CSM Abstracts

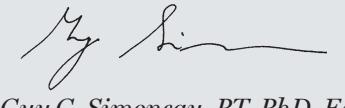
The *Journal of Orthopaedic & Sports Physical Therapy* is pleased to publish abstracts of the 2019 Combined Sections Meeting (CSM), which will take place in Washington, DC, January 23-26, 2019. This collection of abstracts provides a glimpse into the research presented as part of the scientific programming of the Academy of Orthopaedic Physical Therapy and the American Academy of Sports Physical Therapy. The number and variety of the presentations scheduled for 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 CSM plays an important role in encouraging dialog among researchers, clinicians, and educators that contributes to advancing the research process and, where appropriate, translation into clinical practice.

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

I look forward to seeing you all in Washington, DC!

Sincerely,



Guy G. Simoneau, PT, PhD, FAPTA
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Academy of Orthopaedic Physical Therapy: Platform Presentations OPL1-OPL64

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OPL1

WHY TAKE A SHOT WHEN PHONOPHORESIS IS THERE? TREATMENT OF KNEE OSTEOARTHRITIS

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PURPOSE/HYPOTHESIS: Intra-articular corticosteroid injection is considered an adjunct to core treatments for relief of moderate to severe pain in osteoarthritis patients. This study was conducted to determine the effect of dexamethasone phonophoresis, as an alternative to intra-articular injections, on knee osteoarthritis.

NUMBER OF SUBJECTS: Forty-six.

MATERIALS/METHODS: Forty-six female patients with bilateral knee osteoarthritis were randomized into 2 equal groups. Group A (study group) received dexamethasone phonophoresis using 0.4% dexamethasone gel over the medial side of the knee joint, transcutaneous electrical nerve stimulation (TENS) and quadriceps strengthening exercises. Group B (control group) received ultrasound therapy using drug free gel, TENS and the same exercise program. Treatment sessions were conducted 3 times per week for 4 weeks. Pain was assessed in all subjects using the visual analog scale (VAS) and the pain subscale of Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) before and after treatment. Functional mobility was assessed by the timed up-and-go (TUG) test, total WOMAC score, and the joint stiffness and physical function subscales of the WOMAC. Mixed-design 2-by-2 multivariate analysis of variance (MANOVA) was used to compare the tested variables (VAS, TUG and 3 WOMAC subscales) for the 2 groups and unpaired *t* tests were conducted to compare results between the 2 groups using an alpha level of .05.

RESULTS: There were no significant differences in the mean values of age, body mass index between both groups. The VAS, TUG, and WOMAC scores (the total score and each of the 3 WOMAC subscales) improved with both modalities. The posttreatment results revealed a significantly superior improvement in the phonophoresis group. The study group had a 50.56% to 58.05% improvement in pain intensity (VAS and pain subscale of WOMAC respectively) compared to 17.8% to 28.64% for the control group (mean difference [MD], −19.82; 95% confidence interval [CI]: −30.43, −9.21 for VAS and −2.68; 95% CI: −4.64, −0.72 for pain subscale). The rate of improvement of the total WOMAC after treatment was 56.43% for group A compared to 25.29% for group B (MD, −17.09; 95% CI: −24.68, −9.5). Functional mobility likewise showed a higher rate of improvement in the phonophoresis group compared to control (37.69% versus 17.48% for TUG: MD, −1.40; 95% CI: −2.72, −0.08 and 53.24% versus 22.97%; MD, −1.136; 95% CI: −2.17, −0.11 and 56.1% versus 26.42%; MD, −12.82; 95% CI: −18.45, −7.18 for the joint stiffness and physical function subscales of the WOMAC, respectively).

CONCLUSIONS: The addition of dexamethasone phonophoresis to conventional physical therapy (in the form of ultrasound therapy, TENS and exercises), results in a significantly better pain relief and functional mobility.

CLINICAL RELEVANCE: Dexamethasone phonophoresis improves pain and functional mobility in patients with knee osteoarthritis. Ultrasound combined with dexamethasone resulted in a greater improvement in knee osteoarthritis than ultrasound administered alone.

OPL2

SEVERITY OF LOW BACK PAIN–RELATED DISABILITY IN INDIVIDUALS WITH NONARTHRITIC HIP DISEASE

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PURPOSE/HYPOTHESIS: Low back pain (LBP) is reported by nearly half of patients planning hip arthroscopy for femoroacetabular impingement, a form of nonarthritic hip disease (NAHD). Patients with LBP prior to surgery report worse hip function following arthroscopy than those without LBP. The purpose of this study was to report prevalence of LBP in persons with NAHD and investigate relationships between functional disability associated with LBP, severity of LBP, hip pain and function, and treatment decisions. We hypothesized that (1) worse LBP-related disability would be associated with worse hip function and pain, and that (2) those who had hip surgery reported worse baseline LBP than those who did not have surgery.

NUMBER OF SUBJECTS: Fifty-five participants (mean ± SD age, 39.9 ± 13.7 years; BMI, 28.3 ± 5.3 kg/m^2; 63% female) with symptomatic NAHD presented over a 12-month period to a hip preservation clinic.
MATERIALS/METHODS: The modified Oswestry Low Back Pain Disability Questionnaire (ODI), the 33-item International Hip Outcome Tool (iHOT), and severity (0-100 sliding scale) of back, groin, and lateral hip pain were recorded at initial visit. Participants who indicated LBP greater than 0 were assigned as having LBP and prompted to complete the ODI. For participants enrolled 90 days or longer, treatment within 90 days of evaluation was collected from electronic health records (surgical group, SG; nonsurgical group, NSG). Spearman rank correlations were used to identify if ODI scores were related to iHOT scores, lateral hip and groin pain ($P \leq .05$). Mann-Whitney U tests were used to evaluate LBP severity between participants who did and did not undergo surgery ($P \leq .05$).
RESULTS: Forty of 55 (72%) participants reported LBP (Oswestry, 33.0 ± 18.3). Age, BMI, sex distribution, severity of groin pain and iHOT scores did not differ between those with and without LBP ($P \geq .07$). Those with LBP reported worse lateral hip pain (71.5 ± 18.3) than those without LBP (n = 15, 51.0 ± 31.9, $P = .03$). Higher ODI scores were correlated with lower iHOT scores ($\rho = -0.67$, $P < .01$) and worse groin pain ($\rho = 0.47$, $P < .01$), but not lateral hip pain ($\rho = 0.28$, $P = .07$). Treatment was identified for participants enrolled 90 days or longer (n = 31); those in the SG group (n = 18) were of similar age, BMI and sex distribution as the NSG group (n = 13, $P \geq .46$). Both treatment groups had similar baseline LBP severity (SG, 51.0 ± 33.7; NSG, 43.0 ± 37.8; $P = .44$). When only considering participants with baseline LBP, ODI scores were not different at baseline between persons who underwent surgery (n = 16, 40.5 ± 19.6) and those who did not (n = 8, 30.7 ± 17.4, $P = .32$).
CONCLUSIONS: More severe LBP-related disability was associated with severity of groin pain and perceived hip-related disability. The high prevalence of LBP in this cohort of patients with NAHD may be attributable to the more inclusive diagnostic criteria of NAHD compared to femoroacetabular impingement alone.
CLINICAL RELEVANCE: LBP is highly prevalent and related to increasing severity of pain and dysfunction in patients with NAHD. Thus, evaluation and treatment of LBP-related disability in these patients has the potential to optimize outcomes.

