displacement that could preindicate risk for valgus-related ACL injury. Likewise, 5/6 participants (83.3%) displayed similar knee displacement variability at posttesting. Knee displacements were generally noted to be a small percentage of leg length, as such, rates of displacement were similarly small.

CONCLUSIONS: Participants in this study did not decrease knee displacement (neither medial nor lateral) following training, nor did their rate of knee displacement decrease. It is unclear if the lack of change from pre to posttest observed was due to program related issues (ie, compliance, efficacy, duration), or measurement variability.

CLINICAL RELEVANCE: Injury prevention programs focused on improving biomechanical and strength deficits could potentially decrease the risk of noncontact ACL injuries. Assessing the impact of such programs is essential. The use of inexpensive video recording software could assist physical therapists in these efforts. Further research is needed to determine how this software can enhance injury prevention efforts.

SP065

BLOOD FLOW RESTRICTION TRAINING FOLLOWING SHOULDER STABILIZATION SURGERY: A CASE SERIES

John Hedrick McGinniss, Michael Scott Crowell, John Sterling Mason, William J. Pitt

BACKGROUND AND PURPOSE: Athletes often return to sport before full recovery of strength after shoulder stabilization surgery. Resistance training requires high loads that may compromise healing early after surgery. Blood Flow Restriction (BFR) training uses low loads and vascular occlusion to mimic cellular and hormonal responses seen in heavy resistance training. The purpose of this case series was to explore shoulder function and outcomes in Cadets who completed a rehabilitation program with BFR training.

CASE DESCRIPTION: Seventeen cadets (18-24 years old) who underwent shoulder stabilization performed 10 BFR treatments from 6 to 12 weeks postoperatively. BFR training consisted of 1 upper-body aerobic exercise and 3 shoulder strengthening exercises with the tourniquet positioned on the upper brachium of the involved extremity. Occlusion pressure was maintained at 50% maximal limb occlusion pressure with a 30-minute maximal wear time. Rating of perceived exertion was used to monitor intensity during treatment. We assessed range of motion, isometric strength, and patient-reported outcomes at 6 weeks, 12 weeks, and 6 months postoperatively. The Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST), the Seated Shot-Put Test (SSPT), and the Upper Quarter Y Balance Test (UQYBT) measured function at the 6-month follow-up. One-way, repeated-measures ANOVAs were used to analyze self-reported outcomes and isometric strength ($\alpha = .05$). Post hoc comparisons were performed using a Bonferroni correction to control family-wise type I error.

OUTCOMES: SPADI scores improved significantly and exceeded the MCID in 10 of 16 (63%) participants at 12 weeks ($P = .004$) and in 6 of 8 (75%) participants at 6 months ($P = .027$). There were statistically significant improvements in QuickDASH scores at 12 weeks and 6 months ($P < .001$). However, 13 of 16 (81%) participants had an initial QuickDASH score above the MCID. Normalized external rotation (ER) strength improved

significantly on the surgical limb from 0.11 to 0.17 ($P = .049$) between 6 and 12 weeks and from 0.11 to 0.21 ($P = .006$) from 6 weeks to 6 months. At 12 weeks, there was no significant side-to-side difference in normalized ER strength (surgical, 0.17; uninjured, 0.19). At 6 months, ER strength (0.21 surgical; 0.22 uninjured) surpassed age-based norms for healthy collegiate males and females. At 6 months, mean CKQUEST was 19.9 ± 4.3 reps, mean UQYBT composite LSI was 97%, and the SSPT was similar side to side (surgical, 442 ± 123 cm; uninjured, 489 ± 72 cm).

DISCUSSION: We observed clinically meaningful improvements in self-reported outcomes, shoulder strength, and function following a 6-week post-stop rehabilitation program that included BFR training. While the degree of improvement attributable to BFR is unknown, participants regained upper extremity strength within 12 weeks of surgery and functional limb symmetry within 6 months. Future research should examine the effectiveness of adding BFR to standard upper extremity rehabilitation.

SP066

BLOOD FLOW RESTRICTION TRAINING FOR CHRONIC KNEE PAIN IN A FEMALE ATHLETE: A CASE STUDY

Payton Caroline Rausch McWilliams, Penny Lauren Goldberg, Jeffery Don Gilliam

BACKGROUND AND PURPOSE: The APTA recommends treating knee pain and mobility impairments with therapeutic exercise including range of motion, stretching, and strength training. A series of exercises are prescribed to return to function after injury. Some patients cannot tolerate progressive resistance due to pain. Blood flow restriction training (BFR), when paired with low resistance, high repetition exercise, is an option to increase muscle strength and size while allowing patients with low pain thresholds to progress. This case study explores using BFR training to increase strength and function in a patient who was unable to progress with traditional physical therapy methods due to pain with weight training.

CASE DESCRIPTION: A 40-year-old female fire rescue professional had an insidious onset of bilateral knee pain with meniscus involvement, arthritic changes, swelling, and chondromalacia. She had meniscus debridement and was evaluated for physical therapy 3 months post surgery. After 2 months of standard physical therapy pain persisted and BFR training was introduced. She completed 3 treatments per week, consisting of 3 sets of 4 exercises. She worked to fatigue, with a 10% 1RM resistance, and 150 mmHg of pressure to occlude venous blood flow. She was educated in swelling management and daily stretches. Computerized lower extremity strength testing was performed for baseline and follow-up strength measures.

OUTCOMES: After 8 weeks of BFR training, quadriceps and hamstring strength improved (right quadriceps increased by 75%, left increased by 7%, right hamstring increased by 63%, left decreased by 3.7%). Patient reports of pain and swelling decreased and function increased. LEFS score increased by 8 points.

DISCUSSION: BFR training has been used to complement strength training in athletes, and aid in rehabilitation after injury. This patient was active before surgery, and immediately began knee rehabilitation after surgery, however persistent pain limited progress as well as return to work and play. After completion of BFR training she improved in all areas with no adverse effects. Current research indicates the best protocol for BFR involves 80% limb occlusion, completing 4 sets of exercises (repetitions of 30, 15, 15, 15) with 30 to 60 seconds of rest between sets, performed 2 to 4 days a week. We did not follow these guidelines exactly, the patient worked to fatigue rather than a set number of repetitions, and performed only 3 sets of each exercise, in efforts to reduce total time required and increase patient compliance with training. This suggests there may be room for variation without compromising results. BFR training should be considered for patients with orthopaedic limitations who fail standard strength programs. While there are minimal side effects, its use may be limited in those with pulmonary and cardiac implications. Further re-

search is necessary to demonstrate the ease of adequately introducing BFR to the clinic as part of standard rehabilitation.

SP067

CAN YOU ASSESS STRETCH-SHORTENING CYCLE POTENTIATION BY CONTACT MAT?

Catherine Meyer, Phuong Quach, Mario Inacio, Ling-Yin Liang, Harshvardhan Singh

PURPOSE/HYPOTHESIS: Enhancement of concentric force when preceded by lengthening contraction of muscle is known as stretch-shortening cycle (SSC) potentiation. SSC potentiation is a vital component of physical activities. Jump test performance (JTP) is a well-established technique to assess SSC potentiation. Typically, an isokinetic dynamometer or motion capture system is used to assess SSC potentiation, which may be cost, time, and technology prohibitive for a wider applicability. Thus, our purpose was to determine if SSC potentiation can be assessed using a contact mat and speed analyzer, which is cheaper, mobile, and low technology. We hypothesized that SSC potentiation can be captured using a contact mat and speed analyzer during JTP. A secondary aim was to compare SSC potentiation between different jump conditions. We hypothesized that a higher intensity jump such as drop jump (DJ) will show greater SSC potentiation than countermovement jump (CMJ).

NUMBER OF SUBJECTS: Twenty-one.

MATERIALS AND METHODS: After a period of warm up and familiarization, participants performed 3 successful trials of CMJ, static jump (SJ), and DJ (drop height of 0.15 m), in that order, with 60-second rest in between the jumps. The knee angle for the SJ, prior to the takeoff, was matched to the knee angle achieved during CMJ. For all jumps, participants kept their hands at hips. Jump height (JHt), power (JPow), and velocity (JVel) were collected using a contact mat (Just Jump, AL) and speed and velocity analyzer (Tendo Sports, Slovak Republic). SSC potentiation was calculated as the ratio of JHt, JPow, and JVel between the 3 jump conditions (DJ/SJ, CMJ/SJ, and DJ/CMJ), where a ratio significantly greater than 1 showed SSC potentiation. Differences in SSC potentiation were assessed for all the jump conditions.

RESULTS: The ratios of JPow were greater than 1 for DJ/SJ ($P = .002$), CMJ/SJ ($P = .017$), and DJ/CMJ ($P = .036$) while the ratios of JHt and JVel were greater than 1 for DJ/SJ and CMJ/SJ ($P < .001$ for both). SSC potentiation of JPow, JHt and JVel were greater for DJ/SJ and CMJ/SJ versus DJ/CMJ ($P < .05$), while no difference in SSC potentiation was noted between DJ/SJ and CMJ/SJ.

CONCLUSIONS: Irrespective of JTP variables such as JHt, JPow, and JVel, SSC potentiation can be captured using a contact mat with a speed analyzer. Specifically, JPow potentiation can be captured for a scaled JTP. Although, SSC potentiation was greater for DJ/SJ and CMJ/SJ than DJ/CMJ, no differences in SSC potentiation for any of the JTP variables were captured for DJ/CMJ. Thus, our data suggests that contact mat may be of a limited utility when assessing the differential SSC potentiation for scaled JTP.

CLINICAL RELEVANCE: Contact mat with speed analyzer can be used as a mobile, low technology, user friendly, and cheaper way to assess SSC potentiation in young adults. Thus, it can be used in multiple settings such as clinics, community gymnasium, and field settings. However, more research is required to assess its utility in assessing different degrees of SSC potentiation.

SP068

FLEXOR DIGITORUM SUPERFICIALIS MUSCLE LENGTH COMPARISON BETWEEN THE THROWING AND NONTHROWING ARMS OF BASEBALL PITCHERS

John Connor Montemayor, David Glenn Iodice, Michael Esposito, Lucas Ferreira, Jason Keith Grimes

PURPOSE/HYPOTHESIS: The flexor digitorum superficialis (FDS) is an important muscle for overhead throwing athletes because of the subsequent

injuries often sustained among players who have flexor-mass strains. Overhead throwing athletes experience valgus stress on the ulnar collateral ligament (UCL) during the throwing motion which often exceeds its failure rate. The FDS can help protect the UCL because it is the largest dynamic contributor to stabilization for valgus force at the elbow. However, when the FDS is shortened, it decreases the muscle's capacity to generate force, which can impair its protective ability. The purpose of this study was to examine differences in FDS length between the throwing and nonthrowing arms in collegiate baseball pitchers.

NUMBER OF SUBJECTS: Seventeen collegiate baseball pitchers with a mean $\pm$ SD age of 20.8 ± 1.3 years were assessed. All participants were male baseball pitchers at a single university that were currently cleared for full participation in baseball activities.

MATERIALS AND METHODS: The length of the FDS was assessed by 1 examiner. All measurements were taken prior to the first game of the season. Passive wrist extension range of motion was measured with the elbow extended and forearm pronated in 2 positions. Position 1 had the fingers flexed, while Position 2 had the fingers extended. In order to obtain the length of the FDS, the wrist extension values obtained from the 2 positions on the same arm were subtracted from each other. As the data were not normally distributed, a Wilcoxon test was used to compare the length of the FDS on the throwing and nonthrowing arms to determine if there were length discrepancies between the 2 sides.

RESULTS: There was no significant difference between Position 1 and Position 2 for the nonthrowing arm ($P = .501$). However, there was a significant difference between Position 1 and Position 2 for the throwing arm ($P < .001$) with less wrist extension in Position 2 in 16 out of 17 (94%) participants. For Position 1, there was no significant difference between the throwing arm and nonthrowing arm ($P = .300$), but for Position 2 there was a significant difference ($P = .007$) with less wrist extension in the throwing arm in 15 out of 17 (88%) participants.

CONCLUSIONS: The length of the FDS was found to be significantly shorter on the throwing arm side compared to the nonthrowing arm side in collegiate baseball pitchers.

CLINICAL RELEVANCE: Measuring the length of the FDS should be taken into consideration to provide information regarding muscle performance which could potentially prevent flexor mass strains that could further lead to injury of the UCL. Information obtained from assessing FDS length can provide clinicians with another data point to help guide treatment to the elbow, wrist, and hand.

SP069

THE KERLAN-JOBE ORTHOPAEDIC CLINIC SHOULDER AND ELBOW SCORE USED IN THE YOUTH BASEBALL ATHLETE

Ryan Joseph Monti, Alicia Fernandez-Fernandez

PURPOSE/HYPOTHESIS: The purpose of this study was to determine if the scores on the Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow Score (KJOC) are different between those throwing with and without pain in male youth and high school-aged baseball athletes. Additionally, this study aimed to establish a prediction score for whether a young baseball athlete is throwing with symptoms. The hypothesis was that the scores on the KJOC would be statistically different between groups in the young baseball athlete and would provide a score predictive to determine if a younger athlete is throwing with or without symptoms.

NUMBER OF SUBJECTS: Fifty-six.

MATERIALS AND METHODS: The KJOC questionnaire was used to compare scores of those throwing with and without pain in male baseball players between the ages of 10 through 18 years. Data from 28 subjects who were previously seen in physical therapy for throwing arm pain were reviewed retrospectively and compared to 28 subjects prospectively who were actively participating in baseball with no pain. The Mann-Whitney U test was used to compare the mean scores on the KJOC. Logistic regression, receiver operating characteristic curve (ROC) and Youden's J

statistic were used to establish a threshold score between those throwing with and without pain.

RESULTS: Significant difference was found between the groups ($U = 698.5$, $P < .001$) with capability to discriminate between those throwing with pain versus those throwing without pain ($AUC = 0.891$). The results indicate this threshold score to be at 68.6, which signifies anyone scoring above this threshold would be throwing with no pain and a score below this number indicating throwing with pain.

CONCLUSIONS: The results of this study reflect that the KJOC can differentiate between younger baseball athletes throwing with and without pain. The predictive threshold score of 68.6 can be used in a clinical setting to aid with determining if a youth or high school-aged athlete is suffering from pain while participating in overhead throwing. The KJOC can be utilized with the youth baseball athlete population to monitor progression of treatment and aid with documentation.

CLINICAL RELEVANCE: The use of the KJOC in the youth baseball athlete population is clinically relevant and provides an important tool to guide decision making. Lack of subjective communication given by patients of a younger age can pose a challenge to assess response to treatment. The results of this research can aid with improving communication between a younger demographic reporting pain and assessing subjective levels of function.

SP070

MOTOR AND COGNITIVE CEREBELLAR STRUCTURES AND DUAL-TASK PERFORMANCE AFTER MILD TRAUMATIC BRAIN INJURY

Nathan Morelli, Nathan Forrest Johnson, Allison M. Parks, Jenna Wilson, Kimberly Kaiser, Matthew C. Hoch

PURPOSE/HYPOTHESIS: Dual-task (DT) gait deficits following a mild traumatic brain injury (mTBI) are frequently seen after patients are cleared for full participation. However, little is known about the underlying neurologic mechanisms of DT deficits in mTBI. Given the role of the cerebellum in motor and cognitive control, we aimed to determine if group differences in cerebellar volumes and DT gait performance in patients after mTBI. We hypothesized that patients recovering from mTBI would demonstrate slower DT gait speed and structural difference in cerebellar lobules responsible for motor and cognitive functions.

NUMBER OF SUBJECTS: Five healthy, young adults (5 male; mean $\pm$ SD age, 20.6 ± 2.3 years; height, 1.8 ± 0.1 m; mass, 74.8 ± 4.3 kg) and 5 post-mTBI patients (5 male; mean $\pm$ SD age, 19.0 ± 2.5 years; height, 1.8 ± 0.1 m; mass, 73.0 ± 6.4 kg; days post injury, 25.0 ± 4.4).

MATERIALS AND METHODS: Participants completed single (ST) and DT gait, at self-selected gait speeds, over a 10-m walkway. Each task variant (ie, ST and DT) was completed 3 times. Gait speed (m/s) was averaged for reporting. Serial subtraction was used as the cognitive task for DT gait. DT cost (DTC) was calculated as the relative difference between ST and DT. Participants underwent magnetic resonance imaging within 24 hours of clinical data collection. Cerebellar gray matter volumes in lobules associated with motor and cognitive functions were derived from high-resolution T1 structural scans. Lobule volume was normalized to total cerebellar volume. Independent t test, with Cohen's d effect sizes (ES), were used to compare cerebellar volumes and clinical variables between controls and post-mTBI patients. Significance was set to $P = .05$ for all comparisons.

RESULTS: Patients with mTBI demonstrated a significant slower in DT gait speed (mTBI, 2.11 ± 0.39 ; control, 2.32 ± 0.28 ; $P = .036$; ES, -0.62) compared to controls; however, no differences were identified in ST gait (mTBI, 2.57 ± 0.38 ; control, 2.65 ± 0.26 ; $P = .79$; ES, -0.18). As a result, there was a significant difference between groups for DTC of gait speed ($P = .017$; ES, -0.96). Patients with mTBI also demonstrated significantly greater gray matter in lobules I to IV, V, VI, crus I, and crus II ($P \leq .05$; ES, 1.37 - 2.20) compared to healthy adults.

CONCLUSIONS: Patients recovering from mTBI demonstrated DT gait deficits and greater gray matter volumes in cerebellar lobules underlying mo-

tor and cognitive functions. These findings provide preliminary evidence of a potential underlying neurologic mechanism of DT deficits in this patient population. Continued longitudinal investigations are warranted to determine the association of post-mTBI cerebellar changes to clinical cognitive and motor outcomes.

CLINICAL RELEVANCE: These data provide preliminary evidence of differences in cerebellar volumes underlying cognitive and motor function in patients with mTBI relative to matched controls. Furthermore, these DT gait findings were established using routine clinical tests in patients beyond the typical return-to-activity periods in athletic populations.

SP071

RELATIVE ENERGY DEFICIENCY IN SPORT IN ADOLESCENT FEMALE DANCERS, GYMNASTS, AND CHEERLEADERS

Christyn-Jo Morris, Nicole Melfi, Emily Francione

PURPOSE/HYPOTHESIS: Relative Energy Deficiency in Sport (RED-S) is a condition in which an athlete's energy expenditure exceeds dietary intake during exercise and athletic participation. Youth athletes participating in sports emphasizing leanness and aesthetic are at an increased risk for developing RED-S. The purposes of this study were to (1) evaluate RED-S components in adolescent female dancers, gymnasts, and cheerleaders as measured by the RED-S Specific Screening Tool (RST), (2) determine risk level for developing RED-S via RST scores, (3) assess knowledge of RED-S in this population, (4) determine if BMI alone significantly predicts RST score, and (5) determine if there is a difference in RST scores based on BMI when dichotomized ($\pm 18.5 \text{ kg/m}^2$). We hypothesized >50% of participants would be considered "High Risk" for developing RED-S via RST scores, with <25% of participants having knowledge of the condition itself. Additionally, we hypothesized BMI would significantly predict RST score, with significant differences in scores between BMI groups.

NUMBER OF SUBJECTS: Twenty adolescent female dancers, gymnasts, and cheerleaders, aged 11 to 18 years, participated in this study.

MATERIALS AND METHODS: Participants were recruited via convenience sampling and each completed a digital version of the RST. Descriptive statistics were analyzed along with linear regression and independent *t* tests at $\alpha = .05$.

RESULTS: Mean participant age was 15.20 ± 1.852 years, with a mean BMI of $20.81 \pm 2.41 \text{ kg/m}^2$. Concerning nutrition and body image, 80% reported a "sometimes" to "always" fear of being overweight, 35% reported intentional vomiting after eating, 45% felt guilty after eating, 75% were concerned with fat on their bodies, 85% reported worrying about what they ate, and 65% wished they were thinner. Regarding menstrual health, 15% reported having infrequent periods, with 40% of this subsample reporting 3+ months without a period. From a psychological standpoint, 30% reported depressive symptoms, 70% reported anxiety and decreased attention/focus, and 80% reported experiencing stress, all within the last 6 months. The average RST score was 243.95, with scores ranging from 84 to 378 ± 90.01 . Based on these scores, 89.5% of the sample was identified as "Medium Risk" for developing RED-S; however, 0% of participants had heard of the condition. BMI alone did not significantly predict RST scores at $r = -0.316$, $P = .187$. There was also no difference in RST scores between those with BMIs $>18.5 \text{ kg/m}^2$ (mean, 244.71) and $<18.5 \text{ kg/m}^2$ (mean, 237.50) at $t = 0.104$, $P = .918$.

CONCLUSIONS: This study demonstrates the prevalence of various RED-S components in adolescent female dancers, gymnasts, and cheerleaders. Significant lack of education regarding this condition presents concern and highlights an important gap in promoting safe and healthy sports participation.

CLINICAL RELEVANCE: RED-S is highly prevalent in this population due to sport-specific demands and has serious implications on physical health and psychological well-being. The RST is an age-appropriate screening tool for RED-S that may be utilized by physical therapists as both an educational piece and preventative measure for at-risk athletes.

SP072

PRESEASON UPPER EXTREMITY FUNCTIONAL TESTING OF COMPETITIVE YOUTH SWIMMERS

Matthew Naftilan, Steven Cilliotta, Nicole Dahl, Matthew Fedro, John Giametta, Chris Heymann, Jamie Wallace, Tracey Llewellyn, Lynne P. Roberts, Andrew Cavaliere Shannon

PURPOSE/HYPOTHESIS: Swimming is a sport that regardless of stroke involves highly repetitive motions potentially leading to increased risk of overuse and nontraumatic injuries. Elite swimmers often swim 11 months out of the year and 4 to 10 mi/d beginning at age 10 to 12 (Hibberd et al 2013). This combination has led to a high reported incidence of injury and pain. Shoulder injuries are reported to be the most common with prevalence between 40% and 91% (Wanivenhaus et al 2012). While there are several studies that have looked at injury risk in the swimming population (Walker et al 2012, Reimann et al 2011, Sein et al 2010) the majority of these studies have focused on the elite level (college, Olympic, etc) and have not looked exclusively at the youth and adolescent population and none have looked at functional measures that are frequently used to help make return to sport decisions (Wilk et al 2020). This study aims to examine the baseline characteristics of competitive junior swimmers in order to identify potentially modifiable risk factors for future interventional studies.

NUMBER OF SUBJECTS: Fifty-three.

MATERIALS AND METHODS: Participants were recruited from a local competitive swimming club. Participants underwent a physical exam including range of motion and strength measures at the shoulder, functional testing of the shoulder and pelvis/core, and several questionnaires at the beginning of their season prior to the first competition of the year. We measured closed kinetic chain upper extremity stability test (CKCUEST) counting the number of touches in a push up position with a 3-ft hand width over 15 seconds. Prone ball drop test was performed prone on a plinth with a 1-kg weighted ball. The participant was asked to drop and catch the ball as many times as possible in 30 seconds. This was performed at 90° abduction with elbow extended and then again with elbow flexed to 90°.

RESULTS: Twenty-eight Females and 25 Males were enrolled between the ages of 11 and 18 (mean $\pm$ SD, 14.2 ± 1.9). Average number of years swimming was 8.17 ± 3 and 6.04 ± 2.4 competitively; 90.5% reported swimming for > 10 months per year and only 32% of participants indicating that they participated in other sports. Average closed kinetic chain upper extremity stability test was 17.8 ± 3.5 . Prone ball drop average was 31.8 ± 12.1 on dominant side and 28.6 ± 11.0 on nondominant side. Prone 90°-90° ball drop was 43.7 ± 13.6 on dominant side and 39.6 ± 15.4 on nondominant side.

CONCLUSIONS: The use of criteria based return to sport testing is important in order to minimize subjective decision making and establish some uniformity as to when clinicians are allowing athletes to return to the pool. However, in order to use many of the upper extremity functional tests that have been described in the literature there first needs to be normal values established for different populations.

CLINICAL RELEVANCE: This study provides a baseline of normal values for upper extremity functional measures in a competitive youth swimming population that can potentially be used in return to sport testing in the future.

SP073

RELIABILITY OF KNEE MOTION COLLECTED WITH A SINGLE-CAMERA 3-D MOTION-ANALYSIS SYSTEM

Elizabeth S. Norris, Michael Wesley Kennedy, Matthew Parker Dye, Paige N. Harris, Kinsy H. Shofner, Nicholas M. Smith

PURPOSE/HYPOTHESIS: The purpose of this study was to evaluate the test-retest reliability of the VSTPro for the measurement of knee valgus and knee flexion during a drop vertical jump (DVJ) task.

NUMBER OF SUBJECTS: Twenty-five healthy subjects (12 female, 13 male) aged 24.5 ± 3.1 years participated in the study.

MATERIALS AND METHODS: The VSTPro is a portable single-camera motion analysis system that utilizes infrared technology to conduct 3-D kinematic measurements during functional tasks. The camera was positioned on a tripod at a consistent distance and height from each participant. Participants performed 6 trials of the DVJ from a 30-cm box on 2 separate days, 7 to 10 days apart. Within and between-day reliability was estimated for right and left knee motion separately using intraclass correlation coefficients (ICCs) and 95% confidence intervals. Within-day reliability was examined across all 6 trials ($ICC_{2,1}$) and between the averages of trials 1 to 3 and trials 4 to 6 on days 1 and 2 ($ICC_{2,3}$). Between-day reliability was examined using the average of 6 trials ($ICC_{2,6}$) and the average of trials 1 to 3 on day 1 and day 2 ($ICC_{2,3}$). Both within and between-day reliability was estimated for knee valgus and knee flexion on first landing of the DVJ. Standard error of measurement (SEM) and minimal detectable change (MDC) were calculated.

RESULTS: VSTPro measures of knee valgus yielded moderate-excellent within-day reliability ($ICC = 0.539-0.928$) and good-excellent between-day reliability ($ICC = 0.866-0.911$). For knee flexion, within-day reliability of VSTPro measures was good-excellent ($ICC = 0.647-0.955$), and between-day reliability was good-excellent ($ICC = 0.885-0.913$). The lower bounds of the confidence interval of within-day reliability estimates were 0.373 to 0.502 for knee valgus and 0.793 to 0.758 for knee flexion, while the lower bounds of the confidence interval for the between day reliability estimates were 0.661 to 0.799 for knee valgus and 0.618 to 0.804 for knee flexion. Within-day SEM of knee valgus was 1.6° to 2.1° for single measures and $<1^\circ$ for average measures. Between day SEM of knee valgus was $\leq 1.1^\circ$. Within-day SEM of knee flexion was 9.2° to 11.7° for single measures and 4.5° to 6.3° for average measures. Between day SEM of knee flexion was 6.5° to 8.6° .

CONCLUSIONS: Reliability of the VSTPro single camera 3-D motion analysis of knee valgus and knee flexion at initial contact landing of a DVJ task is moderate to excellent. When using average measures across 3 trials, within-day reliability of knee valgus and flexion is good-excellent with ICC values of 0.868 to 0.906. Between-day reliability is similar when estimated using the average of 6 or 3 trials for both variables.

CLINICAL RELEVANCE: Study findings suggest the VSTPro system produces reliable measures of knee valgus and knee flexion during a DVJ task. The single camera and markerless infrared technology enhance the clinical utility of the VSTPro system. When using the VSTPro system to assess knee motion during a DVJ task, clinicians should consider a change $\geq 2.5^\circ$ and 17.5° to reflect true change in knee valgus and knee flexion, respectively.

SP074

SIMULATED UNSTABLE ANKLE ALTERS POSTURAL CONTROL STRATEGY DURING THE STAR EXCURSION BALANCE TEST

Shojiro Nozu, Kristin Ann Johnson, Yuji Takazawa, Richard K. Shields

PURPOSE/HYPOTHESIS: Determining sensorimotor function in individuals with ankle sprains is crucial to inform the decision to return them to sports. The Star Excursion Balance Test (SEBT), especially the postero-medial (PM) reach distance, identifies postural control deficits in individuals with unstable ankles. Due to sensorimotor deficits including proprioceptive deficits and ankle joint stiffness, individuals with unstable ankles have difficulty controlling their center of mass (COM) and the rotation around the ankle joint while performing the PM reach of the SEBT. However, few studies have examined changes in COM parameters and ankle joint kinematics in relation to the PM reach distance. It is well known that altered postural control responses like decreased ankle joint moments and occur when standing on a compliant surface such as a foam pad due to unreliable somatosensory information. In an effort to understand changes that occur with an unstable ankle, determining the postural control strategy during the PM reach when standing on a foam pad is

warranted. In this study we examined the change in COM position and ankle joint kinematics during the PM reach of the SEBT on a foam pad. We hypothesized that performing the PM reach on a foam pad would alter COM position and ankle joint kinematics compared to performing the task on a hard surface.

NUMBER OF SUBJECTS: Twenty healthy participants (10 male, 10 female; mean $\pm$ SD age, 23.9 ± 3.0 years; height, 174.2 ± 7.4 cm; weight, 71.2 ± 16.7 kg).

MATERIALS AND METHODS: Participants reached as far as possible in the PM direction of the SEBT while standing on a hard surface and on a foam surface. We measured the maximum reach distance (MRD), COM position (anterior-posterior/medial-lateral), and ankle joint angles on 3 planes via a Vicon 3-D motion analysis. We used a paired *t* test to compare MRD between the hard surface and foam conditions. We used a 2-way repeated-measures ANOVA (surface condition by reach distance) to test for changes in COM positions and ankle joint angles. Significance was set at $P < .05$.

RESULTS: When standing on the foam the MRD was shorter than when standing on the hard surface ($P < .001$). Compared to the hard surface condition, the COM was displaced more laterally when performing the PM on the foam surface ($P < .001$). There was also a condition by reach distance interaction for ankle dorsiflexion/external rotation ($P < .001$ and $P = .032$, respectively), and a main effect of condition for ankle inversion ($P = .001$) during performance of the PM reach.

CONCLUSIONS: By using a foam pad to disrupt somatosensory input, participants demonstrated a shorter reach distance in the PM direction of the SEBT and distinct COM positioning and ankle motion. Such changes could be compensatory strategies to maintain dynamic balance when somatosensory input is disrupted. The shorter PM reach distance may be considered as postural control deficit occurred with unstable ankles.

CLINICAL RELEVANCE: Individuals' control of the body, specifically the ankle joint, during the PM reach direction of the SEBT may be an indicator of their somatosensory function which may help inform the decision to return an athlete to sport after an ankle sprain.

SP075

RETURN TO RUN AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION WITH SYMMETRY-NORMALIZING BIOFEEDBACK AND AN IMPACT-REDUCTION TREADMILL: A CASE STUDY

James Zachary Odenthal, Robert Aaron Wagner

BACKGROUND AND PURPOSE: Isolated ACL injury has an annual incidence of 68.6 per 100000 person-years. A recent meta-analysis found that 83% of elite athletes returned to preinjury sport after anterior cruciate ligament reconstruction after 6 to 13 months. Despite returning to preinjury sport, gait asymmetries exist in peak knee flexion, peak knee extensor moment and rate of knee extensor moment in the ACLR limb when compared to preinjury testing. Peak knee flexion, peak knee extensor moment and rate of knee extensor moment asymmetries were present 12 months following ACLR. Decreased vertical ground reaction forces deficits have been found up to 24 months post ACLR. To reduce these biomechanical asymmetries augmented feedback has been found to be effective in healthy and injured runners. Inertial measurement units (IMU) can provide augmented feedback on variables such as ground contact time (loading of the knee) with excellent reliability. The purpose of this case study was to determine the efficacy of real-time augmented feedback via IMU during gravity altered treadmill training to improve contact time asymmetries in an athlete post ACLR.

CASE DESCRIPTION: A-21-year-old male collegiate football player underwent right ACLR with bone-patellar tendon-bone autograft. At approximately 3 months post ACL a 3-D data were collected using a 10-camera motion analysis system (Vicon, Oxford, UK). Force data were sampled at 1000 Hz via an instrumented treadmill (Bertec, Worthington, OH). Kinematic and kinetic running data collected during treadmill running. A RunScribe IMU 9-axis motion sensor with 500-Hz sampling rate, 16-MB onboard

flash memory was utilized to access Efficiency (Stride Rate, Contact Time, Flight Ratio), Motion (Footstrike Type, Pronation, Pronation Velocity), Shock (Impact Gs, Braking Gs), Symmetry, and Power. The athlete underwent traditional ACLR rehabilitation consisting of strengthening, balance/proprioceptive training, perturbation training and neuromuscular re-education. In addition, a BOOST (impact reducing treadmill) was utilized along with the RunScribe IMU to provide real-time feedback to normalize contact time during 5 PT sessions. Training was initiated at 60% body weight and progressed to 100%. A follow-up 3-D gait analysis was then performed 4 months after initial testing.

OUTCOMES: Initial 3-D motion analysis showed decreased contact time, decreased peak knee flexion angle and knee excursion. Posttreatment 3-D motion analysis showed symmetrical contact time (288 milliseconds). A 6° difference was found between pretesting and posttesting peak knee flexion angle, while a 7° difference was noted with knee excursion in the ACLR versus the nonoperative limb.

DISCUSSION: Based on the findings of the pre and post 3-D motion analysis, augmented feedback was beneficial in reducing contact time asymmetries, while loading was improved at the knee as well as peak knee extensor moment. Augmented feedback via RunScribe IMU can serve as a cost effective means of decreasing gait asymmetries post ACLR.