OPL3

FALLING RISK IN PATIENTS WITH END-STAGE KNEE OSTEOARTHRITIS

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PURPOSE/HYPOTHESIS: Falling among older adults is a major cause of mortality and morbidity, which accounted for 135 000 deaths in people older than 65 years in the United States between 2008 and 2013. One-quarter of patients with knee osteoarthritis (OA) have reported a fall, and previous work has found that functional limitations, pain, and stiffness are more important risk factors for falls than radiological changes alone. Although previous work has identified the incidence of falling in older adults, studies examining risk factors for falling have included individuals with and without OA. No study has examined clinical factors associated with falling risk in patients with end-stage OA awaiting total knee arthroplasty (TKA). Knowledge of risk factors may enhance decision making as to the timing of surgery, lead to better preoperative rehabilitation programs, or help to manage patients on waiting lists for surgery. The purpose of this study was to identify clinical and functional measures associated with greater risk of falling.
NUMBER OF SUBJECTS: Two hundred fifty-nine subjects with end-stage knee OA participated in this study. Subjects were divided into 2 groups (fallers and nonfallers) based on self-reported falling history in the prior 6 months.
MATERIALS/METHODS: Patients completed a battery of clinical and functional measures that included: bilateral hip and knee pain scores, neck and back pain scores, active knee range of motion, isometric quadriceps strength, 6-minute walk test (6MWT), timed up-and-go test, and the Knee injury and Osteoarthritis Outcome Score (KOOS). Pain scores were recorded on a 0-to-10-point scale. Multiple independent t tests were used to examine differences between groups (fallers and nonfallers) for these measures. Odds ratio and P values were calculated to examine the association of the clinical and functional measures with the chance of falling.
RESULTS: Forty-seven (18%) subjects reported a fall. There were no significant differences between groups for age, BMI, and sex. Significant differences between fallers and nonfallers were only found for low back pain and 6MWT. Fallers had 30% greater low back pain than nonfallers (3.0 ± 2.5 versus 2.1 ± 2.6, $P = .025$) and fallers walked 12% shorter distance than nonfallers (378 ± 100 versus 422 ± 105 m, $P = .010$). For every 1-point increase in low back pain, there was a 14% (1.14 times, $P = .028$) greater chance of falling. For every 10-m increase on 6MWT, there was 3.8% (0.96 times, $P = .011$) less chance of falling.
CONCLUSIONS: Greater low back pain and worse walking endurance are associated with falls in individuals with end-stage OA. Future studies should determine if total knee arthroplasty (TKA) reduces the risk of falling or if different factors are associated with falls after surgery.
CLINICAL RELEVANCE: Interventions that reduce low back pain and improve walking performance may reduce the chance of falling for individuals awaiting TKA. This may be particularly important for individuals who are on the waiting list for surgery, as is common in countries with socialized medicine, or individuals participating in "prehabilitation."

OPL4

CENTER OF PRESSURE AND VERTICAL GROUND REACTION FORCE PREDICT KNEE EXTENSOR MOMENT DEFICITS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: IMPLICATIONS FOR CLINICAL ASSESSMENTS

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PURPOSE/HYPOTHESIS: Individuals following anterior cruciate ligament reconstruction (ACLr) reduce extensor moments in surgical knee during squats by shifting demands to the other limb or to adjacent joints within the limb. Shifting demands between limbs can be identified using vertical ground reaction forces (vGRF). Recent data suggest that anterior-posterior center of pressure (apCoP) relates to the distribution of extensor moments within the limb. It is not known how well these variables predict knee extensor moment deficits following ACLr. The purpose of this study was to determine the predictive value of between-limb vGRF and apCoP ratios during a bilateral squat for the estimation of unilateral knee extensor moment deficits in individuals following ACLr.
NUMBER OF SUBJECTS: Twenty-four.
MATERIALS/METHODS: Twenty-four individuals (14 female; mean ± SD age, 28.9 ± 11.7 years; height, 171.0 ± 10.8 cm; weight, 69.7 ± 11.8 kg) 142 ± 22.5 days post ACLR participated. Kinematics (250 Hz) and kinetics (1500 Hz) were calculated using 3-D motion analysis while individuals performed 2 trials of 5 consecutive squats to self-selected depth. Knee flexion angles and knee extensor moment (kEXT; inverse dynamics) were calculated. apCOP was calculated as the anterior distance from the heel normalized to foot length. Peak knee flexion angle and kEXT were compared between limbs using paired t tests. Surgical/nonsurgical limb ratios for kEXT, vGRF and apCoP were considered in a stepwise linear regression to determine if vGRF and apCoP ratios predict kEXT ratio; significance $\alpha \leq .05$.
RESULTS: Smaller kEXT was observed in the surgical limb compared to the nonsurgical limb (0.39 ± 0.21 Nm/kg, $P < .001$). Peak knee flexion angle was not different between limbs ($P = .745$). apCoP and vGRF ratios

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together predict knee extensor moment ratio (R^2 = 0.69, P<.001). apCoP entered the regression equation first and was the largest predictor of knee extensor moment ratio (R^2 = 0.52, P<.001) followed by vGRF ratio (R^2 = 0.17, P = .002).

CONCLUSIONS: Subjects exhibited a 33% deficit in kEXT in the surgical limb along with no differences in flexion angle. Between limb ratios in apCOP and vGRF explained 69% of the variance in knee extensor moment ratio. Ratios indicate that a more anterior apCOP and smaller vGRF in the surgical limb relates to smaller kEXT. apCOP was the largest predictor explaining 52% of the variance.

CLINICAL RELEVANCE: Variables calculated with force platforms alone, may be able to provide clinicians with valuable information regarding knee extensor loading deficits calculated using 3-D motion-capture systems. Typically, these deficits are difficult to detect clinically without observable difference in knee flexion.

OPL5

HIP STRENGTH PREDICTS FUNCTION AMONG ADULTS WITH CHRONIC LOW BACK PAIN WITH AND WITHOUT HIP PAIN

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PURPOSE/HYPOTHESIS: Decreased muscle strength is a predictor of mobility deterioration in older adults. This study evaluated baseline hip muscle strength as a predictor of physical function at 1-year follow-up among older adults with chronic low back pain (LBP) with and without concurrent hip pain. We hypothesized hip muscle strength would predict dynamic balance, functional mobility, and walking endurance, after considering LBP intensity. Further, we sought to determine which hip muscle group was most important in predicting function for each patient subgroup.

NUMBER OF SUBJECTS: Two hundred fifty older adults with chronic low back pain (n = 119 with concurrent hip pain). Mean ± SD age was 69.7 ± 6.84 years, mean body mass index (BMI) was 29.4 ± 5.7 kg/m^2, and the sample was predominantly female (n = 51.2%).

MATERIALS/METHODS: Average baseline hip strength was assessed using handheld dynamometry for each hip muscle group (flexors, extensors, abductors, adductors, internal, and external rotators). Participants performed 3 trials per hip; the best trial per hip was recorded and right and left hip strength for each muscle group was averaged. At the 12-month follow-up, participants completed a valid test of dynamic balance, ie, the Narrow Corridor Walk Test (NCT), a reliable and valid test of functional mobility, ie, the timed up-and-go (TUG), and a reliable and valid walking endurance test, ie, the 6-minute walk test (6MWT). Regression modeling was used to evaluate baseline hip strength as a predictor of physical function, after controlling for sex, age, BMI, and 12-month LBP intensity, among adults with and without concurrent baseline hip pain, ie, groin or lateral hip pain (P≤.001).

RESULTS: Above and beyond covariates, reduced hip extensor, abductor, adductor, internal, and external rotator strength were found to be predictive of poorer functional performance at 1-year follow-up (all, P<.001; R^2 change = 0.02-0.15). For older adults with LBP and hip pain, reduced external rotator strength was most associated with poorer functional performance (all, P<.001; R^2 change = 0.14-0.29), while reduced hip adductor strength was most associated with poorer functional performance among adults with LBP without hip pain (all, P<.001; R^2 change = 0.10-0.12).

CONCLUSIONS: Among older adults with chronic LBP, decreased strength of the hip extensors, adductors, abductors, internal and external rotators predict reduced 1-year physical function.

CLINICAL RELEVANCE: Older adults with chronic LBP, regardless of hip pain presence, may benefit from targeted hip muscle strengthening to improve long-term balance, functional mobility, and walking endurance. Specifically, physical therapists should consider including hip external rotator and adductor strengthening exercises for older adults with chronic LBP, with and without hip pain, respectively, as part of the patient's treatment to maximize long-term function.

OPL6

FACTORS INFLUENCING PATIENT USE OF SELF-REFERRAL TO PHYSICAL THERAPY: A QUALITATIVE APPROACH

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PURPOSE/HYPOTHESIS: Nonpharmacologic treatments such as physical therapy (PT) are advocated for musculoskeletal pain for decreasing opioid use. Early access to PT has been shown to decrease costs and improve outcomes through self-referral. Although self-referral to PT is permitted in the majority of US states, health insurance coverage has been identified as a barrier preventing some patients with musculoskeletal complaints from using it. Few studies had examined patient factors related to early access to physical therapy via self-referral. The purpose of this study was to identify the factors outside of insurance that influence the choice to access physical therapy care through the self-referral or usual care pathway.

NUMBER OF SUBJECTS: Thirty-two.

MATERIALS/METHODS: A program removing these barriers was administered in partnership with a self-funded employer where a physician referral was not required with lower copayments for each visit. After program implementation, the majority of patients still selected to access PT by seeking a referral from a physician (usual care pathway). Thirty-two in-depth semi-structured interviews were conducted after patients with this benefit accessed physical therapy for nonoperative musculoskeletal complaints. Interviews lasted approximately 35 minutes. Each interview was audiorecorded and transcribed for qualitative analysis. Concurrent patient data were pulled from the ATI Patient Outcomes Registry including comorbidities, sex, and patient-reported disability and duration of pain. A grounded theory approach using open, axial, and selective coding techniques thematically identified major factors contributing to the choice of the self-referral or the usual care pathway when accessing PT. Chi-square and Fisher's exact tests were used to compare baseline patient differences between groups (α≤.05).

RESULTS: There were no significant differences in clinical or socioeconomic (race, education, or income) variables between patients using the self-referral or usual care pathway. However, thematic differences included: (1) patients' knowledge of the program, (2) attitudes/preferences toward treatment, and (3) prior experiences with PT. Patients selecting the usual care pathway lacked program knowledge, preferred pharmacological treatments, and desired physician reassurance. Patients selecting self-referral knew about the program, were open to a wide array of treatment options which were associated with existing beliefs about pharmacological treatments and surgery. Patients using direct access also had positive prior experiences with PT or members of their network did.

CONCLUSIONS: Results suggest that knowledge, attitudes and beliefs about treatment, and experiences influence patient choice selected self-referral to PT. The sample is limited to employees of 1 employer in 1 metropolitan area within the southeastern United States and is generalizable only to this demographic.

CLINICAL RELEVANCE: Programs aimed at improving patient knowledge and changing patient attitudes appear warranted to increase utilization of self-referral to PT for musculoskeletal complaints.