SP076

EFFECTIVENESS OF SINGLE- AND DOUBLE-LEG BLOOD FLOW RESTRICTION ON AEROBIC PERFORMANCE DURING CYCLING EXERCISE

Wesley Okeke, David Calderon, Gian Carlo Cruz, Jaime Gonzalez, Nicole Hoppe, Savannah Nickel, Jovannah Ortiz, Derek Wengert, Jason Winchester, Alexis Ortiz

PURPOSE/HYPOTHESIS: To compare changes in peak aerobic capacity (VO₂ peak) following a cycling exercise protocol with BFR occlusion in 1 leg versus 2 leg occlusion.

NUMBER OF SUBJECTS: Forty-three healthy subjects (mean age, 24.7 years; 20 male, 23 female) participated in this study.

MATERIALS AND METHODS: Subjects were randomly assigned to either: BFR-1 (single leg occlusion, n = 16), BFR-2 (double leg occlusion, n = 14), and control (n = 13). Aerobic capacity was measured at baseline, 3 weeks, and 6 weeks during a submaximal cycle ergometer protocol on a stationary ergometer connected to a metabolic analyzer for the assessment of peak oxygen consumption (VO₂ peak). Aerobic capacity was assessed during the YMCA protocol which consisted of pedaling at 70 rpm with a load of 25 W. Heart rate (HR) was monitored continuously at the end of the first 3 minutes and used to determine the load increase for the remaining 15 minutes. After the first 15 minutes a 25-W increase occurred every 3 minutes until the participant reached 1 or more of the following criteria: 80% of their predicted HR using the HR reserve formula, or an RER >1.0. The training program consisted of cycling at 70 rpm for 15 minutes 3 times a week. The BFR group performed the cycling with their respective occlusion in the dominant leg while the control group did not use any occlusion. The variable of interest was VO₂ peak (ml·kg⁻¹·min⁻¹). All 3 groups were homogenous at baseline for anthropometric characteristics, physical activity levels, and VO₂ peak values. VO₂ values were normally distributed, therefore a 3-by-3 (time by group) repeated measures ANOVA was used to perform between and within-group comparisons and appropriate post hoc follow-up tests. Statistical significance was established at an alpha of .05 for all analyses.

RESULTS: The time by group interaction ($P = .41$) and the group main effect ($P = .31$) were not statistically significant. Time main effect was statistically significant ($P = .01$). Post hoc analyses showed statistically significant changes between baseline and 3-week follow-up ($P < .001$).

CONCLUSIONS: The addition of BFR restriction during an aerobic cycling protocol does not improve aerobic capacity beyond a control condition not using BFR occlusion.

CLINICAL RELEVANCE: Low-intensity cycling can improve VO₂ peak in a 3-week period. The use of BFR occlusion simultaneously during low intensity cycling does not provide an additional stimulus to improve VO₂ peak in healthy adults.

SP077

THE EFFECTIVENESS OF SINGLE- AND DOUBLE-LEG BLOOD FLOW RESTRICTION TRAINING ON ISOKINETIC QUADRICEPS STRENGTH

Jovannah Ortiz, David Calderon, Gian Carlo Cruz, Blake Doughtie, Jaime Gonzalez, Nicole Hoppe, Savannah Nickel, Wesley Okeke, Derek Wengert, Jason Winchester, Alexis Ortiz

PURPOSE/HYPOTHESIS: To study the effects of single and double leg blood flow resistance training on isokinetic torque and work of the quadricep muscles.

NUMBER OF SUBJECTS: Forty-three healthy subjects (mean age, 24.7 years; 20 male, 23 female) participated in this study.

MATERIALS AND METHODS: Subjects were randomly assigned to 3 groups: single leg blood flow restriction (16 subjects), double-leg blood flow restriction (14 subjects), or the control group (no blood flow restriction; 13 subjects). Isokinetic quadricep torque and work was assessed at baseline, 3 weeks, and 6 weeks, using an isokinetic dynamometer at speeds of 60°/s, 180°/s, and 300°/s using a standardized knee extension protocol. The training program consisted of cycling 3 times a week on a cycle ergometer at 25 W and 70 rpm over the course of 6 weeks. Given all 3 groups were homogeneous for anthropometrics measures and isokinetic values at baseline, a 3-by-3 (time by group) repeated-measures ANOVA was used to compare within time and between groups effects and their interaction for both, torque, and work. Post hoc analyses were performed when appropriate. Statistical significance was set at alpha of .05 for all analyses.

RESULTS: For the measures of torque, the time-by-group interaction ($P = .5$) and the group main effect ($P = .3$) were not statistically significant while the time main effect was statistically significant ($P < .001$). Torque at 60°/s post hoc analyses showed that changes were statistically significant from 3-week to 6-week follow-up. Torque at 180°/s and 300°/s post hoc showed statistically significant changes from baseline to 3-week follow-up ($P < .001$) and baseline and 6-week follow-up ($P = .004$). For the measures of work, the time-by-group interaction was ($P = .5$) and group main effect ($P = .1$) were not statistically significant while the time main effect was statistically significant ($P = .006$). Work at 60°/s showed no statistically significant for any time interval. Work at 180°/s post hoc showed statistically significant changes between baseline and 3-week ($P = .003$) and 6-week follow-ups ($P = .02$). Work at 300°/s showed statistically significant changes from baseline to 6-week follow-up ($P = .004$).

CONCLUSIONS: Aerobic cycling while using BFR cuffs does not provide an additional benefit for quadriceps torque and work after 6 weeks than cycling without BFR cuffs. Aerobic cycling can increase quadriceps torque and work after 6 weeks of training.

CLINICAL RELEVANCE: Aerobic cycling at a low intensity appears to create transferable gains in quadriceps strength and endurance during a 6-week period regardless of using BFR cuffs or not.

SP078

COMPARISON OF DOMINANT AND NONDOMINANT KNEE KINETICS IN HEALTHY CONTROLS VERSUS ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Olivia Panchal, Shiho Goto, Steve B. Singleton, Lindsey Dietrich, Craig Craig Garrison, Joseph Patrick Hannon

PURPOSE/HYPOTHESIS: To examine the knee joint loading with anterior cruciate ligament reconstruction (ACL-R) of the dominant (ACL-D) or non-dominant (ACL-ND) limb at the time of return to sport (RTS) compared to matched healthy controls (CON).

NUMBER OF SUBJECTS: A total of 150 athletes volunteered. (ACL, $n = 75$; mean $\pm$ SD age, 15.56 ± 1.74 years; height, 167.93 ± 9.77 cm; mass, 67.22 ± 11.39 kg; CON, $n = 75$; mean $\pm$ SD age, 15.52 ± 1.91 years; height, 168.84 ± 8.33 cm; mass, 63.74 ± 11.61 kg). Participants in the ACL-R group underwent ACL-R with a patellar BTB or hamstring graft and were assessed at time of RTS. All subjects in the CON group were considered healthy with no history of lower extremity injury in 3 months prior to testing and IKDC ≥ 95 .

MATERIALS AND METHODS: Lower extremity 3-D joint angles and ground reaction force data were collected using an 8-camera 3-D Motion Capture System and force plates. Participants performed 5 double-leg squats (DLS) at a standardized speed (60 bpm). Peak knee extension moment (KEXT_{mm}) was calculated during the descent phase. Knee joint energy absorption (KnEA) and knee joint energy absorption contribution (KnEAC) were calculated during the same phase. These variables were normalized to the participant's height and weight and averaged across the middle 3 trials. Finally, peak quadriceps (QUADS) isokinetic strength at $60^\circ/\text{s}$ was assessed, normalized to body weight, and averaged across 3 trials. Separate ANOVAs were performed to examine difference between groups. Comparisons were made between those with ACL-D and the dominant limb of the CON-D and between those with an ACL-ND and the nondominant limb of CON-ND.

RESULTS: In both the ACL-D and ACL-ND groups, KnEA (ACL-D, -0.04 ± 0.02 ; CON-D, -0.05 ± 0.02 ; $P = .016$; ACL-ND, -0.04 ± 0.01 ; CON-ND, -0.05 ± 0.01 ; $P < .001$) and QUADS (ACL-D, 1.36 ± 0.51 ; CON-D, 1.79 ± 0.45 ; $P = .001$; ACL-ND, 1.40 ± 0.38 ; CON-ND, 1.69 ± 0.41 ; $P = .001$) were significantly decreased compared to controls. KnEAC (ACL-D and CON-D, $P > .05$; ACL-ND, 51.73 ± 12.54 ; CON-ND, 60.93 ± 9.83 ; $P < .001$) and KEXT_{mm} (ACL-D and CON-D, $P > .05$; ACL-ND, -0.04 ± 0.01 ; CON-ND, -0.05 ± 0.01 ; $P < .01$) were significantly decreased in the ACL-ND group compared to CON-ND. Significant differences were not observed for these variables between the ACL-D and CON-D groups ($P > .05$).

CONCLUSIONS: Nonsignificant difference in KnEAC and KEXT_{mm} in the ACL-D group indicates these subjects performed DLS task at the level observed in the healthy population. However, the significant difference in KnEA in the ACL-D group indicate an overall lower level of loading on the involved limb. All other variables, regardless of side of injury, the ACL-R groups exhibited significantly decreased kinetic and muscle performance relative to healthy controls indicating that side of dominance had little influence on knee biomechanics during DLS at RTS.

CLINICAL RELEVANCE: Clinicians should take into consideration which limb underwent ACL-R when designing rehabilitation programs and be aware of these kinetic deficits at the knee joint and attempt to address these differences prior to time of return to sport.

SP079

ROCK CLIMBING-SPECIFIC FINGER STRENGTH IN 2 TYPES OF HAND GRIPS AND SHOULDER POSITIONS

Lena Naomi Parker, Johnathon R. Crawley, Emily Jennifer Higgins, Stephanie Huang, Shawn Caitlin Wood, Claire Elizabeth Lorbiecki, Erika Jo Nelson-Wong, Kevin Michael Cowell

PURPOSE/HYPOTHESIS: The sport of rock climbing has seen growth in the past 2 decades. It is helpful to identify the factors that contribute to increased performance to guide clinicians in developing training and rehab strategies. Research suggests that shoulder position and grip type impact a climber's force development due to biomechanical demands of the positions. These relationships were found under a testing environment that does not replicate rock climbing activities. Our aim is to explore the interactions between 90° and 120° shoulder angles and half-crimp versus open grip positions on strength using methods specific to the demands of rock climbing. We hypothesize that there will be a difference in strength be-

tween shoulder positions and that the half-crimp will elicit greater force production than the open hand during the testing protocol.

NUMBER OF SUBJECTS: Forty-nine (23 female, 26 male).

MATERIALS AND METHODS: Participants between the ages of 19 and 48 years were tested in this study under informed consent. Test protocol was approved by Regis University IRB. Climbing skill and experience level were collected via questionnaire. After standardized warm up, participants completed max pull testing protocols using a 20-mm lip climbing hold attached to a load cell sampled at 250 Hz. Max isometric pulls were performed with the dominant hand in 2 grip types: open grip, second-fourth digits of the DIP and PIP joints greater than 90° , and half-crimp, second-fifth digits of the PIP at 90° . Both grip types were tested in 90° and 120° of shoulder flexion. Two trials were tested in each position and were randomized with 2-minute rest intervals after each trial for a total of 8 trials. Force values were normalized and expressed as a percent of body weight (percent BW). Paired t tests were conducted to determine repeatability between trials. Based on lack of significance, the 2 trials for each position were averaged as a data reduction measure. Force values for the 4 shoulder-grip combinations were entered into 2-way repeated-measures ANOVAs (2 shoulder positions, 2 grip types). SPSS software was used with significance set at $P < .05$.

RESULTS: There was a main effect of grip type ($F_{1,48} = 52.654$, $P < .05$), with half-crimp force being higher than open grip in both 90° and 120° ($65.38\% \pm 19.23\%$ and $66.36\% \pm 19.73\%$ BW versus $55.71\% \pm 15.88\%$ and $55.84\% \pm 15.88\%$ BW, respectively). There were no main effects of shoulder position and no interactions between shoulder and grip positions.

CONCLUSIONS: Our hypotheses are partially supported as climbers were stronger in half-crimp than open grip positions. Shoulder position did not impact climbing specific grip strength. Climbers exhibit greater strength in a half-crimp position versus an open hand for many reasons, such as functionality of half-crimp grip in activities outside of a rock climbing setting. One limitation to this study involves the climbing hold being suspended and therefore allowing for movement, compared to standard climbing holds that are fixed to the wall.

CLINICAL RELEVANCE: Clinicians can focus more on grip type rather than shoulder position when measuring climbing specific grip strength for collecting baseline measures in rehabilitation or for tracking the progress of a training program.

SP080

REHABILITATION OF A TRIATHLETE FOLLOWING DISTAL BICEPS FEMORIS REPAIR: A CASE REPORT

Corey Pasquarelli

BACKGROUND AND PURPOSE: Hamstring injuries are among the most frequently reported sports injuries and responsible for significant time out of competition. Proximal hamstring strains are prevalent in running and kicking sports. Distal hamstring injuries are rare and reported across a large variety of sports. Much research has been done on flexibility and eccentric strength, however, reinjury rates remain high. The author found limited research on return to triathlon following distal hamstring repair. This case report highlights the successful accelerated return to triathlon following a distal hamstring repair.

CASE DESCRIPTION: A 31-year-old triathlete sustained a traumatic biceps femoris tear, lateral collateral ligament (LCL) laceration and peroneal neuropathy while snowboarding. Following closure of the wound, the patient was unable to return to run due to consistent knee buckling. He followed up with an orthopaedic surgeon for magnetic resonance imaging to diagnose the injury and elected to undergo surgical intervention. At the initial physical therapy evaluation, the patient met phase 1 post operative protocol goals (active range of motion [AROM] 0° - 90° , no evidence of swelling or quadriceps lag) with a score of 27/80 on the Lower Extremity Functional Scale (LEFS). By 8 weeks post operative, he progressed to full AROM with full quadriceps control. Based on a high prior level of func-

tion and meeting all post operative goals, the patient progressed on an accelerated return-to-sport program while in communication with the surgeon. The program initiated cycling at 8 weeks and returning to run at 10 weeks. At 12 weeks postoperative, hamstring index was 86.2% at 60°/s via isokinetic testing. Due to the patient's competitive status and his accelerated progression postoperatively, return-to-sport training was initiated early to allow for return to competition for half-ironman distance racing at 5 months post operative.

OUTCOMES: After 18 weeks the patient was discharged scoring LEFS 80/80, AROM was symmetrical with unaffected limb, hamstring index was >90% and patient was performing triathlon training 10 to 15 hours per week.

DISCUSSION: Proximal hamstring strains are one of the most common sports injuries, though little research is published on distal hamstring injury. This case report describes the rehabilitation of a high level triathlete after distal hamstring repair and suggests the implementation of isokinetic testing for specific return to sport criteria. This patient's rehabilitation process included concentric and eccentric hamstring strengthening specific to the swim, cycle, and run stages of competition. This case study notes an accelerated program and use of Biodex testing of a high level athlete for return to report after a distal biceps tendon and LCL repair. This unique case sheds light on the lack of data regarding distal biceps repair and multisport athletes, return to sport testing for a triathlete, and use of the Biodex for distal biceps repairs. Further research and testing is required to develop more data in this athletic population.

SP081

THE EFFECT OF SHOE COLLAR HEIGHT ON SINGLE-LEG BALANCE IN INDIVIDUALS WITH FUNCTIONAL ANKLE INSTABILITY

Sneha Paswan, Daniel Hernandez, You-Jou Hung

PURPOSE/HYPOTHESIS: An estimated 628 000 ankle sprains are seen in the emergency rooms every year in the United States. Considering footwear can provide mechanical constraints and proprioceptive feedback about the ankle joint, shoe collar height can have an impact on ankle stability and balance control. The purpose of this study was to investigate the impact of shoe collar height on single-leg balance control in individuals with and without functional ankle instability.

NUMBER OF SUBJECTS: Thirty-one subjects (16 male, 15 female; age, 18-31 years) participated in the study. Inclusion criteria included being able to stand on the dominant leg without pain or discomfort for 1 minute, and having the experience of wearing both high-collared and low-collared shoes.

MATERIALS AND METHODS: Participants were asked to fill out the Cumberland Ankle Instability Tool (CAIT) to determine their functional ankle stability status. Subjects were classified as having functional ankle instability if their CAIT scores were 25 or less, according to the new clinical practice guidelines from 2021. The Athletic Single-leg Stability Test (ASLST) of the Biodex Balance System (BBS) was used to examine single-leg balance. Subjects performed the balance test with either high-collared or low-collared shoes in random order over 2 testing sessions. The test sessions were 1 week apart to washout the motor learning effect prevent fatigue. The official testing included three 20-second trials, with a ten-second rest period between trials. Subjects were also asked to perform a 5-minute general warm-up and 3 practice trials before each official data collections.

RESULTS: The height of shoe collar had no significant impact on single-leg balance (overall, $P = .838$; anterior/posterior, $P = .556$; medial/lateral, $P = .454$). In addition, subjects with functional ankle instability exhibited significantly worse single-leg balance than those without functional ankle instability in the overall ($P = .031$) and medial-lateral ($P = .020$) directions, but not in the anterior-posterior ($P = .139$) direction. No significant interaction was found between shoe collar height and ankle stability status (overall, $P = .796$; anterior/posterior, $P = .638$; medial/lateral, $P = .907$).

CONCLUSIONS: Results show wearing high-collared shoes did not enhance single-leg balance control in comparison to wearing low-collared shoes. Moreover, subjects with functional ankle instability were not selectively benefited from wearing high-collared shoes that provided more mechanical support and proprioceptive feedback. One possible explanation for the results is that the BBS only allows 20° of platform tilting and the perturbation speed is likely slower than real-life scenarios that cause ankle sprains.

CLINICAL RELEVANCE: Clinicians should consider implementing single-leg balance training for those who are identified as having functional ankle instability. In addition, wearing high-collared shoes may not enhance single-leg balance control. Studies with a more functional setting to simulate real-life injury mechanisms will be beneficial to further examine the impact of shoe collar height on single-leg balance and ankle injuries.

SP082

SYSTEMATIC REVIEW OF CENTER OF MASS AS A MEASURE OF DYNAMIC POSTURAL CONTROL FOLLOWING CONCUSSION

Sarah Patejak, Joshua Kyle Forrest, Emily Harting, Mabel Gee Sisk, Eric Jon Schussler

PURPOSE/HYPOTHESIS: The incidence of sports-related concussion in the US is between 1.6 and 3.8 million annually. Identification of ongoing impairment post concussion continues to be challenging, as research indicates many patients are cleared for return to activity while still suffering subclinical impairment of function. The purpose of this systematic review is to identify and review the current literature on the use of center of mass (COM) during gait as a potential indicator variable after concussive injury.

NUMBER OF SUBJECTS: After searching the PubMed database and screening articles, results yielded 22 articles for full-text review. Author agreement for inclusion/exclusion prior to full-text review and after full-text review was satisfactory. Ultimately, 6 articles met the inclusion criteria, and quality and bias standard and were accepted for inclusion into this systematic review. Analysis was completed on the final 6 articles.

MATERIALS AND METHODS: Search of the PubMed database identified 6 articles which matched the determined criteria. The average STROBE score was 26.5/34 (range, 23-30). The areas that had the poorest scoring were bias, study size, statistical methods, participants, descriptive data, and main results.

RESULTS: Results of the review indicate that COM displacement was higher in concussion groups with a sufficiently taxing task, such as a dual task paradigm.

CONCLUSIONS: Center of mass may be an indicator of ongoing injury involvement after clinical indications have subsided.

CLINICAL RELEVANCE: People who have suffered a concussion often have balance problems immediately after the injury. Gross measures of balance are used to determine when the patient is ready to return to activity, but recent research indicates that alterations in stability during gait exist well beyond typical clearance.

SP083

OVERGROUND RUNNING KINEMATIC AND KINETIC PATTERNS IN A HEALTHY ADOLESCENT POPULATION

Kelly Pogemiller, Dawn W. Roller, Arthur Fredericks

PURPOSE/HYPOTHESIS: Running kinetics and kinematics have been extensively studied in the literature. Prior studies focused on factors of running related injuries, reduction of injury rates, and performance improvement. Limited research exists examining adolescent running kinematic and kinetic patterns. A study comparing young adult and adolescents in treadmill running found differences in center of mass excursion. Another study found kinetic data differed significantly with a change in running surface, concluding that overground running assessment is more accurate in the adolescent population. Also, late stance kinematic changes and a higher

vertical ground reaction force (GRF) loading rate were noted with children wearing aging shoes. The purpose of this study is to contribute to defining running kinetics and kinematics of the healthy adolescent population. Additionally, we sought to evaluate the relationship between kinematic and kinetic variables in this population.

NUMBER OF SUBJECTS: Forty-six control subjects were extracted from an existing IRB study who underwent 3-D gait analysis of overground shod running.

MATERIALS AND METHODS: Variables analyzed included lower extremity kinematics and kinetics, temporal stride parameters, and center of mass height. Descriptive statistics were calculated for subject, kinematic, and kinetic data. A Spearman correlation was used to measure association between vertical GRF loading rate at initial contact (IC) with select variables.

RESULTS: Subjects were 15.3 ± 2.0 years with 26 males; 19 females. Self-selected speed was 4.1 ± 0.4 m/s and cadence was 169.5 ± 12.9 steps per minute. At IC, mean lower extremity angles were $6.4^\circ \pm 10.3^\circ$ dorsiflexion, $12.0^\circ \pm 4.2^\circ$ knee flexion, and $44.5^\circ \pm 6.6^\circ$ hip flexion. Peak angles in stance were $21.0^\circ \pm 4.4^\circ$ ankle dorsiflexion, $44.3^\circ \pm 4.5^\circ$ knee flexion, and $46.9^\circ \pm 6.6^\circ$ hip flexion. Peak vertical GRF was 268.5 N. Front stride length was 0.21 ± 0.04 m. A statistically significant moderate correlation was found between GRF loading rate and ankle angle at IC ($r_s = -0.44$, $P = .002$) and between GRF loading rate and front stride length ($r_s = -0.40$, $P = .005$).

CONCLUSIONS: Our study contributes to the knowledge of adolescent running patterns. Compared to overground running research with a younger mean age, knee and ankle peak angles in stance were similar in 1 study, though decreased in another where both speed and cadence were decreased compared to our group. During IC, our study found slightly less ankle and knee angles during overground running compared to literature. Our findings coincide with the knee flexion and ankle dorsiflexion angles at IC and in stance with a matched aged group that was collected using a treadmill. Further, our results show that GRF loading rate decreased with less ankle plantar flexion at IC with a wide range of ankle angles present in our group.

CLINICAL RELEVANCE: Defining typical biomechanical running patterns in the healthy adolescent population is vital in optimizing training and injury prevention in this population.

SP084

EFFECT OF CHRONIC EXERCISE IN FEMALE ATHLETES ON THE PELVIC FLOOR AND RELATED CONDITIONS: A SYSTEMATIC REVIEW

Mahin Rahman

PURPOSE/HYPOTHESIS: Due to the unique demands of sport participation, female athletes may be at a higher risk for pelvic floor disorders (PFD). The most common PFD identified in female athletes is stress urinary incontinence; however, there is insufficient data regarding other PFDs. The primary purpose of this study is to investigate the effect of recreational and competitive sport participation on pelvic floor health in female athletes. A comprehensive discussion regarding the best methods of prevention and management of pelvic floor disorders (PFD) in this population is also included.

NUMBER OF SUBJECTS: Adolescent to skeletally mature adults, nulliparous competitive and recreational female athletes (mean $\pm$ SD age, 22.6 ± 7.60 years; mean BMI, 23.1 ± 10.29 kg/m²; total subjects resulted, $n = 5042$).

MATERIALS AND METHODS: A systematic search of PubMed, Embase, Google Scholar, and Cochrane Databases was conducted to determine the effect of sport and exercise participation on pelvic floor health. Key words and phrases used in the search were "female athlete," "pelvic floor disorders," "sports," "pelvic floor dysfunction," and "physical activity." Studies investigating female athletes with the following pelvic floor conditions were included: urinary incontinence, pelvic floor dysfunction, pelvic girdle pain, pelvic organ prolapse, and anal incontinence. Citations including subjects

with a history of pelvic floor—related surgeries, neurological compromise, and/or trauma were excluded.

RESULTS: Of the 398 studies identified, 22 articles (14 cross-sectional cohort studies, 3 cross-sectional exploratory studies, 1 cross-sectional observational study, 2 prospective comparative cohort studies, 1 retrospective cohort study, 1 case study) were included for the final analysis. According to Joanna Briggs Institute (JBI) Levels of Evidence, majority of the studies ($n = 18$) were determined to be of Level 4b quality. The top 3 sports with the highest prevalence of PFD were gymnastics, volleyball, and trampolining. The top PFD conditions identified were stress urinary incontinence, anal incontinence, and pelvic pain.

CONCLUSIONS: Higher-impact athletic activities were the greatest predictor of PFD for female athletes. It is suspected that decreased pelvic floor muscle endurance and/or pelvic floor muscle weakness is a strong contributing factor in this patient population. There is a need for higher quality studies such as randomized control trials using pelvic floor muscle training (PFMT) to determine the best management and prevention strategies for PFDs in female athletes.

CLINICAL RELEVANCE: High-impact athletic activities and sport participation are a predictable risk factors of PFD in the recreational and competitive female athlete. PFMT for strength and endurance may be beneficial in this patient population to prevent and manage PFDs. Future research will seek to identify optimal management and prevention strategies.

SP085

TOTAL AND PERCENTAGE BODY FAT MASS ASSESSED WITH SKINFOLD CALIPERS HIGHLY CORRELATES WITH ULTRASOUND IMAGING

Angel Rene Rodriguez, Sebastian Lopez, Alvaro N. Gurovich

PURPOSE/HYPOTHESIS: Fat mass is of great concern because excess fat mass can have serious health consequences. When it is in an optimal range, it can have positive effects on sports performance and improve the overall health of an individual. Elite athletes are always trying to find ways to give themselves an edge against their opponents; 1 major factor contributing to performance is fat mass. Total body fat mass and percent body fat mass can be estimated by performing a full body anthropometric composition profile. Skinfold calipers is the tool that is used to estimate fat mass. We have previously studied the correlation between skinfold calipers and ultrasound (US) imaging to estimate subcutaneous adipose tissue and have found a high to very high correlation. The purpose of this study is to determine if there is a correlation between skinfold calipers and US imaging in estimating total body fat mass and percent body fat mass. Our hypothesis is that US imaging will be very highly correlated with skinfold calipers in estimating total body fat mass and percentage body fat mass.

NUMBER OF SUBJECTS: Twenty-five male and 24 female subjects participated in this study.

MATERIALS AND METHODS: This a cross-sectional, nonexperimental study, consisting of 1-visit in which 2 independent measurements were taken for each subject. Following the International Society for the Advancement in Kinanthropometry (ISAK) protocol and standards, full body profiles were taken to gather skin mass, adipose mass, muscle mass, bone mass, and residual mass using Deborah Kerr's method. All sites were marked and measured by an ISAK-certified Level 2 technician. US imaging was performed to assess fat mass, using a 12-MHz probe (Esaote, Italy) and by another ISAK-certified Level 2 technician, trained in US imaging measurements. Each technician was in a separate room to be blinded to each other's data collection to minimize an interrater reliability bias. The correlation between skinfold calipers and ultrasound image of subcutaneous tissue and skin was used to derive its own estimate of subcutaneous tissue. This data were then plugged into the Deborah Kerr Body composition formula to get an estimated fat mass and fat mass percentage.

RESULTS: Results showed a very high correlation of estimated percent fat mass and total fat mass when using ultrasound imaging as a tool to measure subcutaneous fat mass. Estimated total fat mass ($r = 0.932$, $P < .05$)

and estimated fat mass percentage ($r = 0.936$, $P < .05$) were highly correlated when compared to using measurements from skinfold calipers and plugging data into formulas from graphs.

CONCLUSIONS: Ultrasound imaging can be used as a reliable tool to estimate total and percentage fat mass using Deborah Kerr's body composition formula.

CLINICAL RELEVANCE: These findings suggest that ultrasound imaging is a reliable tool to measure fat mass and reliably estimate total fat mass and fat mass percentage. This has future implications in tracking progress of fat loss goals to improve athletic performance or overall health.

SP086

POSTURAL STABILITY FOLLOWING BLOOD FLOW RESTRICTION TRAINING IN HEALTHY INDIVIDUALS

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PURPOSE/HYPOTHESIS: The purpose of this study was to evaluate the impact of blood flow restriction training (BFRT) on dynamic balance in healthy individuals. We hypothesized that (1) lower extremity Y Balance Test (LE-YBT) reach distances would decline immediately following BFRT in the dominant LE (DLE), (2) LE-YBT reach distances would return to pre-BFRT levels by 15 minutes following BFRT, and (3) immediate post BFRT impact on LE-YBT would lessen with successive BFRT sessions.

NUMBER OF SUBJECTS: Twenty-five participants (15 male, 10 female), aged 18 to 35 years, completed 4 training sessions.

MATERIALS AND METHODS: The LE-YBT was completed prior to BFRT, immediately after BFRT, and 15 minutes following BFRT on the DLE followed by the nondominant LE (NDLE), during each training session. The Delfi Personalized Tourniquet System was applied to the DLE using 80% of arterial occlusion pressure. Single-leg heel raises were performed, using the DLE, followed by a 1-minute rest and then split squats at each training session. A set and repetition scheme of 30-15-15-15 was utilized for each exercise. Repeated-measures analysis of variance using 3 within-subjects factors (extremity, time, and session), and gender as a between subjects factor, was utilized to evaluate the LE-YBT performance. These factors were evaluated as fixed effects in the repeated-measures ANOVA, and P values for the main effects and interactions were evaluated. P values for differences in pairwise combination of means were adjusted due to multiple comparisons.

RESULTS: For the anterior (ANT) reach there was a main effect for session with reach distance ($F_{3,249} = 4.93$, $P < .003$) in session 2 (mean, 59.4) greater than session 4 (mean, 58.4). Posteromedial (PM) reach ($F_{3,253} = 8.96$, $P < .0001$) was greater during sessions 3 (mean, 96.5) and 4 (mean, 97.2) versus session 1 (mean, 95.2). There were no other main effects (extremity or time) or interactions for the ANT or PM reach. For the posterolateral (PL) reach there were main effects for session ($F_{3,250} = 27.61$, $P < .0001$) with session 2 (mean, 91.0) greater than 1 (mean, 89.2), 3 (mean, 92.5) greater than 2 ($P = .01$), and time ($F_{2,250} = 7.41$, $P < .001$) with reach distance at 15 minutes post BFRT (mean, 92.4) greater than prior to BFRT (mean, 90.7). There were no main effects for extremity or interactions for the PL reach.

CONCLUSIONS: Dynamic postural stability, as assessed by the LE-YBT, was not diminished in any reach direction immediately following BFRT. Change in LE-YBT performance in the DLE following BFRT was also not different from LE-YBT performance in the nonexercised NDLE. LE-YBT performance 15 minutes after BFRT was similar to prior to BFRT for ANT and PM reach and greater with PL reach. Between session improvements in PM and PL reach, and increased PL reach at 15 minutes post BFRT versus prior to BFRT are likely the result of learning effects with the magnitude of change being small.

CLINICAL RELEVANCE: BFRT did not elicit short term balance deficits in healthy adults and may thus be incorporated early in training sessions

with low risk of inducing balance deficit-related injury. Further research should examine the effects of BFRT on balance in individuals with LE injury to optimize exercise prescription.

SP087

TRADITIONAL VERSUS ACTUAL PITCH COUNTS IN YOUTH BASEBALL PLAYERS: NOT EVEN IN THE SAME BALLPARK

Paul Anthony Salanh, Cassandra Vrbancic, Kalie Entler, Meredith Parks, Takumi Usui, Garrett Scott Bullock, Eric J. Hegedus, Chad Edward Cook

PURPOSE/HYPOTHESIS: Participation in youth athletics, including baseball, continues to grow with over 4 million youth playing baseball in the United States in 2019. As the number of youth participating in baseball grows so does the incidence of injury with rates ranging from 0.8 to 4.0 per 1000 athlete exposures. This high injury incidence is alarming, especially in light of the evidence that exists to both identify and mitigate overuse arm injuries. One method designed to help prevent injuries among youth baseball pitchers is the Pitch Smart Guidelines (PSGs) put forth by Major League Baseball (MLB), which outline best practices as well as recommended rest for pitch count ranges based on age. Despite efforts to educate the baseball community about these guidelines, a high percentage of coaches and leagues are either not aware of or do not adhere to them. Furthermore, those that do track pitch counts using traditional methods may be underestimating overall pitch load by not accounting for bullpen and warm-up pitches during a game and therefore not allowing for appropriate recovery. The purpose of this study was to investigate the difference between traditional and actual pitch counts among youth baseball players.

NUMBER OF SUBJECTS: Nine youth baseball players.

MATERIALS AND METHODS: The principal investigator (PI) collected live pitch count data for practices and games. For the purpose of this study, only game data were utilized. Traditional pitch counts (TPC) were defined as live pitches during the course of a game. Actual pitch counts (APC) were defined as live pitches during a game in addition to bullpen and in-game warm up pitches during the game. Total APC and TPC were tracked each game over the course of the season for each player. Additionally, TPC and APC were compared against MLB PSGs to determine any difference in recommended rest days for pitchers.