OPL7

FLEXOR HALLUCIS LONGUS TENDON MORPHOLOGY IN DANCERS WITH AND WITHOUT TENDINOPATHY

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PURPOSE/HYPOTHESIS: The aesthetics of dance technique place a unique physical demand on the structures of the lower extremity. Due to the high volume of repetitions completed in practice and performance, dancers most often present with overuse related injury. In particular, changes in both micro- and macromorphology of the Achilles, patellar, and flexor hallucis longus (FHL) tendons have been reported in groups of both symptomatic and asymptomatic dancers. Tendinopathy is categorized based on distinct morphological features. "Tendinitis" is associated with inflammation while "Tendinosis" is characterized by a change in tendon structure due to degeneration. A lower Peak Spatial Frequency Radius (PSFR), measuring fluid content within the tendon and the tendon fiber organization, has been linked to degenerative tendon micromorphology and suboptimal mechanical properties of the tendon. Increases in both cross-sectional area (CSA) and tendon thickness have been reported as either a maladaptive or adaptive mechanism in relation to overuse injuries or sport activity. The purpose of this study was to compare micromorphology and macromorphology of the FHL tendon in healthy nondancers, healthy dancers, and dancers presenting with FHL tendinopathy.
NUMBER OF SUBJECTS: Twenty-six.
MATERIALS/METHODS: A total of 10 healthy nondancers, 9 healthy dancers, and 7 dancers presenting with FHL tendinopathy were analyzed. A physical therapist confirmed the presence of FHL tendinopathy without concurrent Achilles tendinopathy. Longitudinal and transverse B-mode ultrasound images were taken. Macromorphology was analyzed via tendon thickness and CSA using ImageJ software. Micromorphology was analyzed using 2-dimensional Fast Fourier Transformation analysis providing PSFR.
RESULTS: Tendinopathic dancers showed a significant increase in FHL CSA (mean ± SD, 16 ± 10.32 mm_2) compared to healthy dancers (mean ± SD, 6.33 ± 2.65 mm^2; $P = .007$) and healthy nondancers (mean ± SD, 6.3 ± 1.77 mm^2; $P = .006$). Tendinopathic dancers also showed an increased FHL tendon thickness (mean ± SD, 3.48 ± 1.38 mm) compared to healthy dancers (mean ± SD, 2.7 ± 0.19 mm) and healthy nondancers (mean ± SD, 2.78 ± 0.57 mm), although not statistically significant. Interestingly, FHL PSFR was not statistically different between groups and was within previously reported norms.
CONCLUSIONS: A change in macro- but not micromorphology of the FHL tendon in tendinopathic dancers shows an adaptive rather than degenerative change in the FHL tendon structure. The FHL tendon sheath may play a role in preventing degenerative changes in the tendon substance itself.
CLINICAL RELEVANCE: This study aimed to characterize the response of the FHL tendon to the physical demands of dance in both symptomatic and asymptomatic dancers in order to provide a pathoanatomical approach to the treatment of FHL tendinopathy in dancers. The adaptive thickening of the FHL suggests an atypical compensatory response to the demands of dance when other posterior plantar flexors may be inadequately contributing.

OPL8

PREOPERATIVE AND POSTOPERATIVE PSYCHOLOGICALLY INFORMED PHYSICAL THERAPY: A SYSTEMATIC REVIEW OF RANDOMIZED TRIALS AMONG PATIENTS WITH DEGENERATIVE SPINE, HIP, OR KNEE CONDITIONS

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PURPOSE/HYPOTHESIS: Psychological factors are key determinants of recovery after surgery for degenerative musculoskeletal conditions. Psychologically informed physical therapy (PIPT) may be an efficacious and accessible option for addressing psychological burden in these patients. The purpose of this systematic review was to summarize the evidence on preoperative and postoperative PIPT for improving outcomes among patients undergoing surgery for a degenerative spine, hip, or knee condition.
NUMBER OF SUBJECTS: Ten studies (total n = 1127 patients, 636 [56.4%] females) met eligibility criteria.
MATERIALS/METHODS: Four electronic databases (MEDLINE/PubMed, CINAHL, PsycINFO, and Web of Science) were searched from each database's inception to May 2018 for randomized controlled trials in patients undergoing surgery for a degenerative spine, hip, or knee condition. Randomized trials were included if they examined the efficacy of a preoperative or postoperative PIPT intervention, which involved the delivery of psychological-based strategies by a physical therapist, on disability/function or pain. No limitation was placed on type of comparison group. Outcomes measured at 1 year or longer were considered long term. Studies with scores of 6/10 or greater on the PEDro scale were considered moderate-to-high quality.
RESULTS: Of 1057 articles identified, 12 articles representing 10 unique studies met inclusion criteria. PEDro scores ranged from 5 to 8, with 8 studies being moderate-to-high quality. The populations of interest were patients undergoing lumbar spine surgery (n = 7), cervical spine surgery (n = 1), total knee arthroplasty (n = 1), and total knee or hip arthroplasty (n = 1). Two studies examined preoperative PIPT and 8 studies examined postoperative PIPT. The most common PIPT components included behavioral goal setting, coping strategies, relaxation, positive reinforcement, graded activity, and self-management. Two preoperative PIPT studies reported greater effects after PIPT on preoperative pain, but only 1 reported greater effect on preoperative disability/function. Three postoperative PIPT studies reported greater effects after PIPT on short-term disability/function and pain, with 2 studies also reporting greater effect on long-term disability and 1 study reporting greater effect on long-term pain. One postoperative PIPT study reported greater effects after PIPT on long-term, but not short-term, disability/function and pain.
CONCLUSIONS: The effects of PIPT have been examined primarily in patients undergoing spine surgery for a degenerative condition. Preoperative PIPT showed promise for improving preoperative pain, but this is based on 2 total studies. Beneficial effects on disability/function or pain following postoperative PIPT were observed in 4 of the 8 postoperative PIPT studies.
CLINICAL RELEVANCE: PIPT is a potential approach for addressing the multidimensional needs of patients undergoing surgery for a degenerative musculoskeletal condition.

OPL9

PSYCHOLOGICALLY INFORMED PHYSICAL THERAPY FOR PATIENTS FOLLOWING LUMBAR SPINE SURGERY: A RANDOMIZED CLINICAL TRIAL

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PURPOSE/HYPOTHESIS: Studies have found that psychosocial characteristics are strongly related to surgical spine outcomes. The purpose of this study was to compare which of 2 treatments delivered by telephone—a cognitive-behavioral-based physical therapy program (CBPT) or an education program—are more effective for improving patient-centered outcomes after lumbar spine surgery.
NUMBER OF SUBJECTS: Two hundred forty-eight participants (124 in CBPT and 124 in education) undergoing surgery for a lumbar degenerative condition using laminectomy with or without arthrodesis.
MATERIALS/METHODS: A randomized controlled clinical trial was conducted at 2 medical centers. Patient-reported outcomes were disability (Oswestry Disability Index [ODI]), pain intensity (Brief Pain Inventory), and physical and mental health (SF-12). Observed physical activity was assessed using accelerometers and health care utilization data were collected from patients and hospital billing records. Patient assessments occurred pre-

operatively and at 6 weeks (baseline) and 1 year after surgery. Assessors and patients were unaware of the treatment condition. Patients were randomized at baseline using a stratified design based on age and type of surgery. Six postoperative treatment sessions were delivered by a physical therapist over the telephone. The CBPT intervention focused on walking and functional goal setting, relaxation techniques, symptom management through problem solving, and replacing negative thoughts about activity with positive ones. Separate multivariable regression analyses were conducted on the total sample and on those who completed all 6 sessions (n = 179). Intent-to-treat models adjusted for the outcome at baseline, age, study site, depressive symptoms, and type of surgical procedure. Missing data were handled with multiple imputation. The level of significance was set at $\alpha = .05$.

RESULTS: No significant group differences were found for patient-reported outcomes and physical activity in the total sample. However, CBPT participants were 69% less likely to have a rehospitalization compared to Education participants between 6 weeks and 12 months after surgery ($P = .02$). In completer analyses, statistically significant differences across groups were noted for disability and physical health, with CBPT participants having an ODI score 4.3 points lower (95% CI: −5, −0.03) and a SF-12 physical health score 3.2 points higher (95% CI: 0.16, 6.3) than the education group at 12 months ($P<.05$).

CONCLUSIONS: Results from a multicenter trial found that a physical therapist-delivered cognitive-behavioral intervention reduced the odds of rehospitalization and improved disability and physical health for patients who completed the 6-session program.

CLINICAL RELEVANCE: Telephone delivery appears to be an effective platform for incorporating CBT-based strategies into rehabilitation for engaged participants. Future work is needed to determine how to implement a CBPT approach in a typical clinic setting and maintain patient engagement in self-management strategies.

OPL10

REARFOOT-STRIKE LANDING-PATTERN RUN RETRAINING TO PREVENT RECURRENT CALF STRAINS IN A US NAVY SERVICE MEMBER

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BACKGROUND AND PURPOSE: In the US Military, running-related injuries are among the most prevalent musculoskeletal complaints. Run retraining is an extensively researched method for reducing pain and improving function in runners. Real-time visual feedback is effective in modifying kinematics and loading rates, and contributes to reduction in injury likelihood when combined with a faded-feedback design. Researchers have examined the effects of conversion from a rearfoot strike to midfoot or forefoot strike landing pattern; however, the opposite is less often studied. The purpose of this case report is to present the successful implementation of a rearfoot strike landing pattern to reduce a service member's recurrent running-related calf strains.

CASE DESCRIPTION: The patient was a 40-year-old female, active-duty US Navy Officer, presenting with a history of recurrent right calf strains when increasing running mileage since 2011. Prior conventional physical therapy included soft tissue massage, balance training, strengthening, stretching, and modalities, without resolution of symptoms. In 2018, the patient was referred to the Movement Retraining Clinic at Naval Medical Center San Diego. Whole-body mechanics were measured during treadmill running (2.6 m/s), using optical motion capture and an instrumented treadmill. Results from the initial analysis (PRE) revealed right forefoot initial contact, with elevated ankle energy absorption relative to the hips and knees. Over 8 sessions in 2 weeks, the patient received real-time visual feedback during running for foot inclination angle targeting a rearfoot strike. Running mechanics were reassessed posttraining (POST) and at 1-month follow-up (FU).

OUTCOMES: The following outcomes were compared: foot strike index (SI; 0% is rearfoot strike, 100% is forefoot strike), ankle joint energy absorption as a proportion of total leg, energy (AnABS), Lower Extremity Functional Scale (LEFS), and self-reported weekly running frequency. Measurement confirmed patient achieved a rearfoot strike at POST (SI, 27%) and maintained at FU (SI, 33%), compared to a forefoot strike at PRE (SI, 67%). AnABS decreased from 44% at PRE, to 28% at POST, and 23% at FU. LEFS improved from 61 points at PRE, to 67 points at POST, and 74 points at FU. Self-reported running increased from 0 times per week at PRE, to 3 times per week at POST and 4 times per week at FU. No calf pain or strains were reported at any evaluations.

DISCUSSION: With real-time visual feedback over a 2-week training period, the patient achieved a rearfoot-strike landing pattern, and demonstrated retention of this strategy at 1-month follow-up. This strategy has the effect of reducing calf muscle demand, which is expected to reduce this patient's likelihood of further calf strains, and allowed her to tolerate increased running frequency. This case demonstrates the efficacy of appropriate conversion from forefoot to rearfoot strike run pattern, and more broadly the role of movement retraining in treating running-related musculoskeletal complaints.

OPL11

ASSOCIATIONS BETWEEN TRUNK MUSCLE FUNCTION, PHYSICAL PERFORMANCE, AND COMMUNITY PARTICIPATION IN ADULTS WITH LOWER-LIMB AMPUTATION: A PRELIMINARY DATA ANALYSIS

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PURPOSE/HYPOTHESIS: Prolonged sedentary periods have been shown to result in trunk muscle impairments, including decreased muscle size and activity, which persist even after resumption of normal activities. It is well known that lower-limb amputation (LLA) increases the effort required of the trunk muscles for stability during upright activities. Dysfunction of the lumbar multifidi (LM) muscles, given their stabilizing role during mobility-related tasks, may contribute to functional deficits and limited community participation among adults with LLA. Normal L4/5 LM activity has been reported to be 21% to 29%; however, LM activity and its relationship to function and community participation among adults with LLA is unknown. We hypothesized that among adults with LLA, reduced LM activity would be present and significantly associated with lower self-reported community engagement and poorer performance on functional mobility tests.