RESULTS: Nine male athletes, mean age 11, playing on an 11-and-under travel baseball team in the Midwest region participated in this study. Among the 9 athletes enrolled, the total TPC during the entire season was 3043 (per player average, 338.1; per player range, 77-720). The total APC throughout the entire season was 5287 (per player average, 587.4; per player range, 148-1288). Bullpen and warm-up pitches accounted for 42.4% (range, 37.2%-48.0%) of the APC. Additionally, when considering MLB PSGs, tracking bullpen and warm-up pitches would have added a total of 108 additional rest days for the pitching staff (per player average, 12; per player range, 4-25) across the season.

CONCLUSIONS: There are a large number of pitches not accounted for when considering TPC versus APC which could influence recommended rest days among youth baseball pitchers.

CLINICAL RELEVANCE: Given the rise in youth participation in baseball and the alarming rise in the rate of upper extremity injuries among this population it is critical to accurately account for overall pitch load. Taking into consideration APC may help to provide additional rest for players and ultimately prevent injury.

SP088

ILIAC CREST APOPHYSITIS IN A MIDDLE SCHOOL TRACK ATHLETE WITH HEMOGLOBIN C DISEASE

Adam Douglas Saloom, Danielle Farzanegan, Nicholas Keith Purcell

BACKGROUND AND PURPOSE: Apophyseal injuries account for nearly 25% of adolescent athletic injuries. These injuries continue to rise in prevalence

due to the increased physical demand of training and competition among youth athletes. As physical therapists, it is within our scope to screen for nonmusculoskeletal pathologies that may delay healing and ultimately return to sport. This case study presents an unusual delay in healing of iliac crest apophysitis in a youth athlete with Hemoglobin C disease.

CASE DESCRIPTION: A 12-year-old male experienced bilateral hip pain after sprinting at track practice. His pain improved temporarily with stretching provided by an athletic trainer and he continued to participate in track and football for 2 months after onset. His symptoms persisted and he was then referred to a sports medicine doctor for evaluation. He presented with 8/10 pain with walking, jogging, and sprinting that improved with rest. Past medical history included Hemoglobin C disease with his last hematology visit being 3 years prior. Excess fatigue, fevers, night sweats or weight loss/gain were not present at the time of evaluation by sports medicine.

OUTCOMES: Evaluation revealed tenderness to palpation at right ischial tuberosity, and bilateral iliac crest and ASIS. Hip range of motion was painful and limited for hip flexion and external rotation bilaterally. Piriformis test was positive at iliac crest bilaterally and Modified Thomas test was positive for quadriceps bilaterally. Pelvis radiographs showed cortical irregularity consistent with bilateral ischial and iliac crest apophysitis. He was referred to physical therapy (PT) and restricted from sport participation. Following 6 weeks of outpatient sports PT, he scored >90% LSI for the Lower Quarter Y Balance and began a gradual return to running program without pain. After 2 weeks of running, he reported reproduction of symptoms with marked increase in tenderness to palpation of left iliac crest. He was referred back to the sports medicine doctor and received an MRI showing bilateral iliac crest edema and bone marrow changes consistent with anemia or leukemia. Complete blood count testing was then performed showing an elevated reticulocyte count, and hematology began monitoring for end organ damage. He was referred back to PT for strength and functional movement training with relative rest, and will perform return to sport testing after 8 weeks if medically appropriate.

DISCUSSION: Hemoglobin C is a serious condition that may prolong the healing of common musculoskeletal injuries such as apophysitis and delay return sport. Physical therapists will continue to serve in a primary care role for youth athletes as the physical demand of training and competition continues to rise. Screening for nonmusculoskeletal pathologies and referring to appropriate providers outside the scope of physical therapy is imperative. This case demonstrates the delay in healing of apophysitis in an adolescent athlete with Hemoglobin C disease and will help physical therapists to better understand the symptoms, management, and timeline of return to sport for this serious pathology.

SP089

PATELLOFEMORAL JOINT LOADS DURING HIGH-INTENSITY INTERVAL TRAINING AND PROLONGED RUNNING

Dylan Sampson, Stacey A. Meardon, John David Willson

PURPOSE/HYPOTHESIS: Patellofemoral joint (PFJ) symptoms are a common musculoskeletal complaint in active populations with a high rate of chronicity and recurrence. Prolonged running involves repetitive exposure of the PFJ to forces with high magnitude and frequency. Load management strategies that promote physical activity yet shield the PFJ from the detrimental effects of repetitive loading may support successful PFJ rehabilitation strategies. This study aimed to compare PFJ contact forces during a HIT session to both caloric expenditure and time-matched prolonged running.

NUMBER OF SUBJECTS: Twenty recreational athletes (10 male, 10 female; mean $\pm$ SD age, 25.3 ± 2.6 years).

MATERIALS AND METHODS: Participants completed a 25-minute HIT session comprised of 5 bouts of running at 95% estimated VO_2 max speed (3.9 ± 0.3 m/s) for 2 min and walking at preferred speed (1.3 ± 0.1 m/s) for 3 min. At least 48 hours later, participants completed a 25-minute prolonged run at their 5 km training pace (2.8 ± 0.3 m/s). Lower extremity 3-D kinemat-

ics and ground reaction forces from 5 strides were recorded during each HIT run and walk interval and every 3 minutes during the prolonged run. Energy expenditure was monitored using the SenseWear Pro Armband. Lower extremity sagittal plane angles and joint moments were input to a musculoskeletal model to estimate PFJ force. Stride frequency and average peak PFJ contact force and force impulse for each interval were input to cumulative load equations to develop both calorie- and time-matched comparisons of HIT to prolonged running. PFJ contact force peak, impulse, and loading rate were compared across activities and cumulative peak PFJ contact force and force impulse were compared between sessions using repeated measures ANOVA ($\alpha = .05$) and partial eta square effect sizes.

RESULTS: Peak PFJ contact force and loading rate were greatest at the HIT run speed (4.7 ± 1.5 BW, 135.2 ± 40.1 BW/s) compared to preferred run (4.0 ± 1.3 BW, $P < .01$; 99.6 ± 26.1 BW/s, $P < .01$) and walk speeds (0.5 ± 0.2 BW, $P < .01$; 11.6 ± 4.4 BW/s, $P < .01$). Additionally, PFJ contact force impulse during the HIT run (0.44 ± 0.16 BW·s) and preferred run (0.44 ± 0.15 BW·s) were greater than walking (0.16 ± 0.03 BW·s, $P < .01$). Cumulative peak PFJ force was 28% and 44% lower in the HIT session than calorie- and time-matched running, respectively ($P < .01$, $\eta^2 = 0.67$; $P < .01$, $\eta^2 = 0.89$). The calorie matched run time was 19.1 ± 1.7 minutes. Like peak PFJ force, cumulative PFJ impulse during the HIT session was 25% and 42% lower than calorie and time-matched running ($P < .01$, $\eta^2 = 0.58$; $P < .01$, $\eta^2 = 0.84$). Fewer running load cycles were observed during the HIT session (874 ± 60) relative to both calorie and time-matched running (1100 ± 93 , 1397 ± 92).

CONCLUSIONS: Despite having the highest peak loads, a HIT session comprised of 2:3 minute bouts of high-intensity running and walking exposed participants to significantly less cumulative PFJ load than both calorie- and time-matched running. Results are most likely explained by fewer high-magnitude load cycles in HIT relative to prolonged running.

CLINICAL RELEVANCE: HIT may be a viable alternative exercise modality for people with PFJ symptoms exacerbated by the high cumulative loads of prolonged running.

SP090

CUING OF UPPER EXTREMITY KINEMATICS IMPACTS STEP RATE IN THE RECREATIONAL RUNNER

Joel Sattgast, John Fox

PURPOSE/HYPOTHESIS: Recreational runners experience a rate of injury from 56% to 90% each year. Influencing step rate may improve efficiency and economy by reducing load and impact forces.

NUMBER OF SUBJECTS: Fourteen healthy adult volunteers (5 male, 9 female) were recruited, averaging ≥ 15 mi/wk over the previous 6 months without a running related injury.

MATERIALS AND METHODS: Following screening examination, participants completed a warmup on a motor-driven treadmill, followed by 2 sets of 5 minutes running at self-selected pace with a 10-minute rest between to establish baseline values. Educational instruction was provided to the experimental group on self-verbal cueing ("pump arms"). Following 4 weeks of continued training both groups were reassessed, with the experimental group utilizing self-verbal cueing. Kinematics were collected with a 14 camera Vicon Bonita system. Statistical analysis via 2-way ANOVA was performed utilizing R for Statistical Computing (Version 3.6.1).

RESULTS: Two-way mixed effects ANOVA demonstrated a significant main effect for time ($F_{1,11268} = 45.9863$, $P < .0001$) and group by time interaction ($F_{1,11268} = 8.1023$, $P = .0044$) for frequency. Control mean cadence improved by 5.4 ± 4.2 steps/min while experimental mean cadence improved by 6.0 ± 2.52 steps/min. Two-way mixed-effects ANOVA of elbow range of motion over time demonstrated a significant effect for time ($F_{1,11268} = 28.98503$, $P < .0001$) and group by time interaction ($F_{1,11268} = 80.86089$, $P < .0001$) while shoulder range over time demonstrated a significant effect for time ($F_{1,11268} = 391.7752$, $P < .0001$) and group-by-time interaction ($F_{1,11268} = 5.7365$, $P = .016$) as well. Control mean elbow range of

motion reduced by $5.2^\circ \pm 2.9^\circ$ and experimental reduced by $0.3^\circ \pm 9.4^\circ$. Control mean shoulder range of motion reduced by $3.3^\circ \pm 2.06^\circ$ and experimental reduced by $5.6^\circ \pm 0.7^\circ$.

CONCLUSIONS: Cueing targeted toward upper extremity running mechanics impacts step rate and results in a reduction in elbow and shoulder range of motion during arm swing. It is possible this reduction in total range of motion contributes to a higher frequency in both step rate and arm swing. Secondary to upper versus lower extremity reciprocity during running gait, these findings support the use of self-verbal cueing for the upper extremity to improve step rate and minimize impact forces.

CLINICAL RELEVANCE: Intrinsic feedback from self-verbal cueing targeted towards arm swing is an easy, cost-effective strategy to increase running performance and mitigate the risk of running related injuries.

SP091

NO SEX DIFFERENCES IN PATELLOFEMORAL JOINT CONTACT FORCE WHEN RUNNING WITH LOAD CARRIAGE

Kaile Sauro, Brent Ruby, Kelly Christensen, Levi Jade Klawitter, Brittany Hanser, Richard W. Willy

PURPOSE/HYPOTHESIS: Running with load carriage is common in ultra-running and in the military, likely contributing to high patellofemoral pain rates in these populations. Since females in these populations are 2.5 times at risk versus males for patellofemoral pain, we sought to determine sex-related differences in patellofemoral joint (PFJ) kinetics and knee stiffness while running with load carriage. We hypothesized: (a) compared with males, females would exhibit greater peak PFJ contact force running with 15 lb and 25 lb of load carriage; (b) PFJ impulse/km of running would significantly increase at both 15 lb and 25 lb increments, but would be even greater in females due to an assumed shorter step length requiring a greater number of steps per km; and, (c) knee stiffness will increase with greater load carriage.

NUMBER OF SUBJECTS: Thirty-six well-trained individuals with load carriage experience (18 male: mean $\pm$ SD age, 26.8 ± 4.3 years; weight, 76.8 ± 8.2 kg; 18 female: mean $\pm$ SD age, 23.8 ± 4.6 years; weight, 64.7 ± 8.1 kg).

MATERIALS AND METHODS: In a counterbalanced order, participants ran on an instrumented treadmill (2.7 m/s) with 0 lb, 15 lb, and 25 lb in a weight vest while 3-D running mechanics were sampled. Peak PFJ contact force (BW), PFJ impulse/km (BW-s/km), and knee stiffness (Nm/kg-m/deg) were estimated via a musculoskeletal model and analyzed via separate ANOVAs (Sex by Load; $\alpha = .05$).

RESULTS: No significant interactions ($P = .38-.84$) and no main effects of sex ($P = .31-.66$) were found. However, significant main effects of load were found for peak PFJ contact force ($P = .027$), PFJ impulse/km ($P < .001$), and knee stiffness ($P = .004$). Pairwise comparisons revealed no differences in peak PFJ contact force ($P = .33$) or PFJ impulse/km ($P = .88$) between 0 lb and 15 lb; however, significant increases in peak PFJ contact force between 0 lbs and 25 lb load carriage ($P = .012$; 0 lb, 3.75 ± 1.0 BW; 25 lb, 4.0 ± 1.0 BW) and between 15 lb (3.8 ± 1.0 BW) and 25 lb load carriage ($P = .019$) were found. Greater PFJ impulse/km was found between 0lbs and 25lbs load carriage ($P = .006$; 0 lb, 230.1 ± 66.5 BW-s/km; 25 lb, 248.0 ± 68.2 BW-s/km) and between 15 lb (231.1 ± 67.3 BW-s/km) and 25 lb load carriage ($P < .001$). Regardless of sex, knee stiffness increased between 0lbs and 15 lb load carriage ($P = .014$; 0 lb, 0.045 ± 0.009 Nm/kg-m/deg; 15 lb, 0.047 ± 0.008 Nm/kg-m/deg) and between 15 lb and 25 lb load carriage ($P = .039$; 25 lb, 0.048 ± 0.009 Nm/kg-m/deg).

CONCLUSIONS: Regardless of sex, peak PFJ contact force and PFJ impulse/km increased between 0 lb and 25 lb, and 15 lb and 25 lb, but not between 0 and 15 lb. Increased knee stiffness was observed while running with load carriage, perhaps representing a strategy to moderate PFJ kinetics.

CLINICAL RELEVANCE: Running with up to 15 lb may not increase risk of patellofemoral pain, regardless of sex. If load carriage of 25 lb or greater is unavoidable, alternative modifications to reduce PFJ kinetics may be advisable, such as reducing running volume or increasing running ca-

dence which has been shown to reduce PFJ kinetics when running with load carriage. Overall, PFJ loading patterns did not differ between males and females when running with load carriage.

SP092

INFLUENCE OF SHOULDER RANGE OF MOTION AND STRENGTH ON TENNIS FOREHAND VELOCITY IN COLLEGIATE ATHLETES

Beth Horton Schaeffer, Ashley Brown, Harrison David Cruz, Savannah Nicole Freeman, Corey Nickerson, Brianna Brooke Martin

PURPOSE/HYPOTHESIS: (1) To investigate the relationships between shoulder muscle strength and range of motion (ROM) to ball velocity during a tennis forehand swing. (2) To predict forehand velocity from shoulder muscle strength, range of motion, height, weight, and gender.

NUMBER OF SUBJECTS: Thirty-nine (19 male, 20 female) DI and DIII collegiate level tennis players volunteered for the investigation.

MATERIALS AND METHODS: Subjects signed an IRB-approved informed consent and completed an injury history survey prior to testing. Baseline measurements included height and weight. Goniometric ROM and J-Tech Onsite Commander isometric muscle strength measurements were completed on the dominant (hitting) arm which included external rotation (ER), internal rotation (IR), and horizontal adduction (Hor Add). Following a 6-minute warm-up (3-minute jog and stretch and 3-minute hitting on ball machine), subjects were fed a series of balls (from ball machine) to their dominant side for a forehand swing until 3 inbounds cross-court hits were recorded. A calibrated Stalker Pro Radar Gun was used to measure ball velocity. Statistical analysis: bivariate correlations (SPSS-25) were used to determine the relationships between isometric muscle strength, ROM, and maximum ball velocity. Multiple regression analysis was used to predict forehand ball velocity from standard strength and ROM measurements. Statistical significance was set at $P < .05$.

RESULTS: Subject demographics included height (mean $\pm$ SD, 176 ± 8.6 cm); weight (73.46 ± 13.89 kg); body mass index (23.77 ± 4.34 kg/m²). There was a significant positive relationship between max forehand velocity and IR, ER, and Hor Add strength respectively ($r = 0.72, 0.80, 0.75$). Additionally, a significant negative relationship occurred between max velocity and ER ROM ($r = -0.368$) indicating the lower the ER ROM, the greater the max velocity ($r = -0.368$). Strength, ROM, height, weight, gender variables along with internal rotation, external rotation, and horizontal adduction accounted for 73% the variance in ball velocity. A significant regression equation was found with ($F_{9,29} = 17.366, P < .001$), with an R^2 value of 0.843. Subjects predicted maximal forehand velocity was equal to $25.895 + (0.697 \times \text{MMTIR}) + (1.673 \times \text{MMTER}) + (0.003 \times \text{MMTHORADD}) + (0.259 \times \text{ROMIR}) + (0.207 \times \text{ROMER}) + (-0.405 \times \text{ROMHORADD}) + (0.287 \times \text{kg-wt}) + (0.287 \times \text{cm-ht}) + (5.747 \times F = 1; M = 2)$.

CONCLUSIONS: The greater the shoulder IR, ER, and Hor Add strength, the greater the forehand velocity. Conversely, the lower the ER ROM, the greater the forehand velocity. Height, weight, gender, shoulder strength, and shoulder ROM predicts 84% of the variance associated with collegiate tennis players.

CLINICAL RELEVANCE: Based on the sample tested in the current investigation, it appears that common PT measures (ROM and MMT) can predict forehand ball velocity with reasonable accuracy. We are continuing to investigate relationships between the ratio of the shoulder IR-ER ROM, shoulder strength imbalances, and the forehand ball velocity.

SP093

SPORTS SPECIALIZATION VERSUS MULTISPORT JUMP-LANDING MECHANICS IN YOUNG ATHLETES: A SYSTEMATIC REVIEW

Becky Schoeneberg, Bryan Adames, Shelby Tate Reese

PURPOSE/HYPOTHESIS: Sport-specialized young athletes (SS) have a higher risk for serious overuse injuries as compared to multisport youth athletes

(M-S). One hypothesis is poorer neuromuscular skills to prevent injuries due to undiversified activities in training. The purpose of this systematic review was to investigate the neuromuscular skill of jump landing mechanics in SS versus M-S.

NUMBER OF SUBJECTS: A total of 1738 young athletes with an age range of 8 to 18 years old were included.

MATERIALS AND METHODS: Multiple databases were searched including Academic Search Elite, CINAHL Complete, GALE, MEDLINE, PEDro, PubMed, and SPORTDiscus with Full Text and limited to 2012-January 2021. Keywords were ("sport specialization" OR "multisport" OR "sport sampling") AND ("landing" OR "landing mechanics" OR "plane loading") and resulted in 112 articles with 78 remaining after removing duplicates. Only full-text articles addressing jump landing mechanics, SS versus M-S, and athletes ≤ 18 years old were included. Articles were analyzed using the Modified Downs and Black and scored as poor (less than 14), fair (15-19), or good (20 or greater).

RESULTS: A total of 6 articles met inclusion criteria with scores ranging from 19 to 21 and a mean score of 20.5. Five of the 6 articles scored "good" and 1 article scored "fair." Four studies used the Landing Error Scoring System (LESS) and found no significant difference between the SS and M-S groups. Although not significant, the M-S group had a lower number of poor scores, lower movement errors, and "was 2.5 times (95% CI: 1.9, 3.1) as likely to have good control compared with the SS group." Suggestions for the lack of significance included low sensitivity of (1) the LESS "to detect neuromuscular control differences" and (2) "the scale used to classify specialization." Two studies performed biomechanical assessments of the Drop Vertical Jump (DVJ) and found significant differences in kinematics between SS and M-S groups. The SS group had significantly greater postpubertal peak abduction angle ($P = .005$), knee abduction moment ($P = .006$), and knee extensor moment ($P = .032$) showing possible "compromised neuromuscular control." The SS group also showed greater variability in the hip and knee joint ($P < .05$) during angle analysis suggesting less stable coordination and "more risky biomechanical outcomes."

CONCLUSIONS: Overall, M-S demonstrated jump landing activities with decrease number of errors and significantly better biomechanics. Decrease neuromuscular control leading to poorer landing mechanics may be contributing to the increase in overuse injuries in SS, but continued research is needed. Future research recommendations include using additional outcome measures besides the LESS since alone it may not be sensitive enough to detect a difference.

CLINICAL RELEVANCE: The findings of this systematic review support the motor learning principles of varying tasks and environmental contexts. Young athletes should be encouraged to participate in a variety of sports as the research suggests improvements in neuromuscular control, landing mechanics, and a decrease risk for overuse injury.

SP094

GLUTEUS MEDIUS AND TENSOR FASCIA LATAE ACTIVITY WITH RESISTANCE-BAND BIKING: A PILOT STUDY

Alexander Shafiro, Campbell Goldsmith, Silvia Zanini, Eric Thomas Stamer, Sherry I. Backus

PURPOSE/HYPOTHESIS: The purposes of this study are to compare surface electromyography (EMGs) of the gluteus medius (GMed) and tensor fasciae latae (TFL) during the following conditions: while stationary biking with and without a hip abduction resistance band and while performing 5 standard hip-strengthening exercises.

NUMBER OF SUBJECTS: Seven healthy adult volunteers (mean $\pm$ SD age, 26 $\pm$ 4 years; 5 female) were included in this IRB approved study.

MATERIALS AND METHODS: Surface EMGs of right GMed and TFL (1000 Hz) were collected in randomized order for 30 seconds of biking with and without resistance (Band versus no-Band conditions) and for 15 seconds of the 5 standard hip-strengthening exercises: (1) Right Hip IR with

hip ABD (0° extension); (2) side plank with ipsilateral (right) hip ABD; (3) side plank with contralateral (left) hip ABD; (4) single-leg squat; (5) front plank with left hip extensions. EMG linear envelope was normalized to MVC and averaged across a minimum of 7 cycles. Peak amplitude (peak) and area under the curve (work) were compared across conditions with paired t tests ($P \leq .05$).

RESULTS: GMed: Normalized EMG work and peak amplitude were significantly higher for the Band compared to the No Band condition ($P = .002$, $P = .008$, respectively). The average increase of $5\% \pm 3\%$ of MVC in EMG work with the Band represented an increase of 93%; the average increase of $10\% \pm 8\%$ of MVC in peak amplitude represented an increase of 88%. Peak amplitude in the 4 exercises targeting hip ABD (1-4) was significantly higher than the banded condition (range increase, 33%-73% MVC). Peak was lower during front plank. TFL: Band condition was not significantly higher than in No-band condition.

CONCLUSIONS: When rank ordered, GMed activity was lowest in front plank and highest in the side plank with contralateral hip ABD. Activity during biking was lower than 4 of the 5 floor exercises. Banded biking elicits greater GMed activity in comparison to nonbanded biking, but lower than most of the hip strengthening exercises. During the rehabilitation process, when the goal is to elicit submaximal activity, biking without, and then with a band, will provide an intermediate step before progressing to more demanding activities. While no difference was seen for the TFL, our small sample size (currently under powered) will be increased with the completion of data collection. The role of the TFL being a weaker hip abductor may be a reason for it not being significant in healthy subjects. It does, however, warrant further study in injured subjects to assess a change in firing pattern. The inclusion of only healthy subjects is a first step before we study pre-, post-, and non-operative hip and spine patients.

CLINICAL RELEVANCE: This study provides therapists with a better understanding of the progression of exercise and hip abductor muscle recruitment with a goal to further accelerate lumbar spine and lower extremity rehabilitation protocols. The addition of a low-cost resistance band to an exercise that is often a part of standard rehab protocol provides an intermediate step in the strengthening of the hip abductors.

SP095

ARTHROGENIC MUSCLE INHIBITION: BEST EVIDENCE, MECHANISMS, AND THEORY FOR TREATING THE UNSEEN IN CLINICAL REHABILITATION

David Alexander Sherman, Grant E. Norte, Justin Rush

PURPOSE/HYPOTHESIS: Arthrogenic muscle inhibition (AMI) impedes the recovery of muscle function following joint injury, thereby limiting recovery of function throughout rehabilitation. Mechanisms for treating the underlying pathophysiology of muscle dysfunction were first described more than 3 decades ago, yet widespread posttraumatic muscular impairments remain a barrier to patient progress. Collectively, these findings suggest that interventions for AMI are not being successfully integrated into clinical practice. The purpose of this scoping review was to provide updated evidence for the use of clinically accessible AMI treatments and translate the known and theoretical mechanisms for these interventions into clinical recommendations.

NUMBER OF SUBJECTS: Not applicable.

MATERIALS AND METHODS: PubMed and Web of Science electronic databases were searched for articles that investigated the effectiveness or efficacy of interventions to treat outcomes relevant to AMI. Pertinent articles were cross-referenced and discussed among coauthors.

RESULTS: One hundred twenty-two articles that investigated an intervention used to treat individuals with AMI (pathological or artificially induced) were retrieved from 1986 to 2021. Additional articles among uninjured individuals were considered when discussing the mechanisms of action. Most articles described quadriceps muscle impairments (84.3%) in populations with ACL injury (43.9%), osteoarthritis (19.8%), or general knee pain (7.8%). Six categories of treatment mechanisms were iden-

tified: spinal excitability, muscle morphology, muscle activation, muscle strength, cortical excitability, and neurocognition. Sixteen interventions with supporting evidence are synthesized to make recommendations across acute (eg, focal-joint cooling, transcutaneous electrical nerve stimulation [TENS], blood flow restriction [BRF]) and subacute (eg, eccentric exercise, vibration, antagonist fatigue) stages of recovery. Most notable is the “open and exploit” approach, in which the inhibited motor neuron pool of a given muscle or muscle group is disinhibited (open) prior to performing therapeutic exercise to maximize the amount of skeletal muscle one can activate during exercise (exploit).

CONCLUSIONS: AMI contributes to the characteristic muscle weakness, activation failure, and atrophy observed in patients recovering from joint injuries. If left unresolved, AMI impedes short-term recovery and threatens our patients’ long-term joint health and well-being. Growing evidence supports the use of a variety of neuromodulatory strategies to facilitate muscle recovery throughout rehabilitation. Accordingly, we suggest the use an “open and exploit” strategy to address the underlying cause of muscle inhibition before or during conventional rehabilitation.

CLINICAL RELEVANCE: AMI interventions should be individualized to meet the needs of the patient through shared clinician-patient decision making. At a minimum, we propose to keep the treatment approach simple by attempting to resolve inflammation, pain, and effusion as soon as possible following injury.

SP096

MANAGING ELBOW AND FOREARM PAIN IN 2 AMATEUR ROCK CLIMBERS THROUGH IMPROVING SCAPULAR MUSCLE PERFORMANCE

Cheryl Renae Smith, Nolan Shawn O'Malley

BACKGROUND AND PURPOSE: The sport of rock-climbing, competitively and recreationally, is rapidly gaining popularity in the United States and around the world, and is expected to continue to grow as it will be included in the Olympic Games for the first time in Summer 2020. As a result, clinicians must be prepared to evaluate and treat unique climbing related injuries, 5.5% to 13.1% of which are at the elbow. There is little published literature regarding specific interventions that address scapular position and middle and lower trap weakness in patients with elbow and wrist dysfunction due to repetitive use and grip. This case series is unique in that it describes management of elbow pain by solely addressing the scapula in 2 amateur rock climbers. The purpose of this case series is to describe the movement impairments (MIs) and outcomes of 2 rock climbers with elbow pain with treatment focused primarily on scapulo-humeral mechanics.

CASE DESCRIPTION: Patient A was a 24-year-old left-handed male amateur rock climber (<4 months) who presented with right distal biceps and lateral elbow pain with complaints of RUE weakness and fatigue after climbing. He reported pain with rock climbing, tennis and overhead reaching. Patient B was a 24-year-old right-handed female amateur rock climber (<7 months) who presented with left posterior forearm pain and burning as well as an A2 pulley injury with pain exacerbated by grip, typing, pipetting, and climbing. No imaging was performed, and both denied any neck pain or numbness and tingling.

OUTCOMES: Patient A was seen for 5 visits in 7 weeks and patient B was seen for 3 visits in 4 weeks. Both were treated with exercises that focused on addressing MIs of the scapula and humeral region primarily through correcting posture, improving scapular anterior tilt and internal rotation, and strengthening middle and lower trapezius. Pain on the numeric pain-rating scale improved for both patients from 8/10 to 0/10 for patient A and 9/10 to 0/10 for patient B. Middle and lower trapezius strength improved from 2/5 to 4+/5 in both patients. QuickDASH improved from ADL 11.36%, work 0%, sport 87% disability to ADL 0%, work 0%, sport 0% disability for patient A; and from ADL 36.36%, work 25%, sport 68.75% disability to ADL 0%, work 0%, sport 0% disability for patient B.

DISCUSSION: Pain, AROM and QuickDASH scores all improved after a treatment program focusing on improvement of scapular position and strengthening, as well as improved scapular posterior tilt, external rotation and upward rotation of the scapula. Interestingly, despite both patients’ primary complaints of elbow/forearm pain, treatment focusing on improvement of the scapula position and mechanics improved function and sport scores with a full return to pain free activity. While this PT program addressed the position of the arm and forearm, no further treatment was applied directly to the elbow. Physical therapists should consider regional diagnosis and movement impairments in rock climbers with elbow pain as well as implementing appropriate climbing and gripping techniques to improve efficiency with climbing.

SP097

OBTURATOR INTERNUS DYSFUNCTION: IS IT ON YOUR DIFFERENTIAL DIAGNOSIS LIST?

Teresa Smith

BACKGROUND AND PURPOSE: The obturator internus (OI) is a hip stabilizer that shares fascial attachments with the pelvic floor muscles (PFM). In patients with pelvic girdle pain, OI is often tender to palpation and can contribute to pelvic floor dysfunction (PFD). PFD is not well understood, resulting in a delayed or missed diagnosis. Understanding the role of PFM in musculoskeletal pain is critical to a patient’s timely diagnosis and treatment. The purpose of this case report is to describe the treatment of OI dysfunction.

CASE DESCRIPTION: A 53-year-old nulliparous woman presented with right buttocks pain that began 14 months ago during a patient transfer at work. She was diagnosed with hamstring tendinopathy with swelling at the ischial tuberosity on MRI. She had several months of physical therapy with minimal relief. She underwent a sacroiliac joint and steroid injections guided by fluoroscopy. These interventions were ineffective and she was referred for pelvic floor physical therapy (PFPT). Symptoms increased with squatting, driving, and sitting. She described the pain as burning and aching. Symptoms improved with standing or changing positions to offload the right pelvis. She reported discomfort with sexual intercourse but no bladder/bowel dysfunction. She had a history of frequent urinary tract infections and hysterectomy due to adenomyosis. Prior to injury, she did interval training and running.

OUTCOMES: Her initial Lower Extremity Functional Score (LEFS) score was 63 points (78.75%). Verbal pain ratings were 3/10 at best in mornings and 5/10 at worst in evenings. She had full lumbar range of motion. Neurological exam was normal except diminished deep tendon reflexes at S1 bilaterally. She demonstrated weakness via manual muscle testing (MMT) in hip external rotation (R, 4-/5; L, 4+/5), hip internal rotation (4/5 bilaterally), and knee flexion 4+/5 (in prone with pain; 5/5 in sitting without pain). Sacral thrust test was positive, but all other special tests in lumbar, SIJ, and hip were negative. She reported pain with external palpation of OI. She gave consent for an intravaginal PFM exam. PFM strength was normal, but she did have delayed relaxation and minimal bearing-down. The only examination technique that reproduced her familiar pain was internal palpation of OI. She was instructed in a home exercise program (HEP) for relaxation of pelvic diaphragm muscles. She purchased a pelvic wand for addressing trigger points between sessions. Throughout her 7 visits, treatment consisted of dry needling to OI and external deep rotators, intravaginal manual therapy to OI, PFM relaxation exercises, obturator nerve glides, and progressive strengthening exercises. The patient was discharged with 10 points increased on LEFS (91.25%) and returned to all activities. She had 5/5 strength and minimal tenderness to OI.

DISCUSSION: This case describes the successful treatment of buttocks pain with focus on OI dysfunction. In a patient with hip or low back pain whose symptoms have not resolved with other medical interventions, PFPT should be considered.

SP098

EARLY MEASURES OF TORQUE DEVELOPMENT ARE RELATED TO PEAK TORQUE AT 6 MONTHS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

William Mead Swann, Ryan Patrick McGuire, John G. Jurjans, Timothy Lee Uhl

PURPOSE/HYPOTHESIS: Individuals following anterior cruciate ligament reconstruction (ACLR) are at increased risk for subsequent ACL injury, with quadriceps strength deficits being a risk factor. While maximal quadriceps torque takes 300 to 500 milliseconds to develop, many athletic activities occur faster. This has facilitated the use of early rate of torque development (ERTD, 0-100 milliseconds) to measure both neural function and late rate of torque development (LRTD, 100-200 milliseconds), which is influenced by muscle contractile properties. Neural mediating effects appear to reduce RTD in both involved and uninvolved limbs in early ACLR. It is unknown whether isometric RTD measures at 4 months will correlate with isokinetic torque measures at 6 months post ACLR. We hypothesize that isometric ERTD and LRTD will be significantly correlated with isokinetic peak torque at 6 months post ACLR. We hypothesize that involved limb rate of torque development will be significantly slower than the uninvolved limb at 4 months.

NUMBER OF SUBJECTS: Thirty-eight patients (22 male, 16 female; mean $\pm$ SD age, 22 ± 8 years) post ACLR underwent isometric testing at 4 months and isokinetic testing at 6 months. Patients tested outside of the 30-day window were excluded.

MATERIALS AND METHODS: This retrospective cohort study utilized isokinetic and isometric testing from a Cybex Norm between 2018 and 2020. Patients performed isometric testing of two 10-second maximal isometric knee extensions at either 90° or 60° of knee flexion at 4 months post ACLR. Rate of torque development was extracted from raw data collected at 100 Hz and processed using the slope function in excel with units of Nm/s. At 6 months, isokinetic testing was performed to determine peak knee extension torque at 60° /s. As the data did not meet criteria for normal distribution, Spearman's rho correlations were utilized to determine the level of correlation between 4 month isometric ERTD, LRTD, and peak isometric torque to 6 months isokinetic peak torque at 60° /s. Wilcoxon Signed Rank paired comparison was used for ERTD and LRTD between limbs with significance set at $P \leq .05$.