NUMBER OF SUBJECTS: Sixteen adults (mean ± SD age, 60.1 ± 9.8 years) with a unilateral transtibial or transfemoral amputation.

MATERIALS/METHODS: During an on-site clinical evaluation at the University of Delaware in the Delaware Limb Loss Studies laboratory, participants completed the Community Integration Questionnaire (CIQ), an assessment of self-perceived community involvement that has demonstrated validity among adults with LLA. Participants then performed the timed up-and-go (TUG) and 6-minute walk test (6MWT), 2 functional mobility tests with established reliability and validity in adults with LLA. Following clinical testing, a trained examiner performed ultrasound imaging to assess bilateral L4-5 LM thickness at rest and during a contralateral leg, lift to facilitate LM contraction; LM activity was calculated as percent thickness change between resting and contracted states. Linear regression models were used to explore associations between LM activity and clinical measures of interest (ie, CIQ, TUG, and 6MWT), while controlling for low back pain presence, which is known to negatively impact LM activity.

RESULTS: Participants were predominantly male (n = 10), with 50% of the sample (n = 8) reporting low back pain. Median muscle thickness was 3.82 (3.40, 4.18) cm and 4.32 (3.82, 4.89) cm at rest and during contraction, respectively, and median LM activity was 13.01% (10.78%, 21.89%). While low back pain presence did not significantly explain the variance for any outcome of interest, LM activity explained 24.7%, 27.8%, and

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40.6%, of the variance in CIQ (β = .245, P = .048), TUG time (β = –.360, P = .042), and 6MWT distance (β = 11.8, P = .008), respectively.
CONCLUSIONS: Among individuals with LLA, reduced L4-5 LM activity is present and associated with reduced community participation and poorer TUG and 6MWT performance.
CLINICAL RELEVANCE: Adults with LLA may benefit from assessment of LM activity and targeted low back muscle training to increase societal participation and improve physical function.

OPL12

CHANGES IN CLINICIAN ATTITUDES, BELIEFS, AND CONFIDENCE ABOUT LOW BACK PAIN MANAGEMENT: RESULTS FROM A TARGET TRIAL PSYCHOLOGICALLY INFORMED PHYSICAL THERAPY TRAINING COURSE

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PURPOSE/HYPOTHESIS: The purpose was to assess attitudes, beliefs, and confidence outcomes following a psychologically informed physical therapy (PIPT) training course for low back pain management as part of a large pragmatic clinical trial.
NUMBER OF SUBJECTS: Fourteen cohorts of physical therapists (n = 471) from 5 TARGET site locations attended this PIPT course.
MATERIALS/METHODS: The TARGET trial PIPT course consisted of viewing of online educational modules and an 8-hour workshop prior to clinical trial participation. Treatment orientation was assessed by the Pain Attitudes and Beliefs Scale for Physiotherapists (PABS-PT). The PABS-PT consists of biomedical (range, 10-60) and behavioral (range, 9-54) subscales, with higher scores indicating increased respective treatment orientation. Confidence in implementing PIPT was assessed with an 11-point scale (range, 0-10), with higher scores indicating increased confidence. Paired samples t tests assessed pre to postcourse changes in PABS-PT and confidence scores. Multiple regression models were used to evaluate the contribution of TARGET site location and viewing precourse online modules as predictors of postcourse PABS-PT and confidence scores. One-way analysis of variance with Bonferroni post hoc procedures was used to compare PABS-PT and confidence residualized change scores between TARGET site locations to evaluate for potential heterogeneous training effects.
RESULTS: Postcourse follow-up assessment rate was 92.0%. PABS-PT biomedical scores decreased from 31.1 ± 6.8 to 25.0 ± 7.1 (P<.001) and behavioral scores increased from 36.8 ± 4.8 to 41.4 ± 5.2 (P<.001). TARGET site location (β = .09-.12) added to prediction of postcourse PABS-PT biomedical and behavioral scores in final models explaining 16.8% and 37.7% variance, respectively. Confidence in implementing PIPT increased from 4.8 ± 2.2 to 7.3 ± 1.9 (P<.001). TARGET site location (β = .21) and viewing precourse online modules (β = .12) added to prediction of postcourse confidence scores with final model explaining 26.7% variance. Greater postcourse confidence scores were observed for those who viewed modules when compared to those who did not (7.7 ± 1.3 versus 7.2 ± 1.7). After adjustment for precourse scores, there were no differences in PABS-PT biomedical (P = .140) or behavioral (P = .095) scale change scores between TARGET site locations, however differences in confidence change scores were observed (P<.001).
CONCLUSIONS: Favorable PABS-PT changes were observed when PIPT training was pragmatically delivered. Viewing online modules prior to the course did not improve PABS-PT scores; however was associated with better postcourse confidence. TARGET site location had most influential effect on confidence scores.
CLINICAL RELEVANCE: These results indicate that a 1-day pragmatic course favorably impacted domains associated with successful PIPT application. Primary TARGET trial results will determine if these changes were sustainable over time and resulted in improved clinical outcomes.

OPL13

PSYCHOMETRIC PROPERTIES OF THE DANCE FUNCTIONAL OUTCOME SURVEY: RELIABILITY, VALIDITY, AND RESPONSIVENESS

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PURPOSE/HYPOTHESIS: There are no outcomes measures that focus on the unique functional requirements of dancers. We evaluated test-retest reliability, internal consistency, construct validity, sensitivity and responsiveness of the Dance Functional Outcome Survey (DFOS) in professional and preprofessional adult dancers
NUMBER OF SUBJECTS: We examined (1) test-retest reliability of the DFOS within 2 weeks in 198 healthy and injured dancers. In 725 healthy and injured dancers we determined: (2) construct validity of the DFOS to the SF-36; (3) exploratory factor analysis (EFA) and internal consistency; (4) sensitivity by generating receiver operating characteristic curves (ROC) and determining area under the curve (AUC). In a subgroup of 47 injured dancers, we ascertained (5) internal responsiveness across 4 time points.
MATERIALS/METHODS: Data were entered into excel and transformed into: (1) DFOS subtotal and total scores, (2) SF-36 Physical and Mental Component Summary (PCS and MCS) scores. These were transferred to SPSS or JASP for statistical analysis. (1) Intraclass correlation coefficients ($ICC_{2,1}$) were used to assess test-retest repeatability. (2) Persons correlations compared construct validity of DFOS and SF-36. (3) EFA examined factor structure and Cronbach's alpha was calculated to determine internal reliability of the DFOS data set. (4) Sensitivity analysis was measured by generating ROC and AUC; (5) We determined internal responsiveness across 4 time points using repeated measures ANOVA (P<.05) and calculated standard error of measurement (SEM), minimal detectable change at 95% CI (MDC_{95}), standardized response mean (SRM), and effect size. Injured scores were analyzed for floor and ceiling effects.
RESULTS: The DFOS demonstrated high test-retest reliability (ICC≥0.93). Single-factor loading in exploratory factor analysis supported unidimensionality of the scale with high internal consistency (α = .96). DFOS-total, ADL and Technique scores had high construct validity compared with SF-36 PCS (r≥0.76). There was excellent sensitivity with high AUC values (AUC≥0.91). There were significant differences across time for DFOS scores (P<.001), demonstrating responsiveness to change. There were no floor or ceiling effects exceeding 15%.
CONCLUSIONS: The DFOS demonstrated acceptable psychometric performance as an outcome and screening measure for adult dancers.
CLINICAL RELEVANCE: The DFOS is a useful tool to monitor both healthy state and functional limitation following lower extremity or back injury in adult ballet and modern dancers. The DFOS focuses on dance-specific movements that are unaddressed in other sports or generic questionnaires and provides an important tool for investigating clinical efficacy.

OPL14

DEVELOPMENT OF A MUSCULOSKELETAL IMAGING COMPETENCY EXAMINATION FOR PHYSICAL THERAPISTS

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PURPOSE: Medical imaging aides in the diagnosis and management of many musculoskeletal conditions. As physical therapist practice evolves, imaging has become more central to such practice. While some physical therapists have shown competency with imaging privileges, the known level of competency and knowledge is generally lacking within the profession. Therefore, the purpose of this study was to develop a reliable and valid musculoskeletal imaging competency examination for physical therapists.

DESCRIPTION: A sample of competencies, guidelines, and clinical decision rules were used for development of an examination that assessed multiple facets of physical therapist practice in the areas of conventional radiography, magnetic resonance imaging, computed tomography, bone scintigraphy, and ultrasound imaging. A 3-round Delphi method utilized content experts to reach examination consensus. Content experts were selected based upon knowledge of orthopaedics and musculoskeletal imaging, current work setting, and previous contributions to the field of musculoskeletal imaging. There were 29 physical therapists, 3 orthopaedic surgeons, 3 radiologists, and 2 primary care physicians on the Delphi panel. Content experts rated each question on a 5-point Likert rating scale of importance, with 0 being least important and 5 being most important. Consensus was achieved with an a priori decision of (1) 4 or greater on the Likert scale and 75% or greater agreement of the expert panel, and (2) 0.90 or greater on Cronbach's alpha and intraclass correlation coefficients. The examination was subsequently reviewed by 5 additional radiologists with expertise in musculoskeletal imaging for content and external validity.

SUMMARY OF USE: The utilized Delphi methodology resulted in a 151-question musculoskeletal imaging competency exam. Interrater agreement and internal consistency were excellent with a mean intraclass correlation coefficient and Cronbach's alpha of .93 and .95, respectively.

IMPORTANCE TO MEMBERS: A musculoskeletal imaging competency examination for physical therapists was developed through Delphi methodology. The developed musculoskeletal imaging competency examination has the potential to be a standardized test to determine a baseline level of competency and knowledge in the area of musculoskeletal imaging for physical therapists. This could provide a foundation to determine where the need is in assisting physical therapists to achieve proficiency in musculoskeletal imaging. Subsequently, it could become a future model for determining whether a physical therapist is capable of using imaging in their practice. Further validation of the examination is needed through pilot testing.

OPL15

HIP JOINT LOADS ASSOCIATED WITH HIGH-INTENSITY INTERVAL TRAINING

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PURPOSE/HYPOTHESIS: Hip joint loads during walking and running are important to consider for exercise prescription in people with hip-related conditions. While high peak loads are expected during running, cumulative joint load is typically greater in walking due a relatively long stance phase. High-intensity interval training (HIIT) incorporating short bouts of high-intensity running with recovery periods of walking has recently gained popularity. The impact of HIIT on hip contact forces (HCF) has yet to be established. The purpose of this study was to (1) determine how locomotion speed impacts HCF measures and (2) compare cumulative HCF loads during HIIT to a metabolically equivalent walking bout.

NUMBER OF SUBJECTS: Twenty-two active adults (11 female; mean ± SD age, 24.8 ± 3.6 years).

MATERIALS/METHODS: Lower extremity 3-D kinematics, kinetics, and energy expenditure were recorded during walking (1.29 ± 0.14 m/s) and at estimated 75% (2.96 ± 0.31 m/s), 85% (3.40 ± 0.34 m/s), and 95% VO_2max run (3.82 ± 0.38 m/s) speeds on an instrumented treadmill. Stance phase lower extremity joint angles and moments for 10 trials of each condition were input to a musculoskeletal model to estimate HCF. Peak, impulse (load per step), and average rate of loading (ROL) of the resultant HCF were extracted and compared using repeated measures ANOVA with Sidak adjustment for multiple comparison and partial eta square to estimate effect size. Additionally, cumulative HCF was calculated as the product of impulse per step and number of projected steps during 2 different 30-minute HIIT protocols (1:4 and 2:3 run-walk ratios) and compared to kcal-matched prolonged walking protocols.

RESULTS: Locomotion speed affected all HCF measures ($P<.01$, $\eta^2 = 0.70$-0.90). Peak HCF and ROL markedly increased during running compared with walking, regardless of running speed ($P<.01$, $\eta^2 = 0.69$-0.85); but, load/step decreased, especially at 95% VO_2max run speed ($P<.01$, $\eta^2 = 0.92$-0.93). Within running conditions, 95% VO_2max running was associated with greater HCF peak and ROL and lower load per step than 75% VO_2max running. HCF measures did not differ between 75% and 85% VO_2max and 85% and 95% VO_2max run comparisons. Both HIIT protocols resulted in shorter exercise time and lower cumulative HCF, regardless of running intensity, when compared to kcal matched walks (32%-60%, $P<.01$, $\eta^2 = 0.95$-0.96).