RESULTS: The 4 months measures of ERTD ($r = 0.52$), LRTD ($r = 0.71$), and peak isometric torque ($r = 0.75$) were all significantly correlated with 6 months isokinetic peak torque ($P < .001$). The uninvolved limb (median, 320; interquartile range, 192-498 Nm/s) generated significantly greater ERTD than the involved limb (median, 169; interquartile range, 114-329 Nm/s) at 4 months ($P < .001$). The uninvolved limb (median, 285; interquartile range, 208-511 Nm/s) generated significantly greater LRTD than the involved limb (median, 173; interquartile range, 105-258 Nm/s) at 4 months ($P < .001$).

CONCLUSIONS: Four-month isometric RTD and peak isometric force are moderately to strongly correlated to isokinetic peak torque at 6 months which supports our hypothesis. Involved limb rate of torque development was 40% to 48% slower than the uninvolved limb also supporting our hypothesis.

CLINICAL RELEVANCE: The best predictor of isokinetic torque at 60° /s at 6 months was isometric peak force and LRTD at 4 months. Clinicians may incorporate treatments targeting rate of torque development with isometric strengthening in protected ranges to facilitate quadriceps strengthening during the subacute phase of ACLR rehabilitation.

SP099

ANALYSIS OF LOWER EXTREMITY INJURY RISK WITHIN 12 MONTHS POST CONCUSSION AND UTILIZATION OF FUNCTIONAL MEASURES

Claire Switzer, Nicole Melfi, Katy Eileen Mitchell, Robert M. Hofschulte, Purvi Shaan Vora

PURPOSE/HYPOTHESIS: The primary purpose was to determine the prevalence of youth athletes who sustained a LE injury within 1 year post concu-

sion. We hypothesized at least 10% of this population would sustain a LE injury within 1 year. The secondary purpose was to describe the utilization of LE functional testing performed by physicians (MDs), physical therapists (PTs), and athletic trainers (ATs) as part of return-to-sport (RTS) clearance. We hypothesized 51% would report they do not use a LE functional test to clear athletes to RTS post concussion.

NUMBER OF SUBJECTS: The inclusion criteria for the chart review were as follows: male or female, aged 8 to 21 years, diagnosed with a concussion by an MD, and active participation in 1 or more sports. A total of 635 charts were reviewed. The provider survey was sent to Sports Medicine MDs, PTs, and ATs who treat concussion. A total of 37 surveys were analyzed.

MATERIALS AND METHODS: A retrospective chart review was completed including patients from September 2018 to September 2020. The data were collected in Microsoft Forms. Additionally, a Microsoft Forms survey was sent to Sports Medicine providers to assess utilization of LE functional tests. SPSS 25.0 was used for analysis with alpha level at .05. A one-sample chi-square test was utilized to compare reinjury rate to the known rate of 1%. Other proportional comparisons were run using 2-sample chi-square analyses.

RESULTS: Of the charts reviewed, 527 patients participated in at least 1 sport; 12.7% ($n = 54$) of those who sustained a concussion had either a musculoskeletal injury ($n = 36$) or another concussion ($n = 18$) within 1 year, with the highest proportion of injuries being a second concussion (33.3%) or ligament sprain (35.2%); 52.8% of providers do not use a LE functional measure as part of RTS criteria. The most commonly reported reasons that providers do not use LE measures include: not within standard of practice, lack of time, and lack of knowledge.

CONCLUSIONS: The results suggest a LE test battery may be beneficial to assess LE injury risk post concussion. Additionally, the majority of providers do not use LE functional measures when assessing RTS criteria. Considering the lack of knowledge of LE functional testing, further education should be given to providers in order to screen for deficits that increase injury risk. Future studies should analyze the effects of LE strengthening and functional testing on subsequent LE injury risk post concussion.

CLINICAL RELEVANCE: A LE test battery, as is used with postoperative ACL reconstruction, may be beneficial to screen for deficits that put athletes at a greater risk for injury post concussion. Although current research does not understand the mechanism causing increased LE injury risk, clinicians should utilize best available practice when clearing athletes to RTS.

SP0100

WHEN TO CONSIDER RUN RETRAINING FOR RUNNERS WITH KNEE PAIN: RESPONDERS VERSUS NONRESPONDERS

Christina Terracciano, Shawn Farrokhi, Laura Bechard, Adam Yoder, Brittney Nicole Mazzone

PURPOSE/HYPOTHESIS: Run retraining is recommended in the 2019 clinical practice guideline for patellofemoral pain to reduce knee pain. Conversion from rearfoot to nonrearfoot strike reduces ground impact and biomechanical loads at the knee while running. The purpose of this study was to identify potential predictors of success with run retraining focused on conversion from rearfoot to nonrearfoot strike pattern. We hypothesized that younger age, unilateral symptoms, shorter pain chronicity, male sex, lower body mass index (BMI), greater pain with running and lower Lower Extremity Functional Scale (LEFS) scores would be strongly associated with responders to run retraining.

NUMBER OF SUBJECTS: Nineteen service members (11 male; mean $\pm$ SD age, 27.5 ± 7.3 years; BMI, 25.1 ± 3.1 kg/m²; 13 unilateral symptoms) with a chief complaint of knee pain during running and self-selected rearfoot strike pattern.

MATERIALS AND METHODS: This was a retrospective study. peak numeric pain-rating scale (NPRS) while running, function via the LEFS and were

identified as rearfoot strike runners. The participants completed 6 to 8 sessions of run retraining treatment to adopt a nonrearfoot strike pattern using a faded feedback schedule. A follow-up evaluation was completed 1 to 4 months after retraining, where peak NPRS during running, LEFS and strike pattern using motion capture were collected. Run retraining “responders” were identified using 3 criteria: (1) peak NPRS decreased by ≥ 2 points, (2) LEFS improved by ≥ 9 points, and (3) retained nonrearfoot strike pattern at follow-up. The difference in potential predictors (age, laterality, pain chronicity, gender, BMI, peak NPRS and LEFS) between responders and nonresponders was analyzed using Mann-Whitney U test for continuous variables and chi-square test for categorical variables.

RESULTS: Eight participants were “responders” to run retraining. Responders were significantly younger than nonresponders (median $\pm$ standard error, 22.5 ± 1.5 years versus 30.0 ± 2.2 years; $P = .02$). Responders reported lower scores on the LEFS than nonresponders (58.0 ± 1.6 versus 67.0 ± 3.1 points, $P = .03$). Symptom laterality, pain chronicity, gender, BMI, and peak NPRS were not significantly different between responders and nonresponders ($P > .05$).

CONCLUSIONS: Younger age and lower level of function were associated with a positive outcome to run retraining, including pain reduction, functional improvement, and retention of trained strategy. Limitations include a small sample size of Service members, a potential floor effect in peak NPRS, and ceiling effect in LEFS to run retraining. Further investigation with a larger sample size is needed before predictors can be recommended to clinicians when considering run retraining for patients with knee pain.

CLINICAL RELEVANCE: Patient characteristics which suggest success with run retraining are currently unknown and requires further investigation. Younger age and lower self-reported physical function may indicate success with run retraining as treatment for knee pain.

SP0101

MATURATION AFFECTS HIP BIOMECHANICS WHEN TRANSITIONING FROM FORWARD TO BACKWARD RUNNING: IMPLICATIONS FOR ANTERIOR CRUCIATE LIGAMENT INJURY

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

PURPOSE/HYPOTHESIS: Prior evidence has shown that jumping and landing biomechanics change during maturation in female athletes, placing post-maturation athletes at higher risk for anterior cruciate ligament (ACL) injury. There is far less evidence that describes changes due to maturation during tasks that require change in direction, especially during the transition from forward to backwards running. The purpose of this study was to test the hypothesis that participants in later stages of maturation would exhibit higher risk biomechanics during a change in direction when compared to those in earlier stages of maturation.

NUMBER OF SUBJECTS: One hundred thirty-five female soccer players representing 3 maturational groups based on percent adult stature: prepubertal (PRE, $n = 14$; mean $\pm$ SD age, 12.0 ± 1.9 years; height, 151.6 ± 12.0 cm; mass, 44.0 ± 9.6 kg), pubertal (PUB, $n = 30$; mean $\pm$ SD age, 12.8 ± 1.9 years; height, 153.4 ± 10.1 cm; mass, 45.8 ± 9.1 kg), postpubertal (POST, $n = 89$; mean $\pm$ SD age, 14.0 ± 2.1 years; height, 160.0 ± 9.3 cm; mass, 53.5 ± 11.2 kg).

MATERIALS AND METHODS: Standard 3-D motion analysis was used to measure hip, knee, and ankle kinematics at initial ground contact during an unanticipated agility task. Participants ran forward (5 m at 75% of maximal speed) to trigger an illuminated signal that instructed either an immediate 90° cut or deceleration to backpedal. Data from the backpedal were used for these analyses. One-way ANOVAs were performed to identify kinematic differences between maturational groups ($\alpha < .05$).

RESULTS: There were significant differences between groups for sagittal ($P = .04$) and frontal plane ($P = .02$) hip angles at initial contact. There were greater levels of hip flexion in the POST group ($39.5^\circ \pm 8.2^\circ$) than

the PUB group ($35.8^\circ \pm 7.1^\circ$, $d = 0.48$, $P = .03$) and greater levels of hip abduction in the POST group ($3.5^\circ \pm 5.2^\circ$) than the PRE group ($-0.3^\circ \pm 4.9^\circ$, $d = 0.75$, $P = .01$). There were no significant differences between transverse plane hip, or sagittal and frontal plane knee or ankle kinematics between groups ($P > .05$).

CONCLUSIONS: Postpubertal female athletes exhibit greater hip flexion and abduction at initial contact during an unanticipated backpedal task than athletes in earlier maturational groups.

CLINICAL RELEVANCE: While postpubertal female athletes demonstrated lower-risk hip kinematics (greater hip flexion and abduction) than earlier maturational groups, there were no kinematic differences at the knee and postpubertal female athletes continue to incur a higher likelihood of suffering an ACL injury. This may be because of the higher intensity levels and forces, and shorter change of direction times in the more mature athletes. The biomechanics that occur during the transition from forward running to a backpedal, including approach speed, stepping and stride length strategies, warrant continued investigation.

SP0102

THE RELATIONSHIP BETWEEN LOWER EXTREMITY KINEMATICS DURING A DROP VERTICAL JUMP AND UNANTICIPATED BACKPEDAL

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

PURPOSE/HYPOTHESIS: Anterior cruciate ligament injuries (ACL) typically occur during change of direction activities. Both vertical and horizontal change of direction activities are incorporated in injury prevention and rehabilitation programs. There is significant evidence that describes vertical changes of direction during jumping and landing and their relationship to injury risk, yet there is less evidence on horizontal changes of direction (ie, cutting). This is especially true for athletes transitioning from forward to backwards running, a common sport demand. Thus, the purpose of this study was to describe the movement patterns that occur during the transition to a backpedal (BACK) and identify differences and relationships to a standard screening tool (ie, drop vertical jump [DVJ]). It was hypothesized that the BACK would elicit distinct movement patterns that were unrelated to the DVJ.

NUMBER OF SUBJECTS: One hundred thirty-five adolescent female soccer players (mean $\pm$ SD age, 13.5 ± 2.1 years; height, 157.3 ± 10.1 cm; mass, 50.8 ± 11.2 kg).

MATERIALS AND METHODS: All participants completed 3 trials each of a DVJ and unanticipated transition from forward running to backpedaling. Kinematics at the time of initial ground contact were collected for the dominant limb (kicking limb) using standard 3-D analysis. Repeated-measures MANOVAs identified differences in hip, knee, ankle biomechanics between the DVJ and BACK ($\alpha < .05$). Cohen's d effect sizes were calculated for all identified significant differences. Spearman's rank correlations identified the relationship of biomechanics between the 2 tasks.

RESULTS: There were significant differences between the tasks in hip, knee, and ankle kinematics, such that the BACK elicited significantly greater levels of hip flexion ($d = 0.66$), less hip internal rotation ($d = 0.74$), less knee flexion ($d = 0.69$), greater knee abduction ($d = 0.31$), and greater plantarflexion ($d = 6.31$) than the DVJ ($P < .001$). There were moderate relationships between tasks for most kinematic variables (sagittal plane: hip, $r = 0.38$; knee, $r = 0.44$; ankle, $r = 0.13$; frontal plane: knee, $r = 0.85$; transverse plane: hip, $r = 0.41$; knee, $r = 0.39$).

CONCLUSIONS: The BACK task elicits lower extremity kinematics that are significantly different than the DVJ, yet moderate to strong relationships were identified.

CLINICAL RELEVANCE: The BACK task elicits safer hip strategies (greater hip flexion, lesser internal rotation) yet higher-risk knee strategies (lesser knee flexion, greater knee abduction) than the standard DVJ, which may be important considering the mechanism of ACL injury. Although the DVJ is a double-limb task and the BACK is a single-limb task, effi-

cient screening for ACL injury risk may not need to include both tasks, considering the moderate to strong relationships identified. This may also indicate that biomechanical strategies learned and changed during prevention and rehabilitation practices for the standard clinical DVJ may translate to the less commonly tested and trained BACK task.

SP0103

OFFLOADING EFFECTS ON IMPACT FORCES AND PATELLOFEMORAL JOINT LOADING DURING RUNNING IN FEMALES

Charles Nathan Vannatta, Bryce Owen Ertman, Renee Lynn Dade, Thomas Kernozek

PURPOSE/HYPOTHESIS: Structure-specific loading is being increasingly recognized as playing a role in running-related injuries. Interventions targeted at reducing patellofemoral joint loads have shown effectiveness in reducing symptoms of patellofemoral pain. Use of body weight support (BWS) has the potential to reduce loading on the patellofemoral joint during running to augment rehabilitation efforts. It was hypothesized that the use of a harness-based BWS system would effectively reduce vertical ground reaction force (vGRF) and measures of patellofemoral joint loading without affecting knee kinematics.

NUMBER OF SUBJECTS: Twenty-five healthy female recreational runners.

MATERIALS AND METHODS: Participants completed running trials on an instrumented treadmill with varying amounts of BWS using a commercially available harness system (Lightspeed Lift, Duluth, MN) which used elastic cords attached to an external frame to unload the runner. In a randomized order, participants ran under 4 conditions: control (no body weight support), low, medium, and high BWS. The lowest attachment point had the elastic cords from the frame to the harness 30 cm above each participant's greater trochanter when standing. The medium and high attachments were 37.5 cm and 45 cm, respectively. Kinematic data from a 3-D motion capture system and kinetic data from the treadmill were combined in a musculoskeletal model to compare measures of patellofemoral joint loading, quadriceps force, knee kinematics, peak vGRF, and stride frequency. A repeated-measures MANOVA was completed to detect differences between the various amounts of unloading. Alpha was set to .05.

RESULTS: Peak patellofemoral joint stress and time-integral were reduced when running under BWS conditions compared to the control condition. Reductions in patellofemoral joint loading ranged from 11.0% to 23.9%. Peak quadriceps force demonstrated similar changes with BWS. Peak knee flexion was reduced by nearly 3° to 4° during the stance phase of running in all BWS conditions compared to control. Total knee excursion was reduced only between the high BWS condition compared to control (difference, 12.51°). Peak vGRF and stride frequency reduced incrementally with the height of the elastic cord attachment to the external frame of the BWS system.

CONCLUSIONS: A harness-based BWS system appears effective in reducing vGRF, patellofemoral joint loading and peak quadriceps force during running. Overall reductions were observed at all BWS levels compared to the control despite a reduction in stride frequency.

CLINICAL RELEVANCE: Harness-based BWS systems may provide a feasible means to reduce patellofemoral joint loading to assist in rehabilitation efforts, such as addressing patellofemoral pain. More work appears necessary to determine how such loading changes may influence runners with patellofemoral pain.

SP0104

ATHLETES EXHIBIT DEFICITS IN DYNAMIC BALANCE FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION, REGARDLESS OF THEIR MENISCAL INJURY STATUS

Adam VanZile, Malcolm Richard Driessen, Thomas Gus Almonroeder

PURPOSE/HYPOTHESIS: Athletes with a history of anterior cruciate ligament (ACL) reconstruction exhibit deficits in dynamic balance for their

involved limb, compared to their uninvolved limb, which is concerning since persistent deficits in dynamic balance may place an athlete at elevated risk for reinjury. However, previous studies have not examined whether interlimb asymmetries in dynamic balance differ between athletes with isolated ACL injuries and athletes with ACL injuries and concomitant meniscal injuries. This is important to explore since meniscal injuries often accompany ACL injuries. Therefore, the purpose of this study was to compare dynamic balance for the involved and uninvolved limbs, in athletes with and without a history of concomitant meniscal injury.

NUMBER OF SUBJECTS: Thirty athletes with a history of ACL reconstruction; 14 athletes had sustained an isolated ACL tear (7 male, 7 female), while 16 athletes (10 male, 6 female) had sustained an ACL tear and a concomitant meniscal injury. The athletes who had sustained a meniscal injury had either undergone a meniscal repair or a meniscectomy.

MATERIALS AND METHODS: All athletes completed the Lower Quarter Y Balance Test with both their involved and uninvolved limbs. The Y Balance Test is commonly used to assess single leg dynamic balance based on the distance an athlete can reach in the anterior, posteromedial, and posterolateral directions with their unweighted leg. All testing was completed during a standard return-to-sport testing session, which was conducted after the athletes had completed rehabilitation (range, 5 to 11 months after surgery). A mixed-model ANOVA with a within-subjects factor of limb (involved, uninvolved) and a between-subjects factor of meniscal injury status (isolated ACL injury, concomitant meniscal injury) was conducted, with the Y Balance Test anterior reach distances as the dependent variable of interest ($\alpha = .05$). We focused on the anterior reach distances, since deficits in the anterior direction tend to be the most pronounced in athletes with a history of ACL reconstruction and appear to be most relevant to injury risk based on previous studies.

RESULTS: There was not a limb-by-meniscal injury status interaction effect ($P = .50$); however, there was a main effect of limb ($P = .02$), indicating that both groups demonstrated comparable interlimb asymmetries in dynamic balance. When data were combined for both groups, anterior reach distances were 4.3% lower for the involved limb (60.8 ± 13.4 cm) versus the uninvolved limb (63.5 ± 11.3 cm).

CONCLUSIONS: Athletes with a history of ACL reconstruction demonstrated poorer dynamic balance for their involved limb. The magnitude of the observed interlimb asymmetries were similar for athletes who had sustained isolated ACL injuries and those who had sustained an ACL injury along with a concomitant meniscal injury.

CLINICAL RELEVANCE: Clinicians should assess for, and attempt to address, deficits in dynamic balance for athletes with a history of ACL reconstruction, regardless of whether they have suffered a concomitant meniscal injury.

SP0105

QUADRICEPS STRENGTH DOES NOT INFLUENCE KNEE-RELATED SYMPTOM STATE 6 MONTHS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Michelle Christine Walaszek, Terry Lee Grindstaff, Joseph Hart, Thomas Birchmeier, Ashley Triplett, Katherine Collins, Matthew Harkey, Michael Shingles, Michael Straus, Christopher Kuense

PURPOSE/HYPOTHESIS: To determine if isometric quadriceps strength and isometric quadriceps strength symmetry classification of individuals 6 months post ACLR is associated with clinical knee-related symptom state. We hypothesized individuals 6 months post ACLR who are classified as demonstrating strong and symmetrical quadriceps will demonstrate greater odds of reporting clinically acceptable knee-related symptoms when compared to those who do not demonstrate adequate quadriceps strength and/or symmetrical quadriceps strength.

NUMBER OF SUBJECTS: One hundred thirty-one participants who were 5 to 7 months post primary, unilateral ACLR were recruited from 3 institutions

(75 female; age, 18.8 years; months since surgery, 6.1). Participants were excluded if they had a multiligament knee injury or other medical condition which would limit participation.

MATERIALS AND METHODS: Participants completed bilateral isometric quadriceps strength assessments and the Knee Injury and Osteoarthritis Outcome Score (KOOS). Peak isometric quadriceps strength was normalized to body weight (Nm/kg) and the limb symmetry index (LSI [%]) was calculated. Participants were classified as both strong and symmetrical (≥ 3.0 Nm/kg and $\geq 90\%$ LSI), symmetrical only (< 3.0 Nm/kg and $\geq 90\%$ LSI), or neither strong or symmetrical (< 3.0 Nm/kg and $< 90\%$ LSI). Participants were also categorized as demonstrating clinically unacceptable knee-related symptoms, as described by Englund et al, if they scored ≤ 87.5 on the KOOS QOL subscale and met 2 or more of the following subscale cutoff scores: KOOS symptoms ≤ 85.7 , KOOS pain ≤ 86.1 , KOOS ADL ≤ 86.8 , KOOS sports and recreation ≤ 85.0 . Demographics and KOOS scores were compared between quadriceps strength classification groups using ANCOVA controlling for enrollment site. Additionally, using binary logistics regression, we calculated odds ratios and 95% confidence intervals (CIs) to determine the association between quadriceps strength groups and reporting clinically acceptable knee-related symptoms.

RESULTS: The odds of a strong and symmetrical participant ($n = 22$; OR = 1.77; 95% CI: 0.66, 4.79; $P = .26$) or symmetrical only participant ($n = 23$; OR = 1.89; 95% CI: 0.70, 5.06; $P = .21$) reporting clinically acceptable symptoms were not significantly greater than a neither strong nor symmetrical participant ($n = 84$).

CONCLUSIONS: Nearly 40% of individuals report unacceptable knee-related symptoms 6 months post ACLR. However, it does not appear that clinical knee-related symptom state was meaningfully influenced by the presence of adequate quadriceps strength and symmetry in our sample.

CLINICAL RELEVANCE: Six months post ACLR is a common time point in which formalized rehabilitative care is terminated and individuals return to unrestricted physical activity. Clinical knee-related symptoms negatively impact ACLR recovery thus optimizing quadriceps strength and quadriceps strength symmetry at 6-months post ACLR may still be an important component to decreasing the risk of reinjury and improving functional mobility in preparation for return to unrestricted physical activity.

SP0106

NEURAL GLIDING IN THE TREATMENT OF CHRONIC "STINGERS" IN A FOOTBALL PLAYER: A CASE STUDY

Andy George Waldhelm, Steven McDavitt

BACKGROUND AND PURPOSE: Transient brachial plexopathy commonly known as a stinger or burner is a frequent injury in American football. Stinger injuries can cause neurological dysfunction including shooting pain, burning, sensory impairments and muscle weakness. Although the literature is limited, similar neurogenic symptoms have been successfully treated with neural mobilization in upper-quarter injuries such as cervical radiculopathy, cervicobrachial neurogenic pain, lateral epicondylitis and adhesive capsulitis. Therefore, the purpose of this case study was to describe the rehabilitation, including the use of neural gliding, on pain, impaired range of motion, strength and function of a high school football player suffering from reoccurring stinger injuries.

CASE DESCRIPTION: The patient was a 17-year-old male high school senior who played defensive end on his American football team. Initially symptoms included neck pain and shooting pain in his right upper extremity and paresthesia over the lateral aspect of right hand. Patient was evaluated by the team physician that night and examined by a physical therapist 3 days later. During the physical therapy examination, he complained of minimal soreness in neck and shooting pain in his right upper extremity which he rated as a 9 out of 10 at worse. Key objective findings included cervical right side flexion active range of motion (AROM) limited by 50%, gross right shoulder/scapular muscle strength was a 4 out of 5, positive

Spurling's test on right and median upper limb tension test on right where elbow extension provoked symptoms at 70° of elbow flexion compared to 10° on left and the Upper Extremity Functional Scale (UEFS) score was 71 out of 80. Patient was treated 3 times a week of 4 weeks with the following interventions: manual cervical distraction and joint mobilization, neural gliding exercises which was part of his home exercise program, strengthening of the shoulder complex and return to sport activities.

OUTCOMES: Upon discharge from physical therapy, patient complained of intermittent neck pain 2 out of 10 at worse, no radicular symptoms, UEFS was a 76 out of 80, cervical AROM was full and pain free, gross shoulder strength was recorded as a 5 out of 5, all special tests were negative including median nerve ULTT where elbow extension was equal between extremities. Patient made a full return to football after 2 weeks following the injury and did not suffer another stinger that football season.

DISCUSSION: Evidence is lacking on the use of neural mobilization as an intervention to treat stingers. This case study describes the successful treatment and return to sport of a high school football player with reoccurring stingers with neural gliding. Since a common mechanism of injury for stingers is traction of the brachial plexus, neural mobilization may be useful in improving the overall mobility of the neural tissue and surrounding structures and increasing nourishment which may lead to a decrease in symptoms and decrease risk for future stinger injuries.

SP0107

SUBCRANIAL SPINE INFLUENCE ON SHOULDER FUNCTION IN A HIGH SCHOOL VOLLEYBALL ATHLETE

Adam Walsh

BACKGROUND AND PURPOSE: The influence of the mid-cervical spine on shoulder pathology is well established. From nerve root involvement and myotome deficits to mid-cervical pathology symptom referral to the parascapular region, the mid-cervical spine and shoulder complex are interconnected and codependent. Often overlooked is the upper cervical spine's influence on shoulder pathology. This case study demonstrates the immediate and long lasting influence that correcting upper cervical spine pathology has on shoulder pain and function.

CASE DESCRIPTION: A 17-year-old high school junior presents to a private outpatient orthopaedic clinic with reports of right shoulder pain and an inability to play volleyball due to the pain. Prior to presenting to the clinic, she was seen by 2 separate health care professionals with limited success in alleviating symptoms and returning to volleyball. The patient reports focusing on rotator cuff strengthening and dry needling her shoulder complex previously, which give her short-term relief but baseline symptoms returned within 48 hours. Upon evaluation, the patient presented with slight postural abnormalities and pain at the long head of the biceps and infraspinatus. She reported a NPRS of 8/10 with volleyball, 4/10 currently, and 3/10 at best. The infraspinatus had numerous palpable areas of hypertonicity, including 1 area that referred pain to the anterior shoulder upon palpation. Cervical and shoulder ROM was limited with limited and painful R shoulder strength. Specific upper cervical spine mobility testing revealed limited subcranial forward nodding (R>L), left sidebending, and right rotation.

OUTCOMES: Initial treatment focused on improving upper cervical spine mobility via joint mobilizations. The patient reported immediate shoulder relief post treatment with pain diminished to 1/10 and objective assessment cervical and shoulder ROM improved and strength improved and pain free. Palpation of the infraspinatus revealed a decrease in hypertonicity and no symptom referral to the anterior shoulder. The patient was given a HEP focused on maintaining upper cervical spine mobility. On the first follow-up visit 1 week later, the patient reported a NPRS of 0/10 and her shoulder ROM and strength was equal bilaterally and pain free. The patient was seen for 3 subsequent visits over the next 3 weeks as she progressively and successfully returned to full volleyball participation symptom free.

DISCUSSION: This case study is an example of the interconnection between the cervical spine and the functionality of the shoulder complex. Literature demonstrates that cervical positioning influences shoulder and scapular muscle activation, with this case study finding the same results. By improving subcranial spinal mobility utilizing a biomechanical approach to treating the cervical spine, this patient was able to immediately improve shoulder strength and function and maintain that improvement for a full return to prior level of function. A focused regionally interdependent evaluation and individualized treatment is needed for all patients, especially those who have failed conservative care previously.

SP0108

DOES CONCOMITANT MENISCAL REPAIR WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION ALTER PSYCHOLOGICAL READINESS POSTOPERATIVELY?

David Werner, Austin Post, Ashley Marsh, Matthew Tao, Elizabeth Ann Wellsandt

PURPOSE/HYPOTHESIS: Anterior cruciate ligament (ACL) injury often occurs with concomitant injury to the menisci. Meniscus repairs are designed to restore tissue function and reduce risk of later cartilage deterioration. After meniscal repair, range-of-motion and weight-bearing restrictions are more common than after isolated ACL reconstruction (ACLR). While meniscus repairs have low surgical failure rates, it is unknown how these restrictions impact psychological readiness. Therefore, the purpose of this study is to examine the psychological impact of concomitant meniscal repair compared to those who undergo ACLR without meniscal repair.

NUMBER OF SUBJECTS: Twenty-nine individuals in an ongoing cohort study were included. Participants were divided into a meniscal repair group (MR; $n = 14$) or no meniscal repair group (NM; $n = 15$) based on operative reports.

MATERIALS AND METHODS: Participants completed the Tampa Scale of Kinesiophobia (TSK-11, scored 11-44: higher score indicates kinesiophobia) and the ACL-Return to Sport after Injury (ACL-RSI, scored 0-100: higher score indicates greater psychological readiness) at 2, 4, and 6 months after ACLR. They also completed maximal isometric quadriceps strength testing in 90° of knee flexion at 6 months. Separate 2-by-3 (group by time) repeated-measures analysis of variance (ANOVA) were used to determine if the TSK and ACL-RSI differed between the MR and NM groups with Bonferroni post hoc testing as needed. If differences were noted, a secondary exploratory analysis was performed to assess the influence of quadriceps strength at 6 months (entered as a covariate). All tests used an a priori $\alpha = .05$.

RESULTS: Participants were 60% female, 19.5 ± 4.9 years old and had a BMI of 25.3 ± 4.7 kg/m². The group-by-time interaction effect trended toward significance for the TSK ($P = .088$) but not for the ACL-RSI ($P = .687$). The trending interaction corresponded to TSK improvement from 4 to 6 months in the NM group (4 months, 21.9 ± 5.8 ; 6 months, 19.5 ± 5.8) but not in the MR group (4 months, 22.0 ± 3.7 ; 6 months, 22.0 ± 3.7). Secondary analysis revealed that TSK scores across groups at 4 and 6 months were not altered by quadriceps strength ($P = .924$). There was a main effect of time for both the TSK ($P < .01$) and ACL-RSI ($P = .017$) but no main effect of group ($P > .05$). TSK scores were lower at 4 ($P = .010$) and 6 months ($P < .01$) than at 2 months (2 months, 24.5 ± 4.2 ; 4 months, 22.0 ± 4.8 ; 6 months, 20.7 ± 5.0). ACL-RSI scores were higher at 6 months than both 2 ($P = .038$) and 4 months ($P = .024$) (2 months, 55.9 ± 24.8 ; 4 months, 59.5 ± 22.5 ; 6 months, 66.3 ± 19.8).

CONCLUSIONS: Concomitant meniscal repair during ACLR trended towards an effect on the TSK in the first 6 months post ACLR, but not the ACL-RSI. The additional restrictions related to meniscal repair protocols may impact the progression of kinesiophobia.

CLINICAL RELEVANCE: Clinicians can use this data to gauge how psychological outcomes should progress individuals after ACLR with or without

MR. Clinicians may need to track kinesiophobia more closely in those with concomitant meniscal repair to ensure readiness for later sports and activity.

SP0109

SINGLE-LEG SQUAT PERFORMANCE IS IMPAIRED IN PEOPLE WITH FEMOROACETABULAR IMPINGEMENT SYNDROME COMPARED TO HEALTHY CONTROLS

Daniel Wichman, Alejandro Espinoza-Orias, Jorge Chahla, Shane J. Nho, Philip J. Malloy

PURPOSE/HYPOTHESIS: The aims of this study was to: (1) to investigate if people with FAIS demonstrate impaired in SLS performance and lower extremity dynamic range of motion (ROM) compared to healthy controls. We hypothesize that people with FAIS will demonstrate impaired SLS performance and altered sagittal and frontal plane hip biomechanics when compared to healthy controls.

NUMBER OF SUBJECTS: Thirty-four people with FAIS and 26 healthy age and body mass index matched controls.

MATERIALS AND METHODS: Three-dimensional (3-D) kinematic data were collected at 100 Hz using a 20-camera 3-D motion capture system (Natural Point, Corvallis, OR) during 3 SLS trials. Kinematic data were filtered at 6 Hz with a fourth-order low-pass Butterworth filter and a link segment model was built using Visual3D (C-Motion, Germantown, MD). MATLAB (Mathworks, Natick, MA) was used to define the squat cycle based on the vertical position of the center of mass (COM) marker. Squat performance was quantified as squat depth in meters measured as the difference between the highest and lowest vertical position of the COM during the squat cycle. Dynamic ROM at the pelvis and each lower extremity joint for each plane was calculated as the difference between the maximum and minimum joint or segment angle during the squat cycle. The segment and joint biomechanical variables of interest were: dynamic ROM of the pelvis, hip, knee and ankle in all planes. All 3 trials of the variables of interest were ensemble averaged for statistical analysis. Two-tailed independent samples t tests were used to determine between group differences for squat depth dynamic ROM variables. All statistical analysis was performed using SPSS Version 26.

RESULTS: There were no between group differences in age (FAIS, 29.7 ± 6.9 versus controls, 27.3 ± 7.0 ; $P = .18$) or BMI (FAIS, 23.1 ± 2.8 versus controls, 22.6 ± 3.2 ; $P = .51$). Squat depth was less in people with FAI syndrome compared to healthy controls (FAIS, 0.24 ± 0.5 m versus controls, 0.29 ± 0.04 m; $P < .001$). In the sagittal plane, people with FAIS demonstrates less dynamic ROM of the hip (FAIS, $67.8^\circ \pm 12.4^\circ$ versus control, $78.6^\circ \pm 13.1^\circ$; $P = .001$) and knee (FAIS, $71.9^\circ \pm 9.4^\circ$ versus control, $78.0^\circ \pm 11.7^\circ$; $P = .020$) compared to controls. People with FAIS also demonstrate less dynamic coronal plane pelvis ROM (FAIS, $11.3^\circ \pm 4.9^\circ$ versus control, $15.6^\circ \pm 7.4^\circ$; $P = .044$).