CONCLUSIONS: Increasing locomotion speed increases peak forces and ROL but reduces load per step at the hip. Incorporating 1 to 2 minutes of running, irrespective of intensity, into a run-walk HIIT protocol can markedly reduce cumulative hip loads when compared calorically matched walking bouts.

CLINICAL RELEVANCE: Elevated peak HCF and ROL during running may evoke symptoms in individuals with hip-related conditions and caution should be used when increasing locomotion speed. However, high cumulative joint loads have been linked with OA progression. Integrating short bouts of running into routine walking exercise markedly reduces cumulative load and may be a safe alternative to prolonged walking for meeting physical activity recommendations.

OPL16

UTILIZATION OF PHYSICAL THERAPY SERVICES FOR CHRONIC LOW BACK PAIN IN THE YEAR PRIOR TO SPINE SURGERY

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PURPOSE/HYPOTHESIS: Surgery is often considered the end stage treatment for chronic low back pain after all efforts for conservative treatment have failed. Physical therapy is considered an appropriate conservative management approach, as most interventions recommended by current clinical practice guidelines can be delivered by a physical therapist. Although most patients utilize physical therapy after surgery, utilization trends before surgery are unknown.

NUMBER OF SUBJECTS: The study included 444 consecutive individuals, aged 18 to 70 years, undergoing surgery of the lumbar spine at Brooke Army Medical Center between January 1, 2014 and June 30, 2016.

MATERIALS/METHODS: Patients were identified retrospectively through the Surgical Scheduling System (S3) based on procedure type (fusion, laminectomy, arthroplasty, vertebroplasty, and discectomy). Surgical procedure variables were extracted from S3 and health care utilization variables (eg, presurgical care, follow-on surgeries, opioid prescriptions, etc) were extracted longitudinally from the Military Health System Data Repository (MDR), during the 12 months before and the 18 months following surgery.

RESULTS: The mean ± SD age was 45.8 ± 12.3 years, 31.8% female. Only 31 (7.0%) of the patients had an evaluation by a physical therapist in the year leading up to the spine surgery date. Only 16 (3.6%) had at least 1 exercise

therapy billing code present in the year prior to surgery. Surgery type did not influence physical therapy utilization (low versus high intensity surgery). However, 378 (85.1%) received at least 1 opioid prescription (mean of 5.4 unique prescriptions) in the year prior.

CONCLUSIONS: During the 1-year period prior to lumbar spine surgery, opioid prescriptions are common but physical therapy utilization is very uncommon. There are many potential factors driving low utilization of physical therapy, but further investigation is needed to identify specific reasons and potential barriers to low utilization rates.

CLINICAL RELEVANCE: A large majority of patients with chronic low back that undergo spine surgery have not had a recent trial of physical therapy. A better understanding of what constitutes "conservative management" is needed to best serve this patient population.

OPL17

TRAJECTORIES OF SPORT OR RECREATIONAL ACTIVITIES OVER 8 YEARS AND ASSOCIATED FACTORS IN PERSONS AT RISK FOR KNEE OSTEOARTHRITIS

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PURPOSE/HYPOTHESIS: Participation in exercise, sport or recreational activities offers multiple health benefits, promotes wellbeing and weight management, and preserves function and quality of life. Staying physically active is important for persons at high risk for knee OA, but without radiographic disease, for helping to prevent the downward spiral of functional decline and disability onset associated with OA development and progression. Understanding how activity levels evolve over time and associated baseline modifiable factors will inform strategies for activity promotion. In persons at high risk for knee OA, we identified distinct trajectories of weekly hours spent in strenuous activities over 8 years and baseline factors associated with membership in each trajectory.

NUMBER OF SUBJECTS: One thousand one hundred ninety-four.

MATERIALS/METHODS: Weekly hours engaged in strenuous sport or recreational activities, such as jogging, swimming, cycling, singles tennis, aerobic dance, skiing (downhill or cross-country) or other similar activities were estimated using items in the PASE (Physical Activity Scale for the Elderly) questionnaire over 8 years. OAI Participants K-L (Kellgren-Lawrence) grade 0 in both knees and with at least 3 time points of PASE data were included. We used latent mixture modeling with zero-inflated Poisson distribution to identify groups with a similar underlying trajectory of weekly hours spent in strenuous activities. Multinomial logistic regression was used to model associations of baseline predictors with membership in each trajectory. Multivariable models were created by including variables with $P \leq .20$ in the univariate model. Backward selection (removing variables with multivariable $P > .20$) was used to create final models.

RESULTS: Among 1194 OAI participants (mean ± SD age, 58.4 ± 8.9 years; BMI, 26.8 ± 4.5 kg/m^2; 58.4% women), we identified 4 distinct trajectories of weekly hours spent in strenuous sport or recreational activities. Over 8 years, nearly 50% of the participants reported zero hour (grade 1), 30% reported 1 to 2 hours per week (grade 2), 12% reported declining participation (grade 3), and 8% reported 8 hours per week (grade 4). Being older, greater BMI, and more severe knee pain were each associated with a reduced likelihood, and being a college graduate and having stronger knees with an increased likelihood of being in the high trajectory (grade 4 versus 1). Depressive symptoms were associated with a reduced likelihood of being in grade 3 versus 1 or grade 2 versus 1.

CONCLUSIONS: In persons at high risk for knee OA, we identified 4 distinct trajectories of weekly hours spent in strenuous activities over 8 years. Reducing BMI, knee pain, and depressive symptoms and improving knee strength may potentially facilitate continued participation in exercise, sport, or recreational activities.

CLINICAL RELEVANCE: Identifying modifiable factors associated with a consistently high level of physical activity participation across 8 years will help to promote an active and healthy lifestyle in persons at high risk for knee OA.

OPL18

THE ASSOCIATION BETWEEN CHANGE IN PHYSICAL ACTIVITY AND CHANGE IN HEALTH-RELATED QUALITY OF LIFE AFTER TOTAL KNEE REPLACEMENT

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PURPOSE/HYPOTHESIS: Health-related quality of life (HRQoL) is the impact health status has on quality of life. The ability for older adults to maintain or increase physical activity (PA) is important to protect