CONCLUSIONS: People with FAIS demonstrate impaired SLS squat performance and dynamic pelvis, hip and knee ROM compared to healthy controls.

CLINICAL RELEVANCE: Clinicians should consider including exercises that target dynamic sagittal plane ROM impairments at the hip and knee, which could potentially help to improve squat performance. However, rehabilitation programs should be tailored to the patient's specific biomechanical deficits.

SP0110

COMPARISON OF ALL-CAUSE MORTALITY IN PROFESSIONAL WRESTLERS FROM 1980 TO 1990 AND PROFESSIONAL BODYBUILDERS FROM 1965 TO 1985

Z. Taggart Wilber, Stephanie Wilber, James Smoliga

PURPOSE/HYPOTHESIS: Premature deaths of professional bodybuilders (PB) competing from 1965 to 1985 and wrestlers (PW) performing from 1980 to 1990 were historically attributed to steroid abuse. Newer evidence indicates

that head trauma might contribute to early death in athletes, including PW. Physical therapists (PTs) are involved with the care of athletes of all levels, so it is important to understand how these 2 factors influence long-term health. The purpose of this study was to examine the mortality rates of athletes from sports with a historical culture steroid abuse, comparing those with repeated head impact exposure (PW) to those without (PB).

NUMBER OF SUBJECTS: Three hundred five World Wrestling Federation and National Wrestling Alliance male PW who performed in televised or pay-per-view events from 1980 to 1990 and 171 male PB who competed in an International Federation of Bodybuilding and Fitness show from 1965 to 1985.

MATERIALS AND METHODS: Subject characteristics were collected for both sports via online databases. Due to homogeneity of body composition in PB and heterogeneity body composition in PW, a photo of each PW was ranked 1 to 3 (lean, moderate, overweight) by 2 independent raters and by a third in the case of disagreement. To conservatively address confounders, athletes with overweight phenotype, careers <5 or >30 years, no confirmed date of birth/death, or who died 0 to 2 years of retirement were excluded. Linear mixed effects models were used to quantify differences in predictor variables between sports. Survival analysis was performed using a Cox proportional hazards model. Sport (PB versus PW) served as a categorical variable and career duration was a continuous covariate.

RESULTS: Ninety-three PB and 120 PW met inclusion criteria. PB had significantly shorter careers than PW (12.8 versus 19.8 years, $P < .001$) and also had lower BMI (31.1 versus 32.9 kg/m², $P < .001$). Survival analysis revealed a statistically significant effect for sport (odds ratio = 1.88; 95% confidence interval: 1.05, 3.36; $P = .033$) and for elite career duration length (odds ratio = 0.95; 95% confidence interval: 0.92, 0.99; $P = .029$).

CONCLUSIONS: For a given age and career duration, PW are at greater mortality risk than PB, indicating exposure to head trauma increases risk of death in athletes. Previous studies have identified mental illness and cardiovascular disease as potential causes of death in athletes. Additionally, these findings support the use of a wholistic cardiovascular and neurologic evaluation for all athletes with a history of head impacts. It is important to note that the on-stage BMI for both PB and PW may not reflect their true/normal weight.

CLINICAL RELEVANCE: For PTs involved in athlete care, it is important to educate athletes on the variety of mortality risks associated with head impact and offer prevention strategies. Many active and retired athletes who were previously exposed to head impacts will visit PTs for various reasons. The addition of a wholistic screen for early neurologic and cardiovascular signs could facilitate early intervention to prevent premature mortality in both active and retired athletes.

SP0111

SKILL LEVELS IMPACT SEX DIFFERENCES IN ROCK CLIMBING-SPECIFIC GRIP STRENGTH

Shawn Caitlin Wood, Johnathon R. Crawley, Emily Jennifer Higgins, Stephanie Huang, Claire Elizabeth Lorbiecki, Lena Naomi Parker, Kevin Michael Cowell, Erika Jo Nelson-Wong

PURPOSE/HYPOTHESIS: Rock climbing has evolved from training for mountaineering to inclusion in 2021 Olympics. Research has shown multiple factors contribute to skill, particularly grip strength. Currently, females make up 38% of licensed climbing athletes worldwide. This study aims to compare climbing-specific grip strength, in a variety of hand/shoulder positions, between sexes across skill levels. The intent is to guide rehabilitation and training specific to sport, sex and skill level. We hypothesize that there will be force differences between sexes in all hand/shoulder combinations, and these differences will not be impacted by climbing skill level.

NUMBER OF SUBJECTS: Forty-nine (23 female, 26 male; age, 19–48 years).

MATERIALS AND METHODS: Participants' self-reported climbing grades were used to categorize into sex adjusted skill levels as recommended by the

International Rock Climbing Research Association. After warm up, participants completed max pull testing protocols using a 20-mmute lip climbing hold attached to a load cell sampled at 250 Hz. Max isometric pulls were performed with dominant hand in 2 grip types: Open grip (second-fourth digits of DIP and PIP joints greater than 90°) and half-crimp (second-fifth digits of PIP at 90°) in 90° and 120° of shoulder flexion. Two trials were tested per position with 2-min rest between each trial. Force values were normalized and expressed as a percent of body weight (percent BW). Paired t tests were used to determine repeatability between trials. No between trial differences were found, therefore trials were averaged. Force data were entered into 2-by-2 ANOVAs (sex by skill level) with Bonferroni adjusted t tests used for post hoc multiple comparisons as needed. Significance threshold was set at .05. SPSS was used for statistical analyses.

RESULTS: There were significant main effects for sex and skill level for all hand/shoulder positions, with males having higher force than females, and force increasing with skill. There were also significant sex-by-skill interactions for Open 90 ($F_{2,42} = 3.8$, $P = .03$), half-crimp 90 ($F_{2,42} = 3.2$, $P = .05$), and half-crimp 120 ($F_{2,42} = 4.4$, $P = .02$). Post hoc tests revealed males had higher force than females in half-crimp 90 (68.8% $\pm$ 13.5% BW versus 51.9% $\pm$ 10.8% BW) and half-crimp 120 (70.7% $\pm$ 13.6% BW versus 51.5% $\pm$ 10.1% BW) positions for the Advanced category. For the Elite category, males had higher force than females in Open 90 (84.6% $\pm$ 11.8% BW versus 56.8% $\pm$ 7.0% BW), half-crimp 90 (101.0% $\pm$ 7.3% BW versus 70.5% $\pm$ 13.0% BW), and half-crimp 120 (103.0% $\pm$ 11.9% BW versus 69.9% $\pm$ 12.2% BW) positions. There were no sex differences in the Intermediate categories.

CONCLUSIONS: These findings show males have higher grip force than females in all hand/shoulder positions tested. Sex difference were impacted by climbing skill and only started to appear at higher skill levels. As climbers progress, females may rely more on technique, footwork and overall body strength rather than grip strength. Limitations of this study include sex adjusted skill categorization with lower grade thresholds for females and self-reported ability.

CLINICAL RELEVANCE: These findings may provide insight for clinicians and athletes to consider sex differences in grip strength at higher climbing performance levels.

SP0112

ASSESSMENT OF IMPACT ACCELERATIONS DURING PERFORMANCE OF COMMON BALLET MANEUVERS

Paj Nra Yang, Caitlin Fallon, Kyle Micheal Gamoke, Nicole Corene Bednarz, Michelle Marie Reilly, Thomas Gus Almonroeder

PURPOSE/HYPOTHESIS: Ballet dancers perform a high volume of maneuvers that involve jumping and landing during training, rehearsals, and performances. The impact forces generated during ballet landings produce accelerations that are transmitted proximally up the kinetic chain. These impact forces/accelerations place substantial loads on the lower body, which likely contributes to the high rates of lower extremity injury among dancers. Currently, our understanding of which ballet maneuvers result in the greatest lower body loading is unclear. Developing a better understanding of which ballet maneuvers tend to be relatively high impact could help therapists and dance instructors make more informed recommendations regarding which maneuvers an individual should avoid when returning to dance following injury. Therefore, the purpose of this study was to compare the impact accelerations produced by different ballet maneuvers.

NUMBER OF SUBJECTS: Eleven uninjured female adolescent ballet dancers.

MATERIALS AND METHODS: Each dancer performed 9 different common ballet maneuvers in random order. The maneuvers performed were the glissade, pas de chat, petit jete, petit assemble, grand assemble, grand jete, saut de chat, changement, and entrechat quatre. An inertial sensor se-

cured to the pelvis was used to record 3-D accelerations as the dancers performed the maneuvers, and the peak resultant acceleration ("impact acceleration") was identified for each landing (units of g). Previous studies have found that impact accelerations recorded via a pelvis-worn inertial sensor are strongly correlated with the magnitude of the ground reaction force ("impact force") during landing (Almonroeder et al 2020; Simons and Bradshaw 2016), indicating that wearable inertial sensors can be used to indirectly assess lower body loading. Repeated-measures ANOVA was used to compare the impact accelerations among the various maneuvers and post hoc tests were conducted to compare each pair of maneuvers. An alpha of .05 was used for all statistical tests.

RESULTS: The results of the omnibus test indicated that there were differences in impact accelerations among the maneuvers ($P < .001$). In general, the glissade (2.08 ± 0.47 g), pas de chat (2.33 ± 0.23 g), petit jete (2.42 ± 0.29 g), and petite assemble (2.54 ± 0.47 g) tended to produce relatively low impact accelerations, while the grand assemble (2.90 ± 0.41 g), grand jete (2.99 ± 0.33 g), and saut de chat (3.13 ± 0.54 g) tended to produce more moderate impact accelerations. The highest impact accelerations were recorded for the changement (4.10 ± 0.48 g) and entrechat quatre (4.32 ± 0.52 g) maneuvers.

CONCLUSIONS: Impact accelerations differed among the various ballet maneuvers, with the highest impact accelerations recorded for the changement and entrechat quatre.

CLINICAL RELEVANCE: Our results may serve as a basis for prescribing a gradual return to dance following injury, where dancers are initially encouraged to exclusively perform low and moderate impact maneuvers, before progressing to higher impact maneuvers, such as the changement and entrechat quatre.

SP0113

THE EFFECTS OF THE COVID-19 LOCKDOWN ON CLINICAL MEASURES IN DIVISION I COLLEGE SOFTBALL PLAYERS

Giorgio Zeppieri, Brushwood Ashlyn, Marissa Pazik, Katie M. Davis, Michael W. Moser, Kevin W. Farmer, Federico Pozzi

PURPOSE/HYPOTHESIS: The COVID-19 pandemic resulted in a global disruption of college sports. The 2020 college softball season was suspended and eventually cancelled as part of the NCAA response to mitigate the pandemic's spread. This action led to an interruption in organized training as softball players were forced to isolate and unable to use the university's weight room, training, and practice facilities. The purpose

of this study was to examine the effect of the COVID-19 lockdown on shoulder and hip range of motion (ROM) and strength in college softball players.

NUMBER OF SUBJECTS: A prospective cohort of 15 NCAA Division I college softball players (mean $\pm$ SD age, 19.9 ± 1.3 years; height, 1.7 ± 0.1 m; weight, 77.2 ± 9.5 kg; BMI, 27.0 ± 3.1 kg/m²).

MATERIALS AND METHODS: Players participated in 3 data collections: before the start of the 2020 season (January 2020, pre lockdown), after return to campus (September 2020, post lockdown), and before the start of the 2021 season (January 2021). During the lockdown, players did not participate in organized practice or game. Training and within team scrimmage games resumed but were abbreviated after players returned to campus in September. 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. In the analysis we used the clinical measure of the dominant upper extremity and the average between the left and right lower extremity. A 1-way ANOVA with repeated measures was used to compare the effect of time on each preseason clinical variable. In the presence of a main effect of time, pairwise comparison assessed difference between time points (January 2020 versus September 2020; and January 2020 versus January 2021).

RESULTS: We found significant main effect of time for dominant shoulder ER ($P < .01$) and IR ($P = .05$) ROM, and average hip ER ($P < .01$) and IR ($P = .04$) ROM. Shoulder ER ROM decreased 6.5° ($P = .05$), while shoulder IR ROM increased 4.3° ($P = .02$) between January and September. There were no differences of shoulder ER and IR ROM between January 2020 and 2021 ($P = .24$). Hip ER ROM increased 5.1° ($P < .01$) between January 2020 and 2021. No significant main effect of time was found for shoulder and hip strength ($P = .08$).

CONCLUSIONS: Abrupt long-term reduction of organized training affects dominant shoulder and hip ROM. However, it does but not affect shoulder and hip strength of softball players. Resumption of organized practice normalize dominant shoulder ROM.

CLINICAL RELEVANCE: College softball players were more likely to demonstrate a change in dominant shoulder ER, IR, and hip ROM as a result of the decreased training volume following the COVID-19 lockdown, however these findings contrast the usual adaptations seen in overhead athletes (increased dominant shoulder ER, and decreased dominant shoulder IR and hip ROM). Practitioners should be aware of the potential changes in clinical variables after a prolonged period of detraining.

CORRIGENDUM

STATISTICAL ERRORS IN THE FOREST plots in an article from the August 2020 issue of the *JOSPT*, “Which Interventions Enhance Pain Self-efficacy in People With Chronic Musculoskeletal Pain? A Systematic Review With Meta-analysis of Randomized Controlled Trials, Including Over 12 000 Participants,” were

recently discovered. Due to an error with the Stata command used for the meta-analysis (“admetan”), the effect measures with a negative sign generated an error in the forest plots (weights were calculated by the inverse of the variance). As a consequence, incorrect weights were presented in **FIGURES 3** through **6**.

The effect measures of each subgroup, the adjustment tests, and the interpretation of the results were unaffected by the errors in weights.

The authors have revised and corrected the forest plots using the “metan” command. The updated article is available at www.jospt.org. ●

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Hitting the Ground Running in 2022: A New Face and a Renewed Commitment From the JOSPT Editorial Board

CLARE L. ARDERN, PT, PhD
Editor-in-Chief

JACKIE WHITTAKER, PT, PhD
Editor

J Orthop Sports Phys Ther 2022;52(1):1-2. doi:10.2519/jospt.2022.0101

Introducing a New Member of the JOSPT Editorial Team

Last month, we bade farewell to our tireless (and tendon-loving) colleague and friend, Dr Karin Silbernagel, who served the JOSPT community for 7 years as Associate Editor and then as 1 of 4 Editors.

This month, we welcome self-described “knee nerd” Dr Jackie Whittaker, PT, PhD, to the role of JOSPT Editor. Dr Whittaker joins Dr Joshua Cleland, Dr Bryan Heiderscheit, Dr Steven Kamper, Dr Christopher Hughes, and Dr Clare Ardern on the senior editorial team of JOSPT.

Dr Whittaker identifies as a global citizen who embraces the diversity of the planet and its many inhabitants. She recharges by traveling, exercising in nature (easy to do when one lives in beautiful British Columbia), spending quiet (and quality) time with her family and animals, and regularly meditating.

Many in the JOSPT community will have read Dr Whittaker’s field-leading work in preventing and treating sports injuries^{2,4} and knee osteoarthritis^{1,5} (including serving as cochair of the international Stop OsteoARthritis program; <https://bit.ly/SOARKnee>), listened to her engaging and energetic presentations (virtual or in person, Dr Whittaker always brings panache and pizzazz), and observed her commitment to the #GlobalPT com-

munity through her service as chair of the World Physiotherapy Congress 2023 planning committee.

What excites her about joining the JOSPT Editorial Board? Using this platform to build capacity for inclusive research and practice across the breadth of musculoskeletal rehabilitation. Dr Whittaker is committed to serving the broad JOSPT community, learning about her own implicit biases, empowering diverse voices, innovating, and bridging the gap between clinical practice and research.

We Should Reflect the Community We Are Privileged to Serve—so Why Do so Many Journals Look Like They’re Stuck in a Time Warp?

As representatives of an organization that aspires to serve the musculoskeletal rehabilitation community, including those who work in sports, we were intrigued by a recent analysis of the editorial boards of some of our peers in the Sport Sciences (*Journal Citation Reports* category) field.³ The paltry number of female editorial board members



New JOSPT Editor Dr Jackie Whittaker.

(fewer than 1 in every 5 editorial board positions in 14 of the top journals were occupied by women) is shocking, but perhaps sadly unsurprising to at least half of the community.

Especially disappointing was that the positions of Editor-in-Chief of all 14 journals were exclusively occupied by men.³ Yes, you read that right: no women at the top of some of the apparently leading Sport Sciences journals in the 2020s.

JOSPT’s experience is that there are plenty of excellent and well-qualified women who are ready and willing to

[EDITOR'S NOTE]

embrace the responsibility and work of serving on a journal editorial board. If a journal says, "We've asked around and there were no women," perhaps it is time to query, "Whom did you ask?" We humbly suggest that the *JOSPT* (and other journals) is proof that women can (and do) serve journal editorial boards with distinction.

Yet, *JOSPT* is far from perfect. In 2022, we are redoubling our efforts to ensure the *JOSPT* Editorial Board reflects the diverse musculoskeletal rehabilitation community (clinicians, researchers, and patients) that we are privileged to serve.

In welcoming Dr Whittaker to the *JOSPT* Editorial Board team, we also

take the opportunity to celebrate the important contributions to the *JOSPT* community of the 17 women (46% of 37 Editorial Board members, including Dr Silbernagel) who serve on the *JOSPT* Editorial Board and, by extension, serve the vibrant *JOSPT* community. ●

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SEND Letters to the Editor-in-Chief

JOSPT welcomes **letters related to professional issues or articles published in the *Journal***. The Editor-in-Chief reviews and selects letters for publication based on the topic's relevance, importance, appropriateness, and timeliness. Letters should include a summary statement of any conflict of interest, including financial support related to the issue addressed. In addition, letters are copy edited, and the correspondent is not typically sent a version to approve. Letters to the Editor-in-Chief should be sent electronically to jospt@jospt.org. Authors of the relevant manuscript are given the opportunity to respond to the content of the letter.

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The “SHRed Injuries Basketball” Neuromuscular Training Warm-up Program Reduces Ankle and Knee Injury Rates by 36% in Youth Basketball

● **OBJECTIVE:** To evaluate the effectiveness of a neuromuscular training warm-up prevention program, Surveillance in High school and community sport to Reduce (SHRed) Injuries Basketball, for reducing all-complaint ankle and knee injuries in youth basketball players.

● **DESIGN:** Quasi-experimental study.

● **METHODS:** High school/club basketball teams (male and female players aged 11-18 years) in Calgary, Canada participated in 2016-2017 (control; season 1) and 2017-2018 (intervention; season 2). The control season included a standard-of-practice warm-up. In season 2, a SHRed Injuries Basketball coach workshop was completed by participating team coaches. Teams were randomized by school/club to an unsupervised or a supervised (weekly supervision by study personnel) implementation of the coach-delivered SHRed Injuries Basketball program. The 10-minute SHRed Injuries Basketball program included 13 exercises (ie, aerobic, agility, strength, balance). All-complaint ankle and knee injuries were collected weekly using validated injury surveillance. Multilevel, multivariable Poisson regression analyses (considering important covariates, clustering by team and individual, and

offset by exposure hours) estimated incidence rate ratios (IRRs) by intervention group (season 1 versus season 2) and secondarily considered the control versus completion of the SHRed Injuries Basketball program, unsupervised and supervised.

● **RESULTS:** Sixty-three teams (n = 502 players) participated in season 1 and 31 teams (n = 307 players: 143 unsupervised, 164 supervised) participated in season 2. The SHRed Injuries Basketball program was protective against all-complaint knee and ankle injuries (IRR = 0.64; 95% confidence interval [CI]: 0.51, 0.79). Unsupervised (IRR = 0.62; 95% CI: 0.47, 0.83) and supervised (IRR = 0.64; 95% CI: 0.49, 0.85) implementations of the SHRed Injuries Basketball program had similar protective effects.

● **CONCLUSION:** The SHRed Injuries Basketball program was associated with a 36% lower rate of ankle and knee injuries. Neuromuscular training warm-ups are recommended as the minimal standard of practice for injury prevention in youth basketball. *J Orthop Sports Phys Ther* 2022;52(1):40-48. doi:10.2519/jospt.2022.10959

● **KEY WORDS:** adolescent, athletic injury, basketball, injury prevention, neuromuscular training, sport

Sport is the leading cause of injury among youth.^{2,3,10,13,15,23,29} The highest rates of injury are in team sports,^{10,13} including basketball.^{4,11,17,28,40} Given that basketball is one of the most popular sports among Canadian youth, the burden of youth basketball injuries is substantial.^{4,11,17,28,40} Randomized controlled trials have shown that neuromuscular training warm-up programs can reduce injury rates by 29% to 60% in team sports.^{11,12,20,41}

Ankle and knee injuries are common in youth basketball.^{4,10,35,36} Gradual-onset injuries occur as frequently as acute injuries.^{18,25,27} Tendinopathies are among the most prevalent gradual-onset injuries in team sports.¹⁴ Patellar tendinopathy is common in basketball players,^{6,16} likely because players frequently make jumping and landing maneuvers, stops, and

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direction changes, leading to impulsive loading on the patellar tendon. While neuromuscular training programs can prevent acute injuries,^{19,38} their specific effect on tendinopathies is unknown. The preventative effect of neuromuscular training programs on ankle and knee injury risk, considering all-complaint injury definitions to capture injuries such as tendinopathies, is also unknown.

While evidence from systematic reviews supports the use of neuromuscular training programs for preventing sports injury,^{1,7,12,15,21,30,45,47-49} it is unclear how to successfully implement programs in community settings.^{33,51} There is no added benefit of physical therapist-supported implementation of the 11+ neuromuscular training injury prevention warm-up following a practical coach workshop in youth soccer, compared to traditional coach delivery following a workshop.⁴⁶ Given that implementation outcomes are dependent on contexts, it is relevant to further examine these delivery strategies and explore their potential injury risk mitigation effects.

The Surveillance in High school and community sport to Reduce (SHRed) Injuries Basketball neuromuscular training program was adapted from a neuromuscular training program evaluated in floorball and soccer.^{20,41} Some exercise components were modified based on feedback from basketball coaches, physical therapists, strength and conditioning coaches, and basketball players in focus group and interview settings. The 10-minute neuromuscular training warm-up comprises 4 components: aerobic and movement preparation (eg, running drills, change of direction), strength (eg, trunk exercises, the Nordic hamstring exercise), agility (eg, hops, jumps), and balance (eg, single leg, dynamic). Time constraints are a barrier to neuromuscular training adoption,^{8,22,31,43} and limiting the duration of the program to 10 minutes was a priority to improve adherence.

The primary aim of this study was to evaluate the effectiveness of the SHRed

Injuries Basketball neuromuscular training warm-up program for reducing ankle and knee injuries in youth basketball. We also evaluated the effectiveness of 2 implementation strategies (supervised and unsupervised) on reducing injuries in youth basketball players and explored the weekly prevalence of Achilles and patellar tendinopathies.

METHODS

Study Design and Participants

THIS QUASI-EXPERIMENTAL DESIGN IS part of the Injury Prevention in Youth Basketball study, a 2-season project examining basketball-related injuries and risk factors focusing on patellar and Achilles tendinopathies and injury prevention interventions among youth basketball players. Following approval by the school or club administration, coaches and players registered with Alberta High School Athletics (player age, 11-18 years) and the Calgary Minor Basketball Association (2016-2017 and 2017-2018 seasons) and in the top 3 divisions of play (U15 and U18 age groups) were invited to participate. Male and female teams were recruited through the coach and/or team manager. This study was approved by the University of Calgary Conjoint Health Research Ethics Board (ethics approval number REB16-0864).

Eligibility Criteria

Adolescents aged 11 to 18 years in grades 10 to 12 in a high school in Calgary or surrounding regions who were participating on an interscholastic basketball and/or club basketball team were eligible for inclusion. An informed-consent form was signed by all study participants and their parent/guardian prior to study enrollment. Exclusion criteria were (1) recent (within 6 weeks) history of low back, hip, knee, or ankle injury requiring medical attention or the inability to participate in basketball at the commencement of the season; (2) history of systemic disease (eg, cancer, arthritis); (3) neurological disorder (eg, head injury, cerebral palsy);

and (4) history of bone fracture or surgery in the past year that interfered with the ability to participate fully in basketball at the commencement of the season.

Control, Season 1

In season 1, no intervention was offered. Coaches used standard-of-practice warm-ups before practices and games, and this served as the control comparison study group.

Intervention, Season 2

In season 2, all participating high school and club basketball teams were cluster randomized by school/club to 2 groups: (1) the SHRed Injuries Basketball neuromuscular training program coach workshop and supervised weekly follow-up by study personnel (supervised), or (2) the SHRed Injuries Basketball neuromuscular training program coach workshop (unsupervised). The school/club was the unit of randomization, meaning that all teams from the same school/club were assigned to the same group. All team coaches received access to the educational video used in the coach workshop in season 2. To ensure allocation concealment, the randomization sequence (random number generation) was produced by an investigator who was not involved in recruitment. Study group allocation was revealed to study personnel prior to the coach workshop.

Teams in both groups were provided a preseason coach workshop on the SHRed Injuries Basketball neuromuscular training program and a link to a video of the neuromuscular training exercises (see <https://www.youtube.com/watch?v=QLvB9eTC5J8>) and the SHRed Injuries Basketball neuromuscular training program handout (supplemental file). All coaches in both study groups were invited to a 3-hour SHRed Injuries Basketball neuromuscular training workshop, held by a research physical therapist (K.P.) at the University of Calgary before the season. During a workshop, coaches took part in theoretical and practical sessions about basketball injury prevention

and the exercises comprising the SHRed Injuries Basketball neuromuscular training program. All coaches (from both study groups) had the contact number of research personnel if they had questions. In the supervised group only, research personnel visited weekly team practices to support and help coaches with the intervention training and to facilitate proper technique and progress of the SHRed Injuries Basketball exercises. Coaches in both study groups were asked to carry out the SHRed Injuries Basketball program at the beginning of all training sessions (at least 3 times a week) for 10 minutes. The SHRed Injuries Basketball program comprises 4 components: (1) aerobic (4 exercises with 2 having different versions for level 1 and 2), (2) agility (2 exercises with different versions for level 1 and 2), (3) strength (5 exercises with different versions for level 1 and 2), and (4) balance (2 exercises with different versions for level 1 and 2).

Sample Size

The sample-size calculation was based on prevalence comparison (season 1 versus season 2), as this was the original plan for analyses: an injury prevalence of 30% in youth basketball,¹¹ with an intraclass correlation of 0.06, dropout/nonadherence rate of 0.05, average of 8 players per team, significance level of .05, power of 80%, and conservatively estimated relative risk reduction of 33% in youth team sports.^{9,11,12} We aimed at recruiting 452 players (57 teams) each year. Given that exposure data were collected, comparison of rates was deemed to be the most appropriate method, despite the original sample-size calculation.

Injury, Exposure, and Adherence Registration

An all-complaint injury methodology, including an injury report form completed by study personnel and a self-report, was used. All acute and gradual-onset injuries and basketball exposure were recorded weekly by the team designates (team trainer or coach or manager) assigned

to each team, using a validated injury report form and weekly exposure sheet, respectively.⁹ Injuries were registered with the structured injury report form, which included details on time and place of occurrence and the cause, type, location, and severity of the injury. All participants completed the Oslo Sports Trauma Research Center (OSTRC) patellar tendinopathy questionnaire and the OSTRC Achilles tendinopathy questionnaire weekly, both adapted from the validated OSTRC overuse injury questionnaire.⁵ The tendinopathy questionnaires comprise the original OSTRC questionnaire and additional questions to determine the weekly presence or absence of patellar and/or Achilles tendinopathy.³⁹ The injury report form targets medical attention and time-loss injuries, while the OSTRC patellar and Achilles tendinopathy questionnaires target knee and ankle pain and patellar and Achilles tendinopathies. The OSTRC patellar tendinopathy questionnaire has been validated against clinical evaluation in youth basketball players, with an overall sensitivity of 79% and specificity of 98%.³⁷ Details on injury data management, including data audits and removal of duplicates, have been previously described.³⁹ A report of a knee or ankle injury on the OSTRC tendinopathy questionnaires was considered an incident. Recurrent knee or ankle injuries reported over consecutive weeks were only treated as 1 new-onset incidence. Injury data management following study completion was completed by the study physical therapist (O.O.).

Team designates recorded player participation (individual player attendance, duration of training session/game, content of training session) in practices and games on the weekly exposure sheet. The team designate recorded all scheduled warm-up sessions (ie, date, duration, exercises completed, modifications of exercises) and player participation for each session on a warm-up form. The team adherence to the SHRed Injuries Basketball neuromuscular training program was based on the total number of SHRed

Injuries Basketball warm-up sessions completed weekly.

Statistical Analysis

Data were stored and managed using REDCap electronic data-capture tools hosted at the University of Calgary. REDCap is a secure, web-based application designed to support data capture for research studies. Data analyses were completed using R⁴² and Stata (StataCorp LLC, College Station, TX).

Baseline demographics were reported (mean $\pm$ SD or median [interquartile range; IQR] for numeric variables and frequencies and percentages for categorical variables) by study group and sex. Injury outcomes included all knee and ankle injuries. Hours of participation were imputed for participants missing basketball exposure, based on median hours by team and league (school, club). Covariate imputation was performed using multiple imputation by chained equations. Median imputation was used for hours of participation. Based on multiple imputation by chained equations, patterns for missingness were checked in R ("mdpattern" function) and "missing at random" was assumed (10 imputations with a maximum of 70 iterations each). Variables considered for imputing missing previous injury were age, sex, season, weight, height, participant ID, team number, and exposure hours. Crude rates were estimated for all ankle and knee injuries together for each study group, for all participants, and stratified by sex; and 95% confidence intervals (CIs) were estimated, considering clustering (team and participant) and offset by exposure hours, for each season.

For the main aim, a multivariable, multilevel Poisson regression model was performed to estimate incidence rate ratios (IRRs) and 95% CIs for the primary intention-to-treat analysis for all-complaint ankle and knee injuries. We compared the injury incidence rates between season 1 (control) and season 2 (treatment), adjusting for sex (considering the interaction between sex and intervention group) and previous injury, informed by

previous randomized controlled trials evaluating neuromuscular training in youth sport.^{9,11,12} The number of exposure hours was used as an offset, and team- and participant-level random effects were examined to consider the clustering at each level. For the secondary analysis, a similar multivariable, multilevel Poisson regression model was used to compare the injury incidence rates between season 1 (control), season 2 (unsupervised), and season 2 (supervised) ($\alpha = .05$).

In an exploratory analysis, crude season prevalence estimates were reported for all players, by sex and season. Weekly prevalence (ie, total number of players reporting symptoms/total number of OSTRC tendinopathy questionnaires returned) of patellar and Achilles tendinopathies was estimated and displayed graphically, by season, for each outcome. Adherence to the SHRed Injuries Basketball neuromuscular training warm-up

program was reported for each intervention group using median utilization frequency with IQR.³⁷

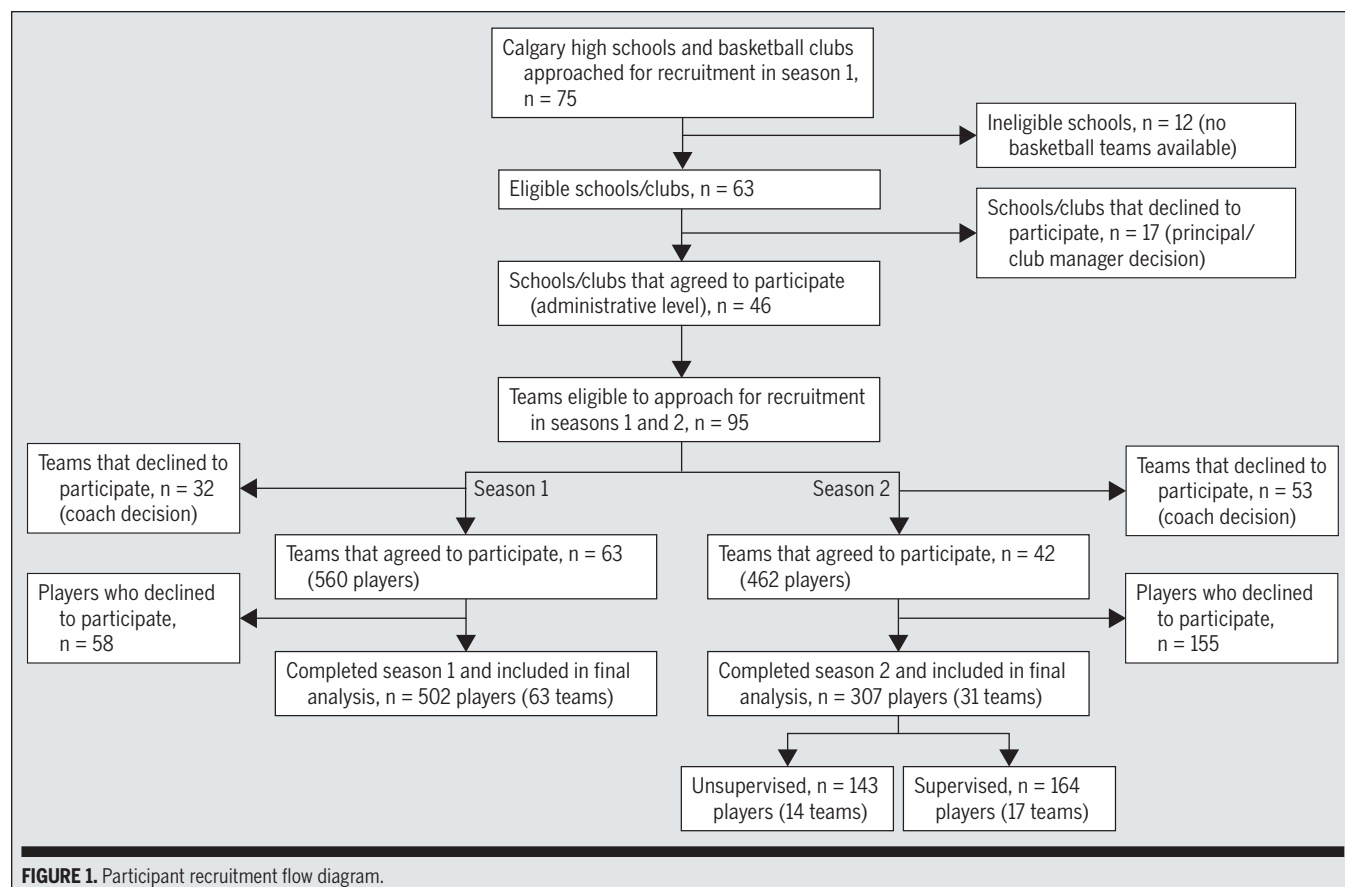
RESULTS

FIFTY-TWO HIGH SCHOOLS AND 23 basketball clubs were invited to participate in season 1 (2016-2017); 19 schools and 25 clubs were invited to participate in season 2 (2017-2018) (**FIGURE 1**). In season 1 (control), we recruited 63 basketball teams (from 19 schools and 12 clubs) and 502 players ($n = 195$, 38.8% female), and in season 2 (intervention) we recruited 31 teams (from 15 schools; 9 were the same schools as in season 1) and 307 players ($n = 172$, 56% female). Baseline study participant characteristics are summarized in **TABLE 1**. Sixty-seven players participated in seasons 1 and 2.

Crude injury rates for all-complaint knee and ankle injuries are summarized in

TABLE 2 across season 1 (control) and season 2 (intervention), and in **TABLE 3** (season 2: supervised and unsupervised). The prevalence of Achilles and patellar tendinopathies is reported in **TABLE 4** across season 1 (control) and season 2 (intervention). The primary analysis (multilevel, multivariable Poisson regression model) showed that the SHRed Injuries Basketball neuromuscular training warm-up program was protective against all-complaint ankle and knee injuries (IRR = 0.64; 95% CI: 0.51, 0.79). Players with a previous injury history (1 year) had a 23% higher rate of injury (IRR = 1.23; 95% CI: 1.02, 1.49), and the protective effect did not differ by sex (IRR = 1.00; 95% CI: 0.81, 1.24).

A secondary multilevel, multivariable Poisson regression model showed that the SHRed Injuries Basketball neuromuscular training warm-up program was protective against all-complaint knee and ankle injuries for both unsu-



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TABLE 1

BASELINE PARTICIPANT CHARACTERISTICS^a

	Season 1 (n = 502)		Season 2: Unsupervised (n = 143)		Season 2: Supervised (n = 164)	
	Male (n = 307)	Female (n = 195)	Male (n = 59)	Female (n = 84)	Male (n = 76)	Female (n = 88)
Age, y ^b	16 (11-18)	16 (13-18)	16 (14-18)	16 (14-17)	16 (14-18)	16 (14-17)
Missing	51 (16.6)	28 (14.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Height, cm ^c	178.5 (13.5)	168.0 (10.9)	180.6 (12.5)	167.6 (13.9)	183.0 (11.8)	171.0 (11.1)
Missing	26 (8.5)	9 (4.6)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.1)
Weight, kg ^c	67.3 (16.1)	61.2 (13.1)	71.4 (16.7)	61.6 (12.7)	71.0 (14.2)	63.1 (12.1)
Missing	23 (7.5)	11 (5.6)	2 (3.4)	0 (0.0)	0 (0.0)	1 (1.1)
Previous injury (1 y)						
Yes	121 (39.4)	105 (53.8)	26 (44.1)	38 (45.2)	31 (40.8)	44 (50.0)
No	121 (39.4)	72 (36.9)	20 (33.9)	38 (45.2)	29 (38.2)	27 (30.7)
Missing	65 (21.2)	18 (9.2)	13 (22.0)	8 (9.5)	16 (21.1)	17 (19.3)

^aValues are n (percent) unless otherwise indicated.

^bValues are median (range).

^cValues are median (interquartile range).

TABLE 2

ALL-COMPLAINT CRUDE INJURY RATES FOR ANKLE AND KNEE INJURIES: BOTH SEASONS

	Season 1 (Control)				Season 2 (Intervention)			
	Players, n	Injuries, n	Player Participation, h	IR per 1000 h ^a	Players, n	Injuries, n	Player Participation, h	IR per 1000 h ^a
All	502	354	29933.23	11.8 (10.2, 13.5)	307	202	26486.28	7.6 (6.2, 9.0)
Male	307	216	17773.75	12.2 (10.0, 14.3)	135	79	11523.20	6.9 (4.9, 8.8)
Female	195	138	12159.47	11.3 (8.9, 13.8)	172	123	14963.08	8.2 (6.3, 10.1)

Abbreviation: IR, injury rate.

^aValues in parentheses are 95% confidence interval.

TABLE 3

ALL-COMPLAINT CRUDE INJURY RATES FOR ANKLE AND KNEE INJURIES: SEASON 2

	Unsupervised Intervention				Supervised Intervention			
	Players, n	Injuries, n	Player Participation, h	IR per 1000 h ^a	Players, n	Injuries, n	Player Participation, h	IR per 1000 h ^a
All	143	97	13072.68	7.4 (5.5, 9.4)	164	105	13413.60	7.8 (5.9, 9.8)
Male	59	42	5209.73	8.1 (4.8, 11.3)	76	37	6313.47	5.9 (3.4, 8.4)
Female	84	55	7862.95	7.0 (4.6, 9.4)	88	68	7100.13	9.6 (6.6, 12.6)

Abbreviation: IR, injury rate.

^aValues in parentheses are 95% confidence interval.

pervised and supervised intervention groups (unsupervised IRR = 0.62; 95% CI: 0.47, 0.83 and supervised IRR = 0.64; 95% CI: 0.49, 0.85). Players with a previous injury history (1 year) had a 23% higher rate of injury (IRR = 1.23; 95% CI: 1.01, 1.49). All-complaint ankle

and knee injury rates did not differ in female and male players (IRR = 1.00; 95% CI: 0.81, 1.24). The protective effect did not differ by sex in the 2 models; as the interaction term between sex and intervention group was not significant, it was removed from the model. The fi-

nal model included intervention group (season 1 versus season 2 in the primary analysis, and season 1 versus season 2 [unsupervised] versus season 2 [supervised] in the secondary model) as the main exposure, sex and previous injury as covariates, exposure hours as the

TABLE 4

SEASON PREVALENCE OF PATELLAR TENDINOPATHY AND ACHILLES
TENDINOPATHY FOR THE CONTROL AND INTERVENTION SEASONS

	Season 1 (Control)		Season 2 (Intervention)	
	Players, n	Percent of Total	Players, n	Percent of Total
Patellar tendinopathy				
All	502	18.5	307	16.0
Male	307	23.2	135	17.3
Female	195	12.8	172	15.0
Achilles tendinopathy				
All	502	4.4	307	3.9
Male	307	4.2	135	3.8
Female	195	4.6	172	4.1

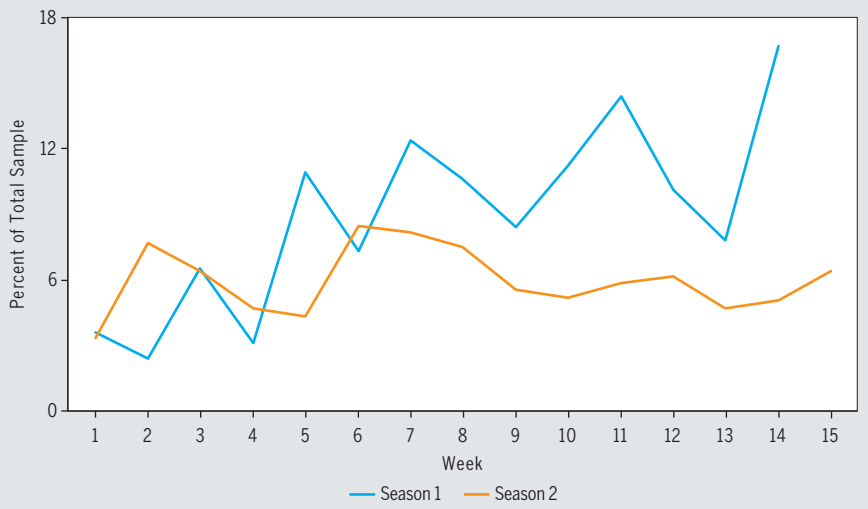


FIGURE 2. Weekly prevalence of patellar tendinopathy: control (season 1) versus intervention (season 2).

offset, and team and participant level as random effects.

TABLE 4 summarizes the prevalence of patellar and Achilles tendinopathies (male and female). The prevalence of patellar tendinopathy was higher in male players and similar between male and female players for Achilles tendinopathy. **FIGURES 2 and 3** summarize weekly prevalence of patellar and Achilles tendinopathies in season 1 and in season 2, respectively.

Adherence in this study to the SHRed Injuries Basketball neuromuscular training program, based on weekly use frequency, was similar in the unsupervised (median, 2.2; IQR, 1.9) and supervised (median, 2.4; IQR, 1.1) intervention

groups. The cumulative use of the SHRed Injuries Basketball neuromuscular training program (proportion of total sessions possible) was 75% in the unsupervised intervention group and 80% in the supervised intervention group.

DISCUSSION

THIS QUASI-EXPERIMENTAL STUDY examining the effectiveness of a neuromuscular training warm-up program in reducing all-complaint knee and ankle injuries in male and female youth basketball players showed a 36% reduction in all-complaint knee and ankle injury rates. A secondary analysis

showed a similar protective effect, with a 38% lower all-complaint knee and ankle injury rate with unsupervised and a 36% lower rate with supervised SHRed Injuries Basketball neuromuscular training warm-up program implementation, compared with a control warm-up, over the 16-week study period. Players with a 1-year injury history had 23% higher all-complaint knee and ankle injury rates, with no evidence of effect modification by sex.

The protective effect for all-complaint knee and ankle injuries was similar to those previously reported in sport-specific youth studies for lower extremity injuries.^{9,11,20,24,26,32,34,41,44,50} The effect of neuromuscular training strategies for preventing knee and ankle tendinopathies has not been previously evaluated. Based on descriptive statistics, there appears to be no overall protective effect of neuromuscular training on the overall season prevalence of patellar and Achilles tendinopathies, but more research is needed. Graphically, weekly prevalence trends across the season for patellar tendinopathy (**FIGURE 2**) and Achilles (**FIGURE 3**) tendinopathy are summarized; however, further longitudinal analyses exploring these trends in a larger sample are warranted. Adherence to the SHRed Injuries Basketball neuromuscular training program was reasonable, based on participating in at least 2 sessions per week, and similar in the unsupervised (2.2 times per

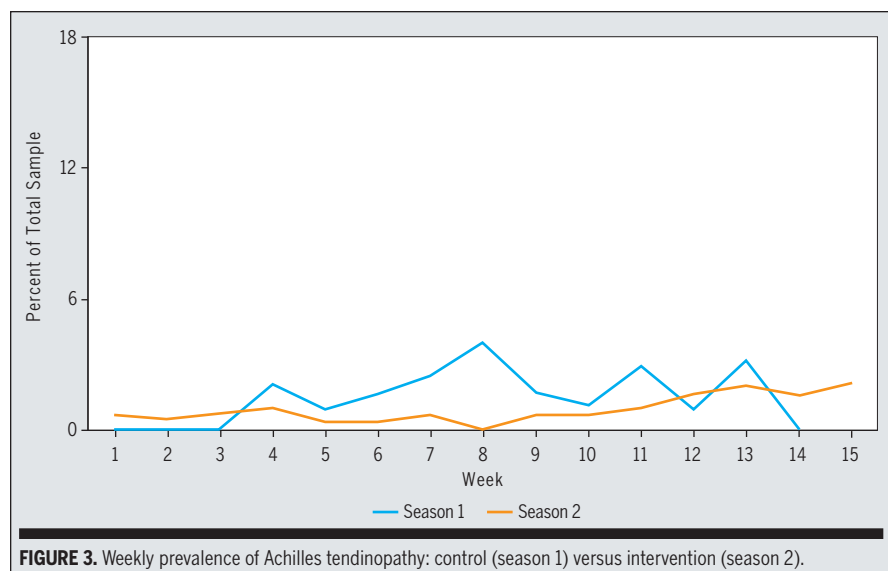


FIGURE 3. Weekly prevalence of Achilles tendinopathy: control (season 1) versus intervention (season 2).

week, 75% of potential sessions) and supervised intervention groups (2.4 times per week, 80% of potential sessions). A larger sample would be necessary to consider a per-protocol analysis or rates of knee and ankle injuries separately.

Strengths and Limitations

The strengths of this quasi-experimental study design include a sample size sufficient to study all-complaint ankle and knee injury rates. The use of a previously validated youth community injury surveillance methodology, the collection of individual-level exposure data, and controlling for clustering by team and participant were all study strengths. Limitations include generalizability based on schools and clubs agreeing to participate in the study. Although the original sample size was based on season prevalence and the number of teams for season 2 was lower than desired, a significant effect of treatment was found in all-complaint knee and ankle rates. Despite teams being randomized to unsupervised or supervised implementation intervention groups in season 2, the quasi-experimental study design has limitations related to equal distribution of unmeasured confounders between seasons 1 and 2.

Known covariates that may influence outcomes were considered in the

analyses, and key characteristics were balanced between study seasons and between the unsupervised and supervised implementation intervention groups. The reasons that school principals and coaches declined to participate were based on other time and school commitments, and therefore may not be related to the outcomes of interest.

This study was powered on the comparison of injury prevalence between season 1 (control) and season 2 (intervention), not on rates. The study was not powered for the secondary aim of comparing the supervised and unsupervised intervention. Despite similar injury rates in these groups, type II error may be a consideration. A larger sample would be required to consider trends in weekly prevalence of patellar and Achilles tendinopathies over time, and interpretation of descriptive weekly prevalence is limited. Analyses were adjusted by team-level cluster rather than by the school level, as coaching is at the team level and this is considered the most significant factor influencing player behaviors.

CONCLUSION

THE SHRED INJURIES BASKETBALL neuromuscular training warm-up program was associated with low-

er rates of all-complaint knee and ankle injuries in male and female youth basketball players. Neuromuscular training warm-ups are recommended as the minimal standard of practice for injury prevention in youth basketball. ●

KEY POINTS

FINDINGS: A neuromuscular training warm-up program is protective against all-complaint ankle and knee injuries in youth male and female basketball players aged 11 to 18 years. Coach delivery of a neuromuscular training warm-up following a comprehensive coach workshop is effective in reducing knee and ankle injuries, and the protective effect was similar with and without additional weekly supervision by a neuromuscular training coach workshop trainer.

IMPLICATIONS: We recommend that coaches deliver a neuromuscular training warm-up program as the minimal standard of practice for injury prevention in youth basketball (age, 11-18 years).

CAUTION: Future research with a larger sample would be required to evaluate trends in weekly prevalence of patellar and Achilles tendinopathies over time.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: Drs Emery, Owoye, Palacios-Derflingher, and Pasanen contributed to the study proposal development. Drs Owoye and Räisänen and Kimberley Befus and Tate HubkaRao contributed to data collection, data entry, and data cleaning. Drs Emery, Owoye, Räisänen, Palacios-Derflingher, and Pasanen and Kimberley Befus contributed to the data analysis and interpretation of study results. Drs Emery, Owoye, and Pasanen contributed to acquisition of funding and study design and led all aspects of the cohort. All authors critically reviewed and edited the manuscript before submission.

DATA SHARING: There are no data available.

PATIENT AND PUBLIC INVOLVEMENT: Basketball Alberta and Alberta High School Athletics were involved as the knowledge broker community partners in contrib-

uting to approval of study design, study recruitment, injury surveillance methods, development of intervention and control group programs, and dissemination of research findings within the school community. The research questions and outcome measures were developed and informed by the priorities, experiences, and preferences of the Basketball Alberta and Calgary school boards. Players, parents, teachers, coaches, and administrators were dedicated to the collection of weekly exposure data, identification of a student with a suspected injury, and supporting communication with the research team for injury follow-up. Partners from Basketball Alberta, the Calgary Board of Education, and the Calgary Catholic School board have received an executive report of the study findings, based on preliminary results and an abstract presented at the Canadian Academy of Sport and Exercise Medicine (2019) symposium, and will inform dissemination of final study results in the school community once the final manuscript results are published. The Alberta Injury Prevention Centre and the University of Calgary Sport Injury Prevention Research Centre will contribute to evidence-informed safety guideline updates for Alberta schools and Basketball Alberta.

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Demystifying Qualitative Research for Musculoskeletal Practitioners Part 3: Phenomeno—what? Understanding What the Qualitative Researchers Have Done

Qualitative research is broad, and its use in the musculoskeletal field represents a small section of a very large landscape. Diverse fields ask different questions and use different strategies to answer them. A qualitative study in musculoskeletal rehabilitation may focus on understanding patients' pain beliefs, while a qualitative study in education may focus on understanding how students from lower socioeconomic backgrounds engage in tertiary education. These studies have different purposes of inquiry and need different strategies to reach their desired outcomes. These different strategies are termed and categorized in many ways: "approaches," "inquiries," "methodologies," "research designs," "methodological frameworks," "methodological approaches," and so on. Authors of qualitative research must always strive to be explicit and transparent about the way they have used terms—something that is not always done well.

To illustrate how the different strategies may be categorized, we have provided some examples in the **APPENDIX**. In this series, we use the term *methodological approach* to encompass the plan of action that underpins the use of methods and desired outcomes.⁹ Here, we focus on what we believe are the key methodological approaches you might encounter in musculoskeletal qualitative research.

To better understand what a methodological approach is, consider the metaphor of building a house. Now that the foundation is laid, we are ready to build.

The house needs both a "concept" and a "plan." The concept for the house may be an apartment, a family home, or a mansion. To make the concept a reality, researchers need a plan that lays out the steps to build the house. The steps may change along the way in response to what materials are available, or to the availability of construction workers. However, the overall concept for the house remains constant. The methodological approach may be thought of as building the house, which encompasses what the researchers are attempting to investigate (the concept) and their plan for the investigation (the building plan). Understanding the methodological approach allows the reader to understand how the qualitative study was "done," from data collection through analysis and findings.

A Note on Theoretical and Conceptual Frameworks

The theoretical framework of a qualitative study can be a difficult concept for both novice and experienced researchers—let alone musculoskeletal practitioners simply trying to read a qualitative study for the first time. There is continued debate about what theory is and its role in qualitative research. Theory has been

• **SYNOPSIS:** In part 3 of "Demystifying Qualitative Research for Musculoskeletal Practitioners," we introduce the concept of "methodological approach" to encompass the plan of action that underpins the use of methods and desired outcomes, as well as the use of theory. Understanding the methodological approach in a qualitative study gives the reader a sense of what the qualitative researchers have "done," while theory has varying uses and mean-

ings depending on type of qualitative study. In this installment, we cover some of the common methodological approaches used in the musculoskeletal field and provide a discussion about the different ways in which theory can be considered and used in a qualitative study. *J Orthop Sports Phys Ther* 2022;52(1):3-7. doi:10.2519/jospt.2022.10485

• **KEY WORDS:** qualitative research, qualitative research design, qualitative theory

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considered to have no role in qualitative research,^{2,13} to represent the methodology and underpinning philosophical perspectives,^{8,9,11,16,25} or to play a broader role in framing and conducting the study.^{1,12,19} In the latter, “theory” is considered to be established social or psychological theories,¹ for example, the fear-avoidance model, Maslow’s hierarchy of needs, or Foucault’s

theory of power, or informal theories such as the researcher’s own ideas.²⁷

Theory can also refer to conceptual frameworks that encompass the broader context of influencing factors guiding the study, from inception through analysis and findings, such as the literature review, the researcher’s own disciplinary orientation, and formal or informal theo-

ries.²⁷ For example, in a musculoskeletal study seeking to understand pain beliefs, a conceptual framework may draw on theories of health behavior in addition to disciplinary knowledge about neurobiological mechanisms or explanations to guide how the research question is formed, the study is designed, and the data are analyzed.

TABLE

METHODOLOGICAL APPROACHES, WITH WORKED EXAMPLES

Approach	Description
Phenomenology	Phenomenology is both a form of philosophy and a type of qualitative research dating back to the work of Husserl (1859-1938). The philosophical focus of phenomenology is the experience itself and how experiencing something is transformed into consciousness. The term <i>lived experience</i> is often associated with phenomenology, as researchers using this approach are often aiming to understand an individual’s lived experience related to a particular phenomenon.²⁹ Since the development of phenomenology from the work of Husserl, there have been various approaches to phenomenological research, which you can read more about in Rodriguez and Smith.²⁸ Here, we are going to focus on interpretive phenomenology, as this is a common form seen in health science research. Interpretive phenomenology was developed by Heidegger (1889-1976), a student of Husserl’s. This approach to phenomenology uses “hermeneutics,” which is the philosophy of interpretation. Interpretive phenomenology is interested in interpreting and describing human experience through a process of in-depth reflective inquiry.²⁹ Interpretive phenomenology uses small, purposeful samples who have experienced the phenomenon of interest.²⁹ Participants are interviewed to gain rich, reflective insights into their experiences.²⁹ Although one-on-one interviews are typically the favored method of data collection, some researchers have also used diary entries and focus groups. Analysis in interpretive phenomenology asks researchers to deeply immerse themselves in the data. Following this, initial notes may be taken, along with development of early themes by identifying “chunks” of the data.^{17,29} These chunks will be compared across cases, and researchers will consider whether there are any key patterns.^{17,29} The final stages of analysis are a deeper consideration of the patterns and themes across the cases and how they relate to existing theory.^{17,29} Phenomenological research can be particularly useful for musculoskeletal and orthopaedic research through understanding complex and emotionally laden experiences,²¹ an opportunity for us to walk in participants’ shoes. For example, from patient accounts, we can better understand where treatment provisions may be best placed. In Snelgrove and Liossi,³⁰ the authors interviewed 10 people with chronic low back pain and identified 3 key themes: “maintaining integrity,” “the crucial nature of pain,” and “managing the pain,” which indicated that the participants understood their pain within a biomedical model. The findings illuminated areas where practitioners can provide helpful pain education to patients experiencing this condition, especially with respect to the use of behavioral strategies due to the participants’ strong biomedical beliefs that may be resistant to cognitive approaches
Grounded theory	Grounded theory was founded by Glaser and Strauss,^{14,15} who examined the experience of death and dying in California hospitals in 1967. Its development was revolutionary during a time when qualitative methods were not considered a rigorous approach to inquiry.^{6,15} Since the development of the original form of grounded theory (now referred to as Glaserian or classical grounded theory), divergent approaches have formed. You can read more about these different approaches in Charmaz.⁷ However, despite the different approaches, a key component of all grounded theory research is constructing theory through a systematic and rigorous analysis. As grounded theory research aims to create new theory, this methodological approach does not typically use existing formal theory as a guiding influence for the study. However, studies may use a conceptual framework to situate and contextualize the design of the study and findings. Grounded theory is also concerned with how meaning is created among communities, rather than individual narratives. Here, we will focus on constructivist grounded theory, a contemporary form of grounded theory gaining popularity in health sciences, which exists within an interpretivist paradigm Constructivist grounded theory was founded by Kathy Charmaz, a former student of Glaser and Strauss. Constructivist grounded theory treats grounded theory as a series of tools for researchers to use and adapt to fit their research question, and acknowledges researchers’ backgrounds as influential in the data analysis.^{7,22} Constructivist grounded theory emphasizes the influence of constructivism, which centers the analysis on the participants’ construction of meaning and events.²² Constructivist grounded theory also emphasizes the coconstruction of meaning between the researcher and the participant (ie, acknowledging the researcher’s role in the analysis and findings).²² To create rigorous theory, grounded theory research employs methods such as “theoretical sampling,” where participants are purposefully selected to explore emerging key themes in the analysis.⁶ Additionally, “constant comparison” is often used, where the researcher is constantly comparing and moving between different stages of analysis (raw data and development of theory) to ensure the theory is grounded in the accounts of the participants⁶ Clinical decision making and therapeutic approaches in osteopathy were discussed in a qualitative grounded theory study³¹ that used a constructivist grounded theory approach, where the authors aimed to create an explanatory theory of clinical decision making and therapeutic approaches of experienced osteopaths in the United Kingdom. The authors purposively sampled osteopaths and used one-on-one interviews. The results revealed 3 key viewpoints that resulted in divergent approaches to patient management: the treaters, the communicator, or the educator. The results were presented in an explanatory model. The findings of this work illuminated the different approaches to, and drivers of, treatment decision making in this profession. This study provides important information about the provision of evidence-based practice in osteopathy

Table continues on page 5.

Last, theory can be the product of a study, as in grounded theory research, where the end point is creating a new theory (**TABLE**). Grounded theory research can create theories about practitioners' decision-making processes or how people with chronic pain make sense of their condition, which may be presented in a conceptual model or diagram.

It is important for authors of qualitative research to be explicit about how theory was used in their study, as this provides evidence for its relevance and rigor, from study inception through analysis and findings. Back to our house metaphor: theoretical and conceptual frameworks can be considered as guiding the design intent of the house. For example, within

an apartment, what are the color schemes, interior layouts, and lighting styles? The concept and plan for the house (methodological approach) will remain the same; however, how it appears will be influenced by the design intent (theoretical or conceptual framework). Of course, the design intent can influence the house in different ways. One approach may be

TABLE

METHODOLOGICAL APPROACHES, WITH WORKED EXAMPLES (CONTINUED)

Approach	Description
Interpretive description	Interpretive description, a more recent methodological approach, was developed by nursing scholars as a form of qualitative inquiry into human health and illness experiences for the purpose of developing nursing knowledge.³² The development of this methodology was in response to calls for more pragmatic forms of qualitative research, which may "borrow" from other methodological approaches such as grounded theory or phenomenology. Interpretive description research is located within existing clinical knowledge, so that it can build on previous knowledge and clinical practice³² When conducting an interpretive description study, participants are sampled with the intention to explore themes emerging from the analysis and from existing theory. Data collection in interpretive description generally includes one-on-one interviews but can also include clinical papers, case reports, and media information. Analytic techniques under this methodological approach encourage the researcher to ask questions of the data, such as, "what is happening here?" and "what am I learning about this?"³² These techniques favor broader theorizing and contextualizing of the data as compared to sorting and coding.³² The analysis in interpretive description also ends with descriptions (themes and patterns between themes) rather than the development of theory Interpretive description has become a useful methodological approach in musculoskeletal research. In Darlow et al,³⁰ the researchers used interpretive description to advance clinical knowledge of how beliefs related to low back pain may influence the perception of threat. Twelve participants with acute low back pain and 11 participants with chronic low back pain were interviewed. Participants described their back pain as vulnerable, needing protection, and unlikely to heal. The authors also described the findings as analogous to self-prejudice, which has been described as part of the maintenance of mental health disorders through attention bias toward negative information.²⁴ This is an example of authors retrospectively applying their findings to an existing theoretical framework to better understand their results. The findings from this study suggest that practitioners should be wary of patients holding self-prejudicial views of their back. Due to this, this study highlights the importance for practitioners to provide positive and empowering education and be wary of information that can reinforce negative beliefs
Generic qualitative research	Generic qualitative research, otherwise known as basic qualitative research, is often described in publications simply as a "qualitative research study," without declaring a specific approach. Similar to interpretive description, generic qualitative research offers more pragmatism than the traditional social sciences (such as grounded theory or phenomenology) but may borrow techniques from these traditions. As discussed in part 2, a key characteristic of qualitative research is that individuals construct reality within their social worlds. Thus, constructivism underlies a generic qualitative research approach.^{20,26a} The overarching purpose of this approach is to understand how people make sense of their lives and experiences^{19,26} Although all forms of qualitative research have some component of seeking to understand, generic qualitative research does not have a specific dimension of this.^{5,19} For example, phenomenology seeks understanding of a lived experience and grounded theory aims to build theory, whereas generic qualitative research just seeks an understanding of a particular phenomenon Generic qualitative research has strength in its flexibility.²⁶ Approaches can be either inductive or deductive, depending on the purpose of the research. The steps taken to answer the research question can be adapted based on the discipline or field asking the question. However, generally, the overall analysis will involve a thematic analysis,^b which will start with initial codes that will collapse into categories and themes to describe the data.²⁶ Data-collection approaches can vary and may include one-on-one interviews, focus groups, observations, diary entries, and so on.²⁶ Due to the flexibility of generic qualitative research, this approach tends to fit well with mixed-methods designs, whereby quantitative and qualitative research methods are integrated to create a broader understanding of phenomena.²⁶ However, it should be noted that although the generic qualitative research approach is flexible, that does not mean the research rigor is any less than other methodological approaches; each methodological decision must be transparent and carefully documented An article by Mallon et al¹⁸ is an example of a generic qualitative study, in which the authors interviewed 16 patients who had experienced a periprosthetic knee infection and subsequent revision surgery. The transcripts were analyzed thematically, and the authors used a theoretical framework of "biographical disruption." Biographical disruption is an explanatory theory of the disruptive experience of chronic illness,⁴ and was used as a theoretical framework to guide the analysis and findings in this study. The experiences of the participants were characterized according to 3 aspects of biographical disruption: onset and the problem of recognition, emerging disability and the problem of uncertainty, and chronic illness and the mobilization of resources. The results indicated that the experience of such infections was devastating for the patient and that current support services were insufficient. Thus, the researchers recommended preparing patients preoperatively for adverse events and better educating health care professionals about early signs of infection

^aAlthough generic qualitative research is generally accepted to be constructivist in nature, some authors may indicate a different epistemological foundation to their generic qualitative inquiry.

^bThematic analysis as a method of data analysis is not to be confused with reflexive thematic analysis and other variants, which are considered stand-alone methodological approaches. For further reading on the distinctions, see Braun and Clarke.³ Generic qualitative analysis can also encompass different approaches to data analysis, such as constant comparison, but thematic analysis is commonly employed.²⁶

in the form of formal design, such as adhering to art deco principles (eg, using a theoretical framework such as Foucault's theory of power), whereas the other may borrow from a range of design influences to achieve a specific look and feel (eg, using a conceptual framework that may be informed by the literature review, the researcher's disciplinary knowledge, and integration of relevant discipline theories such as health behavior theories).

In the discussion of different methodological approaches below, we indicate whether a study used a theory to give you an idea of how theories appear and influence qualitative studies.

Relevant Methodological Approaches

The **TABLE** explains some key methodological approaches you will encounter in musculoskeletal research: phenomenology, grounded theory, interpretive description, and generic qualitative research. This is not an exhaustive list. However, we have selected those we believe you will most commonly encounter. All of the methodological approaches described have rich histories and origins. It is beyond the scope of this introductory series to elaborate on them; we have provided references if you wish to read further. For an introduction to other important methodological approaches that are not included here, such as ethnography and discourse analysis, we suggest the work of Nicholls.²³

Summary

By now, you will have begun to develop a better sense of what a methodological approach is in qualitative research and some of the key approaches used in the musculoskeletal field. In part 3, we attempted to provide an introductory overview of theoretical and conceptual frameworks and how their role in qualitative research will vary. In part 4, we explore different qualitative methods. ●

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APPENDIX

CATEGORIZATION OF QUALITATIVE STRATEGIES^a

	Description
Crotty ²	Four elements: epistemology (objectivism, subjectivism, etc), theoretical perspective (positivism, critical inquiry, feminism, etc), methodology (experimental research, grounded theory, action research, discourse analysis, etc), and methods (sampling, measurement, observation, focus group, case study, narrative, etc)
Patton ⁴	Sixteen theoretical traditions: ethnography, grounded theory, semiotics, chaos theory, etc
Creswell ¹	Five approaches: narrative research, phenomenology, grounded theory, ethnography, and case study
Denzin and Lincoln ³	Presents multiple strategies of inquiry, including case studies, ethnography, grounded theory, and participatory action research
Rossman and Rallis ⁵	Discusses 4 main research genres: ethnographic, phenomenological, sociolinguistic, and case studies

^aBy no stretch is this an exhaustive list of how qualitative research strategies are categorized. However, the idea here is to demonstrate how different authors view qualitative research differently. Importantly, there is no singular or correct way to organize the diversity of these research approaches.

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Demystifying Qualitative Research for Musculoskeletal Practitioners Part 4: A Qualitative Researcher's Toolkit—Sampling, Data Collection Methods, and Data Analysis

Methods are the techniques used to gather and analyze data.⁵ Returning to the house metaphor we introduced in part 2, from the foundations (ontology and epistemology), the concept and plan for the house (methodological approach), and the design intent (theoretical or conceptual frameworks), the methods are like the tools and materials used to build the house. Qualitative researchers use broad data-collection and data-analysis strategies. For example, data collection may encompass one-on-one interviews, focus groups, participant observation, and document analysis, as well as more innovative strategies such as photographs, art, online forums, and much more. Data-analysis approaches are also very broad and may include thematic analysis, constant comparison, hermeneutics, conversation analysis, observation analysis, narrative analysis, and much more. To learn more about the different analytic and data-collection approaches,

*The SAGE Handbook of Qualitative Data Analysis*⁷ is a useful resource.

In this installment, we focus on describing sampling methods, the specific data-collection methods of interviews and focus groups, and the specific data-analysis method of thematic analysis. These methods are commonly used in musculoskeletal qualitative research and are also comparatively easy to grasp. Although the different qualitative methods appear to be presented in a linear format below, this is not the process for most qualitative research. Instead, sampling, data collection, and data analysis occur

at the same time. As most qualitative research is inductive in nature, concurrent sampling, data collection, and data analysis allow researchers to thoroughly explore all aspects of their research question and pursue emerging ideas by adjusting their sampling approach, interview schedule, and data analysis during the course of the study.

Sampling

Sampling approaches in qualitative research can encompass people or other sources such as text, art, and video. Here, we focus on sampling that involves people, which is common in musculoskeletal research. Sampling focuses on recruiting a specific group of people who have experienced a phenomenon of interest. Sampling strategies will vary according to the research question. For example, a study on a sensitive topic such as drug use may employ “snowball” sampling, in which participants inform other potential participants about the study.¹² The technique is useful for sensitive topics, so that the participants have greater trust in the researchers. In musculoskeletal research, you will often see purposive sampling, an intentional selection of informants based

• **SYNOPSIS:** In this editorial, we discuss common methods used in musculoskeletal qualitative research, including approaches to sampling, data collection, and data analysis. We take a particular focus in this editorial on methods that involve “speaking to people.” We highlight the back-and-forth or cyclic nature of qualitative research, and

introduce readers to the use of natural language processing to analyze qualitative data. *J Orthop Sports Phys Ther* 2022;52(1):8-10. doi:10.2519/jospt.2022.10486

• **KEY WORDS:** musculoskeletal research, qualitative methods, qualitative research

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on their ability to elucidate a specific theme, concept, or phenomenon.¹⁴

Sampling ends (and therefore interviews cease) at saturation, which means the researchers believe that recruiting more participants will not change the existing key findings.¹¹ There is some debate as to what constitutes saturation; however, this term is most commonly used to indicate that no new ideas were found in the final interviews.¹¹ Therefore, for researchers to know if they have reached saturation, it is important that data collection and data analysis are conducted at the same time. Qualitative researchers seek to understand common underlying patterns and processes within a diverse sample, and saturation is often achieved within relatively small samples. Qualitative research is not concerned with the prevalence of views, beliefs, or experiences, nor does it aim to draw inferences from these to the wider population.¹⁵ Rather, qualitative research has strength in rich descriptions drawn from purposeful samples. Qualitative research aims for transferability via in-depth descriptions of the sample, so that readers can assess how transferable the findings are to another setting.⁹

Data Collection

There are many different methods of data collection. Musculoskeletal qualitative research typically uses methods of “speaking to people,” such as one-on-one interviews and focus groups. We anticipate that in the future, researchers may expand their use of creative methods, participant observation, and document analysis.

One-on-one interviews are a conversation between a researcher and a participant. Interviews are most useful when it is important to gain a rich understanding of individual experiences and beliefs.¹⁰ Focus groups are a structured discussion between a researcher and a small group, typically 6 to 8 people. This is useful to gain the opinions of a group of people as a whole, and allows participants to bounce ideas and experiences off one another.¹⁰

Both one-on-one and focus group interviews can be considered a conversation with a purpose.^{10,13} Researchers endeavor to understand things that cannot be directly observed, such as thoughts, feelings, and emotions, or how participants view the world and the meanings they bring to it; “the purpose of interviewing, then, is to allow us to enter into the other person’s perspective.”¹³

Data Analysis

The choice of data analysis will largely depend on the methodological approach. For example, in narrative approaches, researchers analyze large “chunks” of data, in contrast to grounded theory, which favors line-by-line analysis.³ Although there are many different approaches to data analysis in qualitative research, a common theme among most forms of qualitative analysis is sorting the data into similarities and differences to capture features of the data that are relevant to the research question. This is true of thematic analysis (we provide a simple overview below). For a more in-depth description of how thematic analysis is conducted, please see the work of Braun and Clarke.^{1,2,4}

Thematic analysis generally begins with researchers familiarizing themselves with the data, which involves thoroughly reading all transcripts.⁴ Next, the researcher begins coding. A “code” is the smallest unit of data analysis that captures features of the data that are of interest to the research question.⁴ Coding can be inductive, meaning the codes are derived from the data (ie, based on words or phrases used by the participants), or deductive (decided before the analysis began and then applied to the words and phrases used by the participants).⁶ Then, the data are collapsed into categories and subthemes, summarizing the key features of the data.⁴ Categories and subthemes are then collapsed into themes—larger patterns in the data, built by codes, categories, and subthemes, which present the key findings of the analysis.⁴ Sometimes, authors refer to “codes” as “nodes,” and

often terms such as *categories*, *subthemes*, and *themes* are used interchangeably. Each of these terms essentially means “qualitative data,” with similar features grouped together. We have provided an example of transforming raw data into codes, categories, and themes in the supplemental file.

Thematic analysis does not occur in a linear format; in addition to concurrent sampling, data collection, and data analysis, there is constant movement between the raw data, codes, categories, and themes. This is often referred to as an “iterative” approach to analysis.³ This allows researchers to ensure the findings are grounded in the participants’ narratives, and informs whether emerging ideas can be better explored through adjusting the interview schedule and the characteristics of the participants they recruit.³

What About Qualitative Data Analyzed by Machine Learning?

Recently, machine learning has experienced a boom in popularity. Natural language processing, a discipline within artificial intelligence that leverages linguistics and computer science to make human language intelligible to machines, has become popular. Natural language processing has the potential to substantially reduce the time required of researchers to read and code numerous transcripts.

Natural language processing assesses the frequency of words or phrases in the transcripts (quantitative method), rather than interpreting meaning in respect to the methodological approach and research question. Additionally, the previous knowledge and experience the researcher brings to a qualitative study are important to creating interpretations that will be useful in practice. While it may be acceptable to use natural language processing as an adjunct to the analysis in the form of a “second coder,” it should not be treated as the primary researcher.⁸ Natural language processing is not to be confused with qualitative

data-management software, such as NVivo and MAXQDA. Data-management software can be a useful adjunct to the research process and is popular among many qualitative researchers. The software is not doing the analysis; rather, consider the software as a sophisticated filing system for qualitative data.

Summary

In this editorial, we looked at specific methods, the materials and tools used in qualitative research. In part 5, we will discuss “rigor,” or the quality of qualitative studies. ●

STUDY DETAILS

AUTHOR CONTRIBUTIONS: All authors contributed to the conception and design of the work, drafted the work or revised it critically for important intellectual content, approved the final version to be published, and agree to be accountable for all aspects of the work to ensure that questions related to the accuracy or integrity of any part of the work are ap-

propriately investigated and resolved.

DATA SHARING: There are no data in this editorial.

PATIENT AND PUBLIC INVOLVEMENT: Patients and the public were not involved in the development of this editorial.

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Dr Freddie H. Fu, MD

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I first met Dr Freddie H. Fu, orthopaedic surgeon and researcher, at the Panther Symposium in Pittsburgh in 1992. He was an engaging, high-energy blend of expertise in scholarship, research, service, and teaching. I used to joke with friends and colleagues at meeting receptions that when Freddie entered the room it was like Mick Jagger making an appearance. In reality, he was more like the Beatles.

Dr Fu possessed too many essential qualities to be accurately compared to any one person or thing. At a European Society of Sports Traumatology, Knee Surgery and Arthroscopy meeting in 2008, he informed the surgeons in attendance that he had been putting his ACL graft in the “wrong place” for more than 20 years, not giving sufficient attention to anatomy and individual patient differences. I was never more impressed by an orthopaedic surgeon for being so forthcoming and honest. Soon, it seemed that sports medicine surgeons started to follow Dr Fu’s lead—they were more willing to admit that their patients’ outcomes were below the 90%+ success rates that seemed to be the norm at the time. By Dr Fu admitting that he was not perfect, it was easier for others to admit that they, too, were less than perfect.

In 2009, I had the pleasure of welcoming Dr Fu to the University of Louisville Department of Orthopaedic Surgery as Visiting Professor and Resident Research Day Judge. I was so proud that he accepted the invitation. Several days after his acceptance, my wife and I received our adoption agency notice that

we needed to travel to Russia to meet our daughter during the time of Dr Fu’s planned visit. When I explained to Dr Fu that I could not attend his upcoming visit, his response was quick, concise, and heartfelt: “Family comes first.” I know that many people considered Freddie to be family, from locally throughout the greater Pittsburgh and University of Pittsburgh communities to globally through the hearts and minds that he touched through his teaching.

From his early days in Hong Kong, Freddie developed leadership skills playing basketball for St Paul’s College and lead guitar for a local rock band. In marrying Hilda, an artist, he found his life partner and expanded his understanding of the importance of ongoing learning, thinking, teaching, considering each patient as an individual, and striving to improve health care one patient at a time.

The JOSPT family extends our sympathies, condolences, and respect for Dr Fu to his wife, Hilda; his daughter, Joyce Lok-See Fu; his son, Gordon Ka-Hong Fu; his 5 grandchildren, Ludivine Ling-Yun Fu Martin, Alexander Zee-Yun Fu



Martin, Axel Wei-Yun Fu Martin, Kendrick Kai Cheng Fu, and Kasen Kai Sheng Fu; his mother, Mabel Fu; his sisters, Susan Lam and Jeanette Maeba; and his brothers, Frank Fu and Nigel Fu. He was preceded in death by his father, Ying Foo.

No one will replace Dr Freddie Fu. We strive to continue his wishes to “respect the past and embrace the future” in musculoskeletal health care.

Dr Freddie Fu passed away on September 24, 2021.

Respectfully,

John Nyland, DPT, SCS, EdD, ATC, CSCS, FACSM

President, JOSPT Board of Directors, on behalf of the JOSPT Board of Directors, Editorial Board, and staff

LETTER TO THE EDITOR-IN-CHIEF

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CONCERNS ABOUT THE METHODOLOGY AND DATA COLLECTION IN A SYSTEMATIC REVIEW

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I read “Diagnostic Accuracy of Clusters of Pain Provocation Tests for Detecting Sacroiliac Joint Pain: Systematic Review With Meta-analysis”⁶ with interest and want to thank the authors for their work. A diagnostic injection criterion was used as the gold standard against various clusters of clinical tests to diagnose sacroiliac joint pain. This information dramatically increases the utility of the review for clinical application of the data analysis. However, I do have a concern about including the study by Nejati et al,⁴ which used the motion palpation test (the Gillet test and forward flexion), along with pain-provoking tests (the flexion, abduction, external rotation test; thigh thrust test; Gaenslen test; yeoman test; compression test; distraction test; and Newton test).

Motion palpation tests for diagnosing the sacroiliac joint have long been disputed due to low interrater and intrarater reliability.^{3,5,10} Using motion palpation as a criterion for diagnosis limits the outcomes and conclusions. Nejati et al⁴ explicitly noted that “[a] major limitation . . . is the adoption of at least one positive palpation test as a diagnostic criteria [sic].” To be consistent with diagnostic test and cluster uses in the other articles in Saueressig et al’s⁶ meta-analysis, I feel that the article by Nejati et al⁴ is sufficiently different from the other 4 articles^{2,7-9} to warrant exclusion, due to

its use of a non-pain provocation test. The use of non-pain provocation tests may also explain why the sensitivity and specificity are significantly different from those in the other 4 studies. As this meta-analysis looks at the “diagnostic accuracy of clusters of pain provocation tests for detecting sacroiliac joint pain,” I believe including a study that uses motion palpation limits the strength of the review.⁶

If Saueressig et al⁶ include the Nejati et al⁴ study in the analysis, I feel they should consider including the alternative diagnostics reported by Laslett et al.² The repeated movement (McKenzie evaluation) and sacroiliac provocation test cluster results were not used in the meta-analyses. Inclusion of these alternative Laslett et al² results would be similar to those of Nejati et al,⁴ with the use of movement tests in determining outcomes. This would also bring consistency to the authors’ classification of the study by Laslett et al² in Table 1 of their review, where they report McKenzie evaluation as a part of the type of index test.⁶ Swapping the Laslett et al² cluster results would effectively raise the reported diagnostic odds ratio by about 1 point.

My second point concerns Schneider et al’s⁷ article. The authors corrected¹ aspects of their original study that may have been printed outside Saueressig et al’s⁶ search time frame or overlooked: an error was noted in referencing sensitivity and specificity in the Results section. However, while this may appear to be a minor issue, because Schneider et al⁷ did not publish their 2-by-2 table, Saueressig et al⁶ had to calculate it from incorrectly reported values. As such, these values contain the error that is displayed in Saueressig et al’s⁶ Figure 3. The sensitivity should be 0.56 (95% confidence interval: 0.34, 0.75) and the specificity should be 0.41 (95% confidence interval: 0.22, 0.64), and the 2-by-2 table should contain the following data: true positive, 10; false negative, 8; false positive, 10; true negative, 7. This will alter the meta-

analytic estimates reported in this review. My calculations find that this will raise the combined diagnostic odds ratio by about half a point.

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Dr Vraa presents educational material on sacroiliac joint diagnosis and interventions. He consults for a medical device company that addresses persistent sacroiliac joint pain, but the company had no influence, affiliation, financial involvement, or assistance in writing this letter to the editor.

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AUTHOR RESPONSE TO “CONCERNS ABOUT THE METHODOLOGY AND DATA COLLECTION IN A SYSTEMATIC REVIEW”

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We would like to thank Dr Vraa for his insightful comments on our article.⁴ We also thank Dr Vraa for pointing out the errors in the paper by Schneider et al.⁵ We were aware of the corrigendum¹ but did not consider it further because there were no data reported and there also was no mention of a change in that paper's Table 2, which included the data necessary for our analysis. We also contacted Dr Schneider for the raw data but received no response from him.

We have repeated our analysis with the corrected data from Schneider et al.⁵ (TABLE 1). No substantive changes are noted in comparison to our previous analysis (TABLE 2).

Dr Vraa questions our inclusion of the study by Nejati et al.³ He cites Nejati et al.³ to strengthen his critique but leaves out an important section: “A major limitation of the present study is that the adoption of at least 1 positive palpation test as a diagnostic criteria [sic] resulted in the 0 specificity of the palpation tests in SIJD-negative patients.”³ This section does not pertain to a cluster of pain provocation tests but to the evaluation of a single motion palpation test. We only considered for our analysis test clusters where more than 3 tests need to be positive to confirm a diagnosis of sacroiliac joint pain. As Nejati et al.³ used a test cluster of 3 or more tests from a pool of 9 tests (2 motion palpation and 7 pain provocation tests), we still think that the data reported by Nejati et al.³ fit into our analysis. Nevertheless, we performed a sensitiv-

ity analysis by removing the data from Nejati et al.³ from our original analysis (TABLE 2). No substantial changes were noted. We also performed a sensitivity analysis by including the data for the repeated movement evaluation by Laslett et al.² Again, no substantial changes were noted (TABLE 2). Overall, these additional sensitivity analyses show that the findings of our meta-analysis are robust to these variations in the underlying studies; a negative sacroiliac joint test cluster gives the clinician 93% certainty that sacroiliac joint pain is not present, but a positive test only gives the clinician 36% certainty that sacroiliac joint pain is present, assuming a prevalence of 20%.

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TABLE 1

TWO-BY-TWO TABLE WITH CORRECTED
VALUES FOR SCHNEIDER ET AL.⁵

Study ^a	TP	FN	FP	TN
Laslett et al. ²²	10	1	7	25
Nejati et al. ²⁷	37	2	8	1
Schneider et al. ³⁵	10	8	10	7
Stanford and Burnham ⁴⁰	9	2	10	13
van der Wurff et al. ⁴⁸	23	4	7	26

Abbreviations: FN, false negative; FP, false positive; TN, true negative; TP, true positive.

^aCitation numbers correspond to those in Saueressig et al.⁴

TABLE 2

SENSITIVITY ANALYSES

Analysis	Studies, n	Pooled Sensitivity ^a	Pooled Specificity ^a	FPR ^a	+LR ^a	-LR ^a	DOR ^a	PPV, % ^{a,b}	NPV, % ^{a,b}
Original results	5	0.83 (0.62, 0.93)	0.59 (0.36, 0.79)	0.41 (0.21, 0.64)	2.13 (1.20, 3.90)	0.33 (0.11, 0.72)	9.01 (1.72, 28.4)	35 (32, 37)	8 (6, 10)
New analysis ^c	5	0.83 (0.65, 0.93)	0.61 (0.39, 0.79)	0.39 (0.21, 0.61)	2.26 (1.35, 3.95)	0.30 (0.12, 0.59)	9.50 (2.50, 25.50)	36 (33, 39)	7 (5, 9)
With Nejati et al. ³ removed	4	0.78 (0.57, 0.90)	0.69 (0.55, 0.80)	0.31 (0.20, 0.45)	2.59 (1.39, 4.37)	0.35 (0.13, 0.71)	10.10 (1.97, 31.20)	39 (36, 43)	8 (6, 10)
Laslett et al. ^{2d}	5	0.83 (0.65, 0.93)	0.62 (0.36, 0.83)	0.38 (0.17, 0.64)	2.39 (1.28, 4.74)	0.30 (0.12, 0.61)	10.20 (2.27, 30.00)	37 (35, 40)	7 (5, 9)

Abbreviations: DOR, diagnostic odds ratio; FPR, false-positive rate; -LR, negative likelihood ratio; +LR, positive likelihood ratio; NPV, negative predictive value; PPV, positive predictive value.

^aValues in parentheses are 95% confidence intervals.

^bPrevalence of 20%.

^cWith corrected data from Schneider et al.⁵

^dWith data from the clinical examination (McKenzie evaluation).

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Developing Clinical and Research Priorities for Pain and Psychological Features in People With Patellofemoral Pain: An International Consensus Process With Health Care Professionals

Anterior knee pain is a characteristic of patellofemoral pain.⁴ Pain is defined by the International Association for the Study of Pain as “an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or

potential tissue damage.”²² The literature on patellofemoral pain is dominated by biomechanical models explaining the drivers of pain. A recent international expert consensus statement framed the pain in biomechanical terms, with the underlying assumption being abnormal patellofemoral joint loading with nociception,²¹ potentially overlooking a role for the underlying sensory and emotional processing as central phenomena associated with the pain experience.

In keeping with its definition, pain is a dynamic interaction that encompasses biological, psychological, and social factors.¹⁶ This biopsychosocial model is important in understanding the holistic management of persistent musculoskeletal conditions.^{10,17} There is an increased awareness that psychological and social factors are important in understanding patellofemoral pain.^{25,27} The result of this increasing awareness is underscored by the increase in conference abstracts on pain and psychological factors in patel-

• **OBJECTIVE:** To decide clinical and research priorities on pain features and psychological factors in persons with patellofemoral pain.

• **DESIGN:** Consensus development process.

• **METHODS:** We undertook a 3-stage process consisting of (1) updating 2 systematic reviews on quantitative sensory testing of pain features and psychological factors in patellofemoral pain, (2) an online survey of health care professionals and persons with patellofemoral pain, and (3) a consensus meeting with expert health care professionals. Participants responded that they agreed, disagreed, or were unsure that a pain feature or psychological factor was important in clinical practice or as a research priority. Greater than 70% participant agreement was required for an item to be considered important in clinical practice or a research priority.

• **RESULTS:** Thirty-five health care professionals completed the survey, 20 of whom attended the

consensus meeting. Thirty persons with patellofemoral pain also completed the survey. The review identified 5 pain features and 9 psychological factors—none reached 70% agreement in the patient survey, so all were considered at the meeting. After the meeting, pain catastrophizing, fear-avoidance beliefs, and pain self-efficacy were the only factors considered clinically important. All but the thermal pain tests and 3 psychological factors were considered research priorities.

• **CONCLUSION:** Pain catastrophizing, pain self-efficacy, and fear-avoidance beliefs were factors considered important in treatment planning, clinical examination, and prognostication. Quantitative sensory tests for pain were not regarded as clinically important but were deemed to be research priorities, as were most psychological factors. *J Orthop Sports Phys Ther* 2022;52(1):29-39. doi:10.2519/jospt.2022.10647

• **KEY WORDS:** clinical priorities, patellofemoral pain, psychological factors, research priorities

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[CONSENSUS STATEMENT]

lofemoral pain at the recent International Patellofemoral Research Retreats, increasing from 6% in 2015 to 29% in 2019. The growth in studies on pain features and psychological factors in patellofemoral pain led us to update pertinent systematic reviews^{5,14} and to use this updated evidence to develop priorities that inform both clinicians and researchers on this topic.

The objective of this consensus development process was to decide clinical and research priorities for pain features and psychological factors in persons with patellofemoral pain.

Methods

We updated 2 recent systematic reviews on pain features and psychological factors associated with patellofemoral pain (stage 1), followed by a survey (stage 2) to determine which were important clinically and priorities for research. The survey was followed by a consensus meeting (stage 3). The survey involved both persons living with patellofemoral pain and

health care professionals. The process was conceived and guided by the steering committee (B.V., M.S.R., S.H., L.M., B.S., and M.v.M.) and is outlined in **FIGURE 1**.

Participants

To achieve a representative group of experts for this consensus study, we selected health care professionals primarily based on their active engagement in original research within the 2 main focus areas (pain features and psychological factors) related to patellofemoral pain. We sought to achieve diversity in terms of different professional disciplines, sex, experience/ stage of career (senior, mid, and early), and geographical distribution. Experts were identified through the International Patellofemoral Research Network, www.expertscape.com, peer-reviewed publications, and screening abstract submissions to the 2019 International Patellofemoral Research Retreat (Milwaukee, WI).

We sought to recruit a minimum of 30 participants, with as many as possible to attend the consensus meeting at the 2019

International Patellofemoral Research Retreat. This number of participants is regarded as optimal, based on previous studies in similar areas.⁶ An agreement (supplemental file 1) was entered into at the point of acceptance of an invitation to participate.

To recruit persons with patellofemoral pain, the steering committee called for volunteers from their research and patient involvement lists (where ethics approvals and local policies allowed), as well as called on health care professionals with a predominant patellofemoral pain caseload to invite patients to participate.

As the survey and meeting were in English, all responders were required to have sufficient English-language proficiency to complete the survey and/or engage in the meeting.

Ethical approval was gained for the study from The University of Queensland Ethics Committee (approval 2019001248), and informed consent was obtained from all participants.

Procedure Stage 1: Systematic Review

We updated 2 systematic reviews of the literature (stage 1: March 8, 2019) on the (1) manifestations of pain features⁵ and (2) psychological factors¹⁴ in individuals who have patellofemoral pain. The aim was to summarize the evidence on pain features and psychological factors in patellofemoral pain. We were interested in quantitative sensory tests of pain and all psychological factors that were reported in studies found in the systematic and comprehensive review of literature. Full details of the systematic searches, data extraction, and data synthesis can be found in supplemental files 2 and 3.^{5,14} The pain features and psychological factors identified from this systematic review were used to construct the items in the online survey (stage 2).

Procedure Stage 2: Online Survey

Available evidence for each pain feature and psychological factor retrieved from stage 1 was synthesized by the steering committee and used in the online survey.

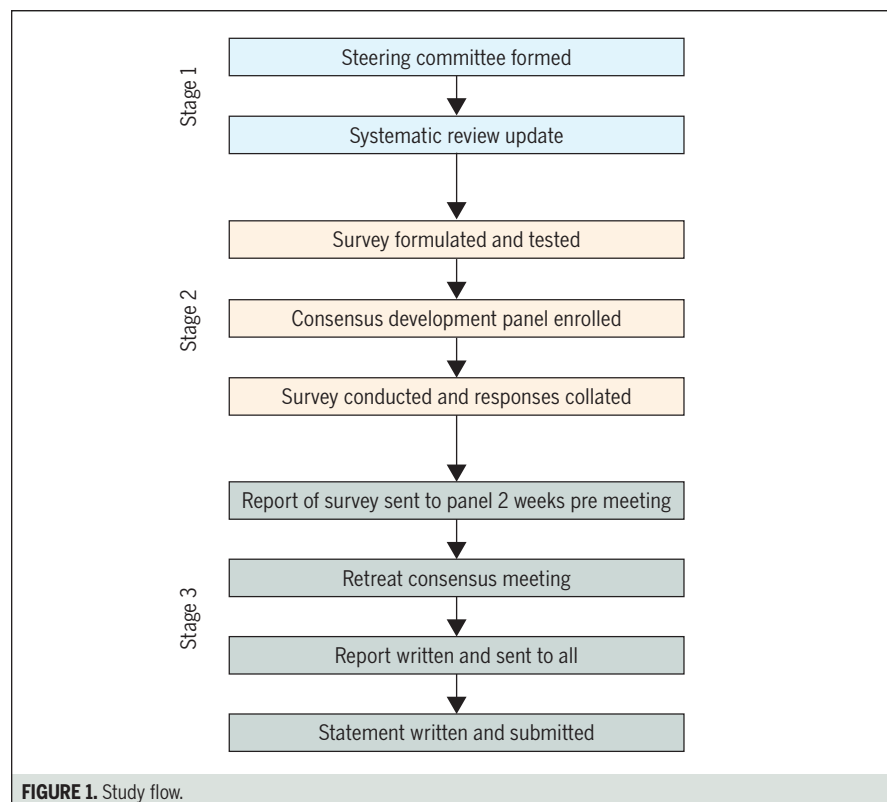


FIGURE 1. Study flow.

The evidence was summarized for each factor and was followed by questions on the prioritization of these factors for clinical practice and research (detailed below).

Prior to inviting participants, we piloted the survey with 7 clinical physical therapists (United Kingdom, Ireland, Australia) and 5 patients (United Kingdom, Australia) to ensure the content was understandable and accessible. Based on feedback, amendments were made to the presentation of the research results—mainly, to present a summary of findings in simple English terms for each survey item, with further information, meta-analysis, and statistical terms presented only in optional drop-downs. This was done to facilitate responses by individuals who did not have formal health/scientific training, while still presenting the research evidence in a transparent manner.

The final version of the online survey is available in supplemental file 4. Each item of the survey took a standardized format: (1) a definition of the construct in plain language (eg, “pressure pain thresholds are . . .”), (2) a summary of current evidence regarding the presence/role of the construct in individuals with patellofemoral pain (including quantitative synthesis where possible), and (3) questions pertaining to the perceived importance of the construct for individuals with patellofemoral pain. The questions related to perceived importance in terms of research and treatment of persons with patellofemoral pain, for example, “Pressure pain thresholds are (a) a research priority for patellofemoral pain, (b) an important feature of patellofemoral pain that must be considered in clinical practice.” The response options were yes, no, or unsure.

When a responder indicated that a pain feature or psychological factor was important, she or he was asked to select for which domains from the following list:

1. Predicting the state of the condition in the future (prognosis)
2. Clinician examination/assessment of a patient

3. Making the decision that it is patellofemoral pain (diagnosis)
4. A measure of the effect of patellofemoral pain treatments (treatment outcomes)
5. Informing the development of treatment (treatment planning and hypothesis generating)
6. The cause(s) of patellofemoral pain (etiology)
7. Risk factors leading to patellofemoral pain (risk factor)
8. Pathophysiology (the pathology or what is wrong)
9. Factors that predict treatment effect/outcomes
10. Other

Domains 1 through 10 were used for research priorities, and domains 1 through 5 and domain 10 for clinical priorities.

Finally, we also asked responders to provide more detail (if relevant) in open-ended response options (see supplemental file 4).

The steering committee made an a priori decision to use a greater than 70% agreement criterion to either include or exclude a pain feature or psychological factor from a list of priorities for clinical practice and research of patellofemoral pain. This agreement criterion has been recommended for consensus-derived recommendations.^{7,19}

The findings of the survey were collated into a report and sent to the survey responders 14 days prior to the retreat in Milwaukee, WI, so that they could familiarize themselves prior to discussing and voting (supplemental file 5).

Procedure Stage 3: International Patellofemoral Research Network Consensus Meeting (Milwaukee, WI)

A presentation of the findings from the systematic review and online survey, along with descriptions of all the pain features and psychological factors used in studies, was first presented at the retreat. We did not consider further any item that met the greater than 70% criterion on the survey of health care professionals and greater than 70% agreement

on the patient survey. All other items (ie, agreement not greater than 70% on each of the surveys) were discussed and voted on. We used paper-and-pen voting forms (directly printed from REDCap as per the online version). Patients were invited but were unavailable to attend the meeting. The discussions were audio-recorded with 1 microphone in the room as a formal record of proceedings.

Results

Stage 1: Systematic Reviews That Defined the Survey Items

Results of the systematic review are available in supplemental files 2 and 3. Five pain features and 9 psychological factors were identified in studies of individuals with patellofemoral pain. The 5 pain features were pressure pain threshold, temporal summation of pain, conditioned pain modulation, and thermal (cold, heat) pain threshold. The 9 psychological factors were pain catastrophizing, pain self-efficacy, fear-avoidance beliefs, coping skills, anxiety, kinesiphobia, general mental health, depression, and combined anxiety and depression. The majority of studies identified were cross-sectional studies, but prospective and randomized, parallel-group studies were also included. A full summary of the synthesized evidence for both constructs is available in supplemental files 2 and 3.

Stage 2: Survey

Thirty-five health care professionals participated in the survey and 20 participated in the meeting. Thirty persons with a current or previous diagnosis of patellofemoral pain completed the online survey (TABLE 1). The health care professionals had a lower proportion of women (43%) compared with the patient cohort (67%). At least 50% of health care professionals had a past history of patellofemoral pain. There was approximately an even representation of health care professionals from the Americas, Australia, and Europe (including the United Kingdom), whereas patients were predominantly from the United Kingdom (78%).

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All health care professionals had postgraduate qualifications, and 43% had over 10 years of experience managing patellofemoral pain. The majority were physical therapists (60%) or medical doctors (18%), and mainly physical therapists attended the meeting (60%).

Research Priorities

No single item achieved 100% consensus in the survey of health care professionals and in that of the patients (TABLE 2). All items therefore progressed to the meeting. In the health care professional survey, greater than 70% of responders agreed that pressure pain threshold, pain catastrophizing, fear-avoidance beliefs, and kinesiophobia were research priorities. A notable observation in both surveys was the high percentage of “unsure” or missing responses due to noncompletion of the survey. Patients did not agree on any items.

Stage 3: Consensus Meeting

At the consensus meeting, greater than 70% of health care professionals agreed that the following were research priorities: pressure pain threshold, conditioned pain modulation, temporal summation of pain, pain catastrophizing, pain self-efficacy, fear-avoidance beliefs, coping skills, anxiety, and kinesiophobia. No item was voted as not being a research priority, as would be signaled by greater than 70% of responders selecting the “no” option.

The domains for which these factors were considered a priority at the meeting are outlined in FIGURE 2. The pain features were considered important for pathophysiology, prognosis, and treatment predictors. The psychological factors were considered important for clinical examination, treatment planning, and prediction and prognosis.

Clinically Important Features

No single item reached 100% consensus on both the health care professional and patient surveys (TABLE 3). In the health care professional survey, greater than 70% agreed that pain catastrophizing, fear-avoidance beliefs, and pain self-effi-

TABLE 1		PARTICIPANT CHARACTERISTICS FROM STAGES 2 AND 3 ^a	
Characteristic	Survey of Persons With PFP (Stage 2)	Health Care Professional Survey (Stage 2)	Health Care Professional Meeting (Stage 3)
n	36 ^b	35	20
Sex (female)	24 (67)	15 (43)	9 (45)
Median (IQR; range) age, y	35 (27-47; 17-61)	40 (36-53; 27-70)	38 (35-45; 27-62)
Role			
Primarily a researcher/scientist	0 (0)	19 (54)	13 (65)
Clinician and researcher/scientist	0 (0)	14 (40)	5 (25)
Primarily a clinician	0 (0)	2 (6)	2 (10)
Neither clinician nor researcher/ scientist	36 (100)	0 (0)	0 (0)
PFP cases per month	NA		
0		15 (43)	9 (45)
≥4		3 (9)	2 (10)
5-10		6 (17)	3 (15)
11-15		3 (9)	3 (15)
≥16		8 (23)	3 (15)
Years managing PFP, n	NA		
0		0	0
<5		1	1
5-10		4	3
11-15		6	4
≥16		9	3
Highest academic qualification			
Undergraduate diploma/cer- tificate	3 (8)	0 (0)	0 (0)
Bachelor	19 (53)	0 (0)	0 (0)
Master	7 (19)	7 (20)	5 (25)
PhD	0 (0)	23 (66)	14 (70)
Clinical doctorate	0 (0)	2 (6)	0 (0)
Other	7 (19)	3 (9)	1 (5)

Table continues on page 33.

Table continues on page 33.

cacy were clinically important. More than 70% of health care professionals agreed that cold and heat pain thresholds were not clinically important. Patients had a high percentage of “unsure” or missing responses, with no items being agreed on.

At the health care professional meeting, consensus was reached for 1 pain feature: heat pain threshold. This feature was agreed to be of no importance for clinical practice. Consensus was reached on 3 of 9 psychological factors (pain catastrophizing, pain self-efficacy, and fear-avoidance beliefs). These 3 factors were agreed to be important for clinical practice.

The domains in which these factors were considered to be most important in the treatment planning, treatment predictors, and prognosis at the meeting are outlined in FIGURE 3. Psychological factors were considered more important for the clinical exam, treatment planning, and prognosis.

Discussion

We addressed an evidence-practice knowledge gap by convening a group of international experts to derive priorities for clinical practice and research in the emerging fields of pain features and

TABLE 1

PARTICIPANT CHARACTERISTICS FROM
STAGES 2 AND 3^a (CONTINUED)

Characteristic	Survey of Persons With PFP (Stage 2)	Health Care Professional Survey (Stage 2)	Health Care Professional Meeting (Stage 3)
Health care profession ^c	NA		
Physical therapist		21 (60)	12 (60)
Athletic trainer		3 (9)	3 (15)
Orthopaedic surgeon		3 (9)	0 (0)
Sports medicine physician		3 (9)	1 (5)
Exercise scientist		1 (3)	1 (5)
Human movement scientist		1 (3)	1 (5)
Psychologist		1 (3)	1 (5)
Radiologist		1 (3)	0 (0)
Other		1 (3) ^d	1 (5)
Current PFP problem	29 (81)	6 (17)	4 (20)
Past history of PFP problem	21 (58)	18 (51)	10 (50)
Country where working			
Australia	3 (8)	8 (23)	6 (30)
Brazil	0 (0)	3 (9)	2 (10)
Canada	0 (0)	1 (3)	
Denmark	4 (11)	4 (11)	1 (5)
Ireland	1 (3)	1 (3)	1 (5)
Spain	0 (0)	2 (6)	0 (0)
The Netherlands	0 (0)	3 (9)	1 (5)
United Kingdom	28 (78)	7 (20)	3 (15)
United States	0 (0)	6 (17)	5 (25)
Italy	0 (0)	0 (0)	1 (5) ^d

Abbreviations: IQR, interquartile range; NA, not applicable; PFP, patellofemoral pain.
^aValues are n (percent) unless otherwise indicated.
^bOf 36 participants, 6 did not complete the survey.
^cThere were no general practitioners or rheumatologists.
^dOne participant who had not completed the survey inadvertently voted at the meeting.

the meantime, there are 3 psychological factors that were considered important for clinicians to be aware of in their daily practice. The consensus was that pain catastrophizing, pain self-efficacy, and fear-avoidance beliefs may be considered when undertaking a clinical examination, designing a treatment plan, and making decisions about the patient's prognosis.

These 3 important factors are consistent with elements of the fear-avoidance model for persistent musculoskeletal pain.^{11,28,29} This aligns with the persistent nature of patellofemoral pain^{18,23} and what is seen/understood in other persistently painful musculoskeletal conditions. The fear-avoidance model posits that pain catastrophizing, fear of pain/injury-related movement, and avoidance of or hypervigilance with movement contribute to disability. In this model, the patellofemoral pain experience is typically appraised in 1 of 2 ways: low fear or pain catastrophizing. If one appraises it as low fear, then the resultant behavioral response is confrontation of the pain, which leads to recovery. If the initial appraisal is pain catastrophizing, then the subsequent emotional response is fear of pain (characterized by threat perception, defensive motivation, and arousal), which can lead to pain anxiety (characterized by hypervigilance, preventative motivation, and arousal). Both fear of pain and pain anxiety may lead to avoidance/escape-related behaviors, which will result in disuse, disability, and depression that will influence the subsequent appraisal of the pain experience.

**Kinesiophobia: Research Priority,
Not Clinically Important, and a
Topic of Much Discussion**

Of the psychological factors that were not considered clinically important, kinesiophobia went from being voted important by 86% of the health care professionals in the survey to 65% at the meeting. One in 4 abstained from voting on this feature at the meeting, and 1 in 10 were unsure on the survey. This item generated much discussion at the meeting, largely around

psychological factors in persons with patellofemoral pain. We used a 3-stage consensus development process. First, we updated the most recent systematic reviews on the topics of pain features and psychological factors of patellofemoral pain. Second, the most up-to-date evidence on the identified pain features and psychological factors framed our surveys—which included both health care professionals and patients. Third, we held a consensus meeting that considered the findings derived from the first 2 stages.

The results point to interesting insights into how health care professionals and persons who have patellofemoral

pain currently view patellofemoral pain. Only 3 factors that were identified in the updated systematic reviews were considered through consensus to meet the criteria for being both clinically important and priorities for research. These were pain catastrophizing, pain self-efficacy, and fear-avoidance beliefs—all psychological factors related to patients' cognitive appraisal of their pain experience. There are other factors that may be relevant for research to enhance our understanding, but until further evidence arises, they are not currently considered clinically important. It is possible that further research will lead to revisions of the identified priorities (clinical and research). In

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TABLE 2

DATA VOTING AT THE MEETING AND FROM THE SURVEYS FOR THE PAIN FEATURES AND PSYCHOLOGICAL FACTORS AS RESEARCH PRIORITIES^a

	Health Care Professional Meeting (n = 20)					Health Care Professional Survey (n = 35)				Survey of Persons With PFP (n = 30)			
	Yes	No	Unsure	Abstain	Missing	Yes	No	Unsure	Missing	Yes	No	Unsure	Missing
Pain													
Pressure pain threshold ^b	18 (90)	0 (0)	0 (0)	1 (5)	1 (5)	29 (83)	1 (3)	5 (14)	0 (0)	14 (47)	1 (3)	15 (50)	0 (0)
Conditioned pain modulation ^b	17 (85)	1 (5)	1 (5)	1 (5)	0 (0)	18 (51)	5 (14)	11 (31)	1 (3)	9 (30)	3 (10)	10 (33)	8 (27)
Temporal summation of pain ^b	17 (85)	1 (5)	1 (5)	1 (5)	0 (0)	17 (49)	5 (14)	13 (37)	0 (0)	12 (40)	2 (7)	9 (30)	7 (23)
Cold pain threshold	8 (40)	9 (45)	2 (10)	1 (5)	0 (0)	4 (11)	21 (60)	10 (29)	0 (0)	5 (17)	11 (37)	9 (30)	5 (17)
Heat pain threshold	3 (15)	12 (60)	4 (20)	1 (5)	0 (0)	4 (11)	24 (69)	7 (20)	0 (0)	2 (7)	12 (40)	12 (40)	4 (13)
Psychological													
Pain Catastrophizing Scale ^b	19 (95)	0 (0)	1 (5)	0 (0)	0 (0)	27 (77)	2 (6)	5 (14)	1 (3)	10 (33)	2 (7)	6 (20)	12 (40)
Pain self-efficacy ^b	19 (95)	0 (0)	1 (5)	0 (0)	0 (0)	22 (63)	4 (11)	8 (23)	1 (3)	13 (43)	1 (3)	4 (13)	12 (40)
Fear-avoidance beliefs ^b	18 (90)	1 (5)	1 (5)	0 (0)	0 (0)	28 (80)	2 (6)	4 (11)	1 (3)	12 (40)	4 (13)	2 (7)	12 (40)
Coping skills ^b	16 (80)	1 (5)	2 (10)	0 (0)	1 (5)	18 (49)	7 (20)	9 (26)	1 (3)	9 (30)	7 (23)	2 (7)	12 (40)
Anxiety ^{a,c}	16 (80)	2 (10)	2 (10)	0 (0)	0 (0)	17 (49)	8 (23)	9 (26)	1 (3)	10 (33)	3 (10)	6 (20)	11 (37)
Kinesiophobia ^b	15 (75)	1 (5)	0 (0)	4 (20)	0 (0)	30 (86)	3 (9)	1 (3)	1 (3)	16 (53)	0 (0)	4 (13)	10 (33)
General mental health	14 (70)	2 (10)	4 (20)	0 (0)	0 (0)	15 (43)	7 (20)	12 (34)	1 (3)	9 (30)	6 (20)	4 (13)	11 (37)
Depression ^c	11 (55)	6 (30)	3 (15)	0 (0)	0 (0)	18 (51)	11 (31)	5 (14)	1 (3)	10 (33)	3 (10)	6 (20)	11 (37)
Anxiety and depression ^c	...	...	...	...	...	15 (43)	12 (34)	7 (20)	1 (3)	9 (30)	5 (17)	4 (13)	12 (40)

Abbreviation: PFP, patellofemoral pain.

^aValues are n (percent).

^bGreater than 70% agreement with being important.

^cDecision at the meeting to keep separate.

whether or not the measure (Tampa Scale of Kinesiophobia¹⁵) measured a phobia—a matter that has been raised elsewhere.²⁴ The original intent of this measure was to capture fear of movement and (re)injury,¹⁵ and our consensus indicated that fear-avoidance beliefs appear to be important in patellofemoral pain. Perhaps the construct or term requires revisiting.¹² A closer look at the 17-item Tampa Scale of Kinesiophobia reveals that fear or being afraid only features twice, with 11 items focused on pain and 8 exploring activity, exercise, or movement. Notwithstanding a contentious name, the questionable construct validity of the Tampa Scale of Kinesiophobia, and failing to reach consensus as clinically important, the term *kinesiophobia* reached consensus as a research priority.

Psychological Factors That Were Considered Research Priorities

Pain catastrophizing, pain self-efficacy, fear-avoidance beliefs, coping skills, anx-

iety, and kinesiophobia were considered research priorities. The former 3 were the only factors that reached consensus for clinical importance, suggesting that they are the factors that should also be prioritized in research. This further research should consider that despite their perceived clinical importance, fear-avoidance beliefs and self-efficacy are difficult to change.^{2,9} Overall, the 6 psychological factors were considered important in treatment prediction/planning and prognosis, and to a lesser extent in the clinical exam. Future research could aim to determine in which ways these factors inform prediction of outcomes.

Quantitative Sensory Tests of Patellofemoral Pain That Are Priorities for Research

We voted as research priorities the assessment of pressure pain threshold, conditioned pain modulation, and temporal summation of pain, but not the 2 thermal pain thresholds. We determined treat-

ment prediction, pathophysiology, and prognosis to be the most important areas of practice in which to focus research. That no one area/domain of practice had more than 70% agreement is consistent with these assessments not being clinically important at this time.

Assessing pressure pain threshold, conditioned pain modulation, and temporal summation of pain in patellofemoral pain involves pressure/mechanical stimuli, as opposed to the thermal pain threshold tests that were not considered research priorities. Could the prioritization of these pain features (from quantitative sensory tests) in some way reflect an alignment with the physical loading in the biomechanical model? This may be an avenue for future research. This research ought to consider that conditioned pain modulation and temporal summation of pain are often referred to as surrogate tests for the dynamic pain processing that occurs within the central nervous system.^{1,8} In addition to

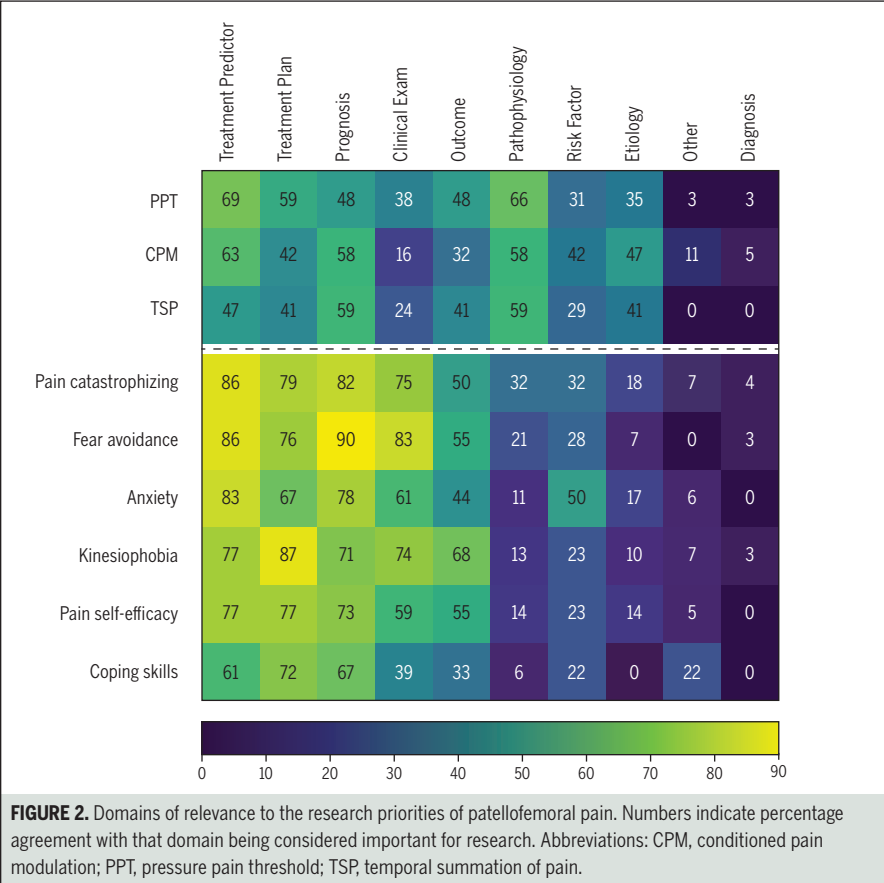


FIGURE 2. Domains of relevance to the research priorities of patellofemoral pain. Numbers indicate percentage agreement with that domain being considered important for research. Abbreviations: CPM, conditioned pain modulation; PPT, pressure pain threshold; TSP, temporal summation of pain.

the measures explored here, recent evidence⁹ points to the importance of more widespread pain in individuals who have patellofemoral pain—considered to be related to widespread sensitization, a central phenomenon. This is another avenue that needs to be explored.

Thermal Pain Thresholds Are Not Clinically Important or Research Priorities

Heat pain threshold was agreed at the meeting not to be clinically important (75%), while cold pain threshold had 65% “no” votes at the meeting. Both heat and cold pain thresholds were not considered research priorities, even though both have recently been reported to be lower than those of controls in patellofemoral pain.¹³ Cold pain thresholds have been implicated in other conditions, such as whiplash-associated disorder²⁶ and some tendinopathies (eg, lateral elbow

and gluteal).^{3,20} Future research was not deemed a priority at this stage, but recent and emerging research may alter the outcome of this consensus.

The Next Stage in Implementing the Findings

Our 3-stage process, which involved surveys and a consensus meeting about pain features and psychological factors of patellofemoral pain, prioritized elements that align with some of the components of the fear-avoidance model of persistent musculoskeletal pain. The discussions at the meeting identified the need to carefully examine the items/questions within many of the measurement tools (questionnaires) with regard to their construct accuracy and validity for persons with patellofemoral pain. We recommend that this should be a focus of future research in patellofemoral pain. We recommend that clinicians consider patient responses

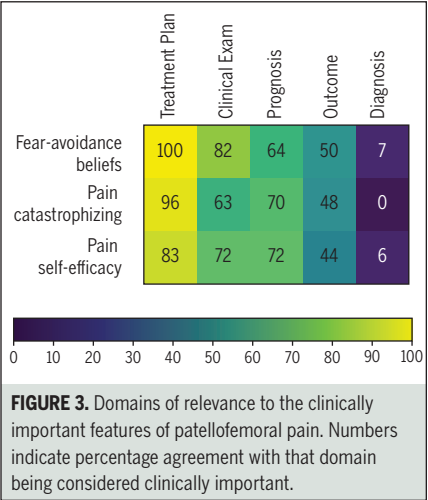


FIGURE 3. Domains of relevance to the clinically important features of patellofemoral pain. Numbers indicate percentage agreement with that domain being considered clinically important.

to individual items in these tools, in addition to the overall score.

Strengths of Our Approach in Developing a Consensus Statement

Consensus statements in “sport and exercise medicine” are proliferating—growing to approximately 54 per year in 2020 from approximately 10 to 15 per year previously. Their methods vary widely. Our methods of arriving at a consensus were transparent and agreed to in advance. The process started with members of the steering committee updating the 2 most recent systematic reviews on the topic. We then engaged persons with patellofemoral pain and health care professionals in an online survey and held a follow-up meeting to finalize the consensus statement. In the surveys, there were discrepancies between responses from patients and health care professionals, and no priorities identified by patients reached greater than 70% consensus. We strived to have—and to some extent achieved—a reasonably diverse representation of sex, geographical region, and professions involved in nonsurgical treatments. The professional participants had higher-level tertiary education (master or doctorate), and the majority had at least 5 years’ experience in managing patellofemoral pain and/or research track records in the field. The research was conducted on a voluntary basis and

[CONSENSUS STATEMENT]

TABLE 3

DATA VOTING AT THE MEETING AND FROM THE SURVEYS FOR THE PAIN FEATURES AND PSYCHOLOGICAL FACTORS AS PRIORITIES FOR CLINICAL PRACTICE^a

	Health Care Professional Meeting (n = 20)					Health Care Professional Survey (n = 35)				Survey of Persons With PFP (n = 30)			
	Yes	No	Unsure	Abstain	Missing	Yes	No	Unsure	Missing	Yes	No	Unsure	Missing
Pain													
Pressure pain threshold	12 (60)	1 (5)	5 (25)	1 (5)	1 (5)	19 (54)	5 (14)	11 (31)	0 (0)	17 (57)	1 (3)	12 (40)	0 (0)
Conditioned pain modulation	4 (20)	10 (50)	4 (20)	1 (5)	1 (5)	5 (14)	16 (46)	13 (37)	1 (3)	7 (23)	3 (10)	11 (37)	9 (30)
Temporal summation of pain	7 (35)	5 (25)	7 (35)	1 (5)	0 (0)	5 (14)	14 (40)	16 (46)	0 (0)	14 (47)	3 (10)	6 (20)	7 (23)
Cold pain threshold	1 (5)	13 (65)	5 (25)	1 (5)	0 (0)	1 (3)	26 (74)	8 (23)	0 (0)	4 (13)	7 (23)	14 (47)	5 (17)
Heat pain threshold ^b	1 (5)	15 (75)	2 (10)	2 (10)	0 (0)	1 (3)	29 (83)	5 (14)	0 (0)	3 (10)	8 (27)	15 (50)	4 (13)
Psychological													
Pain Catastrophizing Scale ^c	17 (85)	1 (5)	1 (5)	1 (5)	0 (0)	26 (74)	1 (3)	7 (20)	1 (3)	13 (43)	2 (7)	3 (10)	12 (40)
Pain self-efficacy ^c	17 (85)	0 (0)	2 (10)	1 (5)	0 (0)	18 (51)	5 (14)	11 (31)	1 (3)	15 (50)	0 (0)	3 (10)	12 (40)
Fear-avoidance beliefs ^c	17 (85)	0 (0)	2 (10)	1 (5)	0 (0)	27 (77)	1 (3)	6 (17)	1 (3)	14 (47)	3 (10)	2 (7)	11 (37)
Coping skills	14 (70)	1 (5)	4 (20)	0 (0)	1 (5)	15 (43)	4 (11)	14 (40)	2 (6)	13 (43)	3 (10)	2 (7)	12 (40)
Anxiety ^d	14 (70)	1 (5)	3 (15)	2 (10)	0 (0)	18 (51)	6 (17)	10 (29)	1 (3)	13 (43)	2 (7)	4 (13)	11 (37)
Kinesiophobia	13 (65)	1 (5)	1 (5)	5 (25)	0 (0)	30 (86)	0 (0)	4 (11)	1 (3)	13 (43)	2 (7)	4 (13)	11 (37)
General mental health	13 (65)	1 (5)	5 (25)	1 (5)	0 (0)	22 (63)	2 (6)	10 (29)	1 (3)	14 (47)	2 (7)	3 (10)	11 (37)
Depression ^d	13 (65)	3 (15)	2 (10)	2 (10)	0 (0)	19 (54)	7 (20)	8 (23)	1 (3)	13 (43)	2 (7)	4 (13)	11 (37)
Anxiety and depression ^d	...	...	...	...	...	19 (54)	8 (23)	7 (20)	1 (3)	13 (43)	2 (7)	3 (10)	12 (40)

Abbreviation: PFP, patellofemoral pain.

^aValues are n (percent).

^bGreater than 70% agreement with being not important.

^cGreater than 70% agreement with being important.

^dDecision at the meeting to keep separate.

independent of any funding source (eg, pharmaceutical companies, health care profession associations, sponsors).

Limitations

This consensus purposefully included experienced health care professionals. While we sought to include a variety of professions, the majority of the health care professionals were physical therapy based—comprising physical therapists, athletic trainers, and exercise scientists (approximately 75% of all survey responders). We were unable to identify and recruit from medical specialties like physical medicine and rehabilitation, rheumatology, and general medicine, although we did recruit orthopaedic surgeons and sports medicine physicians. Our consensus reflects the views of only those involved and may not be generalizable to all persons involved in treating, researching, or experiencing patellofemoral pain. It is tempting to speculate that

this is evidence of the difficulties encountered by physical therapy professionals in understanding the person who presents with patellofemoral pain.

Although we involved clinicians and persons with patellofemoral pain in drafting the survey questions/items, there was a large number of missing survey responses from persons with patellofemoral pain. This occurred particularly toward the end of the survey, implying that the survey might have been too long, and possibly too difficult. Of the patient responses provided, the majority aligned with those of the health care professionals, indicating a level of agreement between health care professionals and patients at the survey stage. Further clarity on the level of consensus between patients and health care professionals would have been facilitated by having patients attend the meeting. Future research should aim to find better ways of including patient perspectives from

a broad range of backgrounds (eg, geographical location, culture, language) and engaging patients more effectively in the process to reduce problems with missing data. Somewhat mitigating the relatively low input on the survey from persons with patellofemoral pain and the lack of patient involvement at the meeting is the finding that there were similar proportions of health care professionals and patients who had a past history of patellofemoral pain (approximately 50% versus 58%)—it is possible that the health care professionals had similar levels of lived experience with the condition, albeit likely biased by their health care knowledge and beliefs. Future consensus meetings may consider adding video links to promote inclusion.

The greater than 70% agreement/disagreement importance threshold ought to be considered in interpreting the results of this study. Using another decision rule (eg, at least 70%) would have resulted in

different recommendations and added factors for both research priorities (general mental health) and clinical practice (coping skills and anxiety). In an aim to be open and transparent in our process, we adopted a decision rule that complied with recommendations—set a priori^{7,19} and previously used in musculoskeletal research.¹⁹

Summary and Recommendations

- Clinicians should consider pain catastrophizing, pain self-efficacy, and fear-avoidance beliefs when undertaking a clinical examination, designing a treatment plan, and making decisions about the patient's prognosis.
- Quantitative sensory tests of pain were not considered important for clinical practice but were priorities for further research.
- Researchers should prioritize studying pain catastrophizing, fear-avoidance beliefs, anxiety, kinesiophobia, pain self-efficacy, pressure pain threshold, conditioned pain modulation, coping skills, and temporal summation of pain.
- Clinicians and researchers should consider the individual item responses when using the measures of the psychological factors voted to be clinically important and research priorities. ●

KEY POINTS

FINDINGS: Our international consensus process identified that pain catastrophizing, fear-avoidance beliefs, and pain self-efficacy are considered clinically important. Quantitative sensory tests, coping skills, anxiety, and kinesiophobia were considered research priorities. Thermal pain tests were not considered research priorities.

IMPLICATIONS: Clinicians should consider pain catastrophizing, pain self-efficacy, and fear-avoidance beliefs when undertaking a clinical examination, designing a treatment plan, and making decisions about the patient's prognosis. Researchers should consider making quantitative sensory testing of pain, coping skills, anxiety, and kinesiophobia priorities for further patellofemoral pain research.

CAUTION: Most of the health care professionals involved in our consensus process were physical therapy based—our findings may not generalize to all health professionals who provide therapy for persons with patellofemoral pain. High percentages of “unsure” and missing responses from persons with patellofemoral pain may have impacted our findings.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: The steering committee for the project included Drs Vicenzino, Rathleff, van Middelkoop, Holden, de Oliveira Silva, MacLachlan, and Smith. Drs Vicenzino and Rathleff were the project leads and developed initial concepts. The steering committee provided oversight and managed the process of data collection, analyses, and manuscript write-up. Drs Holden, de Oliveira Silva, MacLachlan, and Smith led the update of the 2 systematic reviews that informed the survey and subsequent discussion. The Patellofemoral Pain and Psychology Consensus Group authors participated in the consensus process, the retreat meeting, and the write-up and final approval of the document. The 2019 International Patellofemoral Research Network Group collaborators attended the retreat meeting as observers.

DATA SHARING: All data are available in the supplemental files.

PATIENT AND PUBLIC INVOLVEMENT: No patients were involved in the planning of the project. Patients were involved in the pilot test of our survey to patients and during data collection through the survey.

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APPENDIX

PATELLOFEMORAL PAIN AND PSYCHOLOGY (PFPP) CONSENSUS GROUP AUTHORS

Elizabeth Arendt, Monna M. Arvinen-Barrow, Fabio Azevedo, Christian Barton, David Bazett-Jones, Shellie Boudreau, Ronaldo Valdir Briani, Natalie Jane Collins, Sally Cowan, Kay Crossley, Julio Domenech, Scott F. Dye, Jennifer Earl-Boehm, Jean-Francois Esculier, Neal R. Glaviano, Louise Kedroff, Simon Lack, Mark Matthews, Jenny McConnell, James O'Donovan, Marcella Pazzinatto, Clare Robertson, Vicente Sanchis-Alfonso, James Selfe, Mitchell Selhorst, Catherine Thompson, Lilian Tobin, Rianne van der Heijden, Robbart van Linschoten

2019 INTERNATIONAL PATELLOFEMORAL RESEARCH NETWORK (IPFRN) GROUP COLLABORATORS PRESENT AT THE MEETING

Saleh Alsaleh, Andrea Baellow, Claudio Belvedere, Lori Bolgla, Michelle Boling, Michael Callaghan, Amanda Ferreira, Aaron Fox, Naoko Giblin, Harvi Hart, Jonathan Hill, Kai-Yu Ho, Lisa Hoglund, Erin Lally, Erin Macri, Christopher Powers, Gretchen Salsich, Kemery Sigmund, Bruce Stewart, Bianca Taborda, Hsiang-Ling Tang, Cathy Thomson, Jennifer Thorpe, Marina Waiteman, Mitchell Wheatley, Rich Willy

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.

CONCERNS ABOUT THE METHODOLOGY AND DATA COLLECTION IN A SYSTEMATIC REVIEW

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I read “Diagnostic Accuracy of Clusters of Pain Provocation Tests for Detecting Sacroiliac Joint Pain: Systematic Review With Meta-analysis”⁶ with interest and want to thank the authors for their work. A diagnostic injection criterion was used as the gold standard against various clusters of clinical tests to diagnose sacroiliac joint pain. This information dramatically increases the utility of the review for clinical application of the data analysis. However, I do have a concern about including the study by Nejati et al,⁴ which used the motion palpation test (the Gillet test and forward flexion), along with pain-provoking tests (the flexion, abduction, external rotation test; thigh thrust test; Gaenslen test; yeoman test; compression test; distraction test; and Newton test).

Motion palpation tests for diagnosing the sacroiliac joint have long been disputed due to low interrater and intrarater reliability.^{3,5,10} Using motion palpation as a criterion for diagnosis limits the outcomes and conclusions. Nejati et al⁴ explicitly noted that “[a] major limitation . . . is the adoption of at least one positive palpation test as a diagnostic criteria [sic].” To be consistent with diagnostic test and cluster uses in the other articles in Saueressig et al’s⁶ meta-analysis, I feel that the article by Nejati et al⁴ is sufficiently different from the other 4 articles^{2,7-9} to warrant exclusion, due to

its use of a non-pain provocation test. The use of non-pain provocation tests may also explain why the sensitivity and specificity are significantly different from those in the other 4 studies. As this meta-analysis looks at the “diagnostic accuracy of clusters of pain provocation tests for detecting sacroiliac joint pain,” I believe including a study that uses motion palpation limits the strength of the review.⁶

If Saueressig et al⁶ include the Nejati et al⁴ study in the analysis, I feel they should consider including the alternative diagnostics reported by Laslett et al.² The repeated movement (McKenzie evaluation) and sacroiliac provocation test cluster results were not used in the meta-analyses. Inclusion of these alternative Laslett et al² results would be similar to those of Nejati et al,⁴ with the use of movement tests in determining outcomes. This would also bring consistency to the authors’ classification of the study by Laslett et al² in Table 1 of their review, where they report McKenzie evaluation as a part of the type of index test.⁶ Swapping the Laslett et al² cluster results would effectively raise the reported diagnostic odds ratio by about 1 point.

My second point concerns Schneider et al’s⁷ article. The authors corrected¹ aspects of their original study that may have been printed outside Saueressig et al’s⁶ search time frame or overlooked: an error was noted in referencing sensitivity and specificity in the Results section. However, while this may appear to be a minor issue, because Schneider et al⁷ did not publish their 2-by-2 table, Saueressig et al⁶ had to calculate it from incorrectly reported values. As such, these values contain the error that is displayed in Saueressig et al’s⁶ Figure 3. The sensitivity should be 0.56 (95% confidence interval: 0.34, 0.75) and the specificity should be 0.41 (95% confidence interval: 0.22, 0.64), and the 2-by-2 table should contain the following data: true positive, 10; false negative, 8; false positive, 10; true negative, 7. This will alter the meta-

analytic estimates reported in this review. My calculations find that this will raise the combined diagnostic odds ratio by about half a point.

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Dr Vraa presents educational material on sacroiliac joint diagnosis and interventions. He consults for a medical device company that addresses persistent sacroiliac joint pain, but the company had no influence, affiliation, financial involvement, or assistance in writing this letter to the editor.

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LETTER TO THE EDITOR-IN-CHIEF

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AUTHOR RESPONSE TO “CONCERNS ABOUT THE METHODOLOGY AND DATA COLLECTION IN A SYSTEMATIC REVIEW”

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We would like to thank Dr Vraa for his insightful comments on our article.⁴ We also thank Dr Vraa for pointing out the errors in the paper by Schneider et al.⁵ We were aware of the corrigendum¹ but did not consider it further because there were no data reported and there also was no mention of a change in that paper's Table 2, which included the data necessary for our analysis. We also contacted Dr Schneider for the raw data but received no response from him.

We have repeated our analysis with the corrected data from Schneider et al.⁵ (TABLE 1). No substantive changes are noted in comparison to our previous analysis (TABLE 2).

Dr Vraa questions our inclusion of the study by Nejati et al.³ He cites Nejati et al.³ to strengthen his critique but leaves out an important section: “A major limitation of the present study is that the adoption of at least 1 positive palpation test as a diagnostic criteria [sic] resulted in the 0 specificity of the palpation tests in SIJD-negative patients.”³ This section does not pertain to a cluster of pain provocation tests but to the evaluation of a single motion palpation test. We only considered for our analysis test clusters where more than 3 tests need to be positive to confirm a diagnosis of sacroiliac joint pain. As Nejati et al.³ used a test cluster of 3 or more tests from a pool of 9 tests (2 motion palpation and 7 pain provocation tests), we still think that the data reported by Nejati et al.³ fit into our analysis. Nevertheless, we performed a sensitiv-

ity analysis by removing the data from Nejati et al.³ from our original analysis (TABLE 2). No substantial changes were noted. We also performed a sensitivity analysis by including the data for the repeated movement evaluation by Laslett et al.² Again, no substantial changes were noted (TABLE 2). Overall, these additional sensitivity analyses show that the findings of our meta-analysis are robust to these variations in the underlying studies; a negative sacroiliac joint test cluster gives the clinician 93% certainty that sacroiliac joint pain is not present, but a positive test only gives the clinician 36% certainty that sacroiliac joint pain is present, assuming a prevalence of 20%.

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TABLE 1

TWO-BY-TWO TABLE WITH CORRECTED
VALUES FOR SCHNEIDER ET AL.⁵

Study ^a	TP	FN	FP	TN
Laslett et al. ²²	10	1	7	25
Nejati et al. ²⁷	37	2	8	1
Schneider et al. ³⁵	10	8	10	7
Stanford and Burnham ⁴⁰	9	2	10	13
van der Wurff et al. ⁴⁸	23	4	7	26

Abbreviations: FN, false negative; FP, false positive; TN, true negative; TP, true positive.

^aCitation numbers correspond to those in Saueressig et al.⁴

TABLE 2

SENSITIVITY ANALYSES

Analysis	Studies, n	Pooled Sensitivity ^a	Pooled Specificity ^a	FPR ^a	+LR ^a	-LR ^a	DOR ^a	PPV, % ^{a,b}	NPV, % ^{a,b}
Original results	5	0.83 (0.62, 0.93)	0.59 (0.36, 0.79)	0.41 (0.21, 0.64)	2.13 (1.20, 3.90)	0.33 (0.11, 0.72)	9.01 (1.72, 28.4)	35 (32, 37)	8 (6, 10)
New analysis ^c	5	0.83 (0.65, 0.93)	0.61 (0.39, 0.79)	0.39 (0.21, 0.61)	2.26 (1.35, 3.95)	0.30 (0.12, 0.59)	9.50 (2.50, 25.50)	36 (33, 39)	7 (5, 9)
With Nejati et al. ³ removed	4	0.78 (0.57, 0.90)	0.69 (0.55, 0.80)	0.31 (0.20, 0.45)	2.59 (1.39, 4.37)	0.35 (0.13, 0.71)	10.10 (1.97, 31.20)	39 (36, 43)	8 (6, 10)
Laslett et al. ^{2d}	5	0.83 (0.65, 0.93)	0.62 (0.36, 0.83)	0.38 (0.17, 0.64)	2.39 (1.28, 4.74)	0.30 (0.12, 0.61)	10.20 (2.27, 30.00)	37 (35, 40)	7 (5, 9)

Abbreviations: DOR, diagnostic odds ratio; FPR, false-positive rate; -LR, negative likelihood ratio; +LR, positive likelihood ratio; NPV, negative predictive value; PPV, positive predictive value.

^aValues in parentheses are 95% confidence intervals.

^bPrevalence of 20%.

^cWith corrected data from Schneider et al.⁵

^dWith data from the clinical examination (McKenzie evaluation).

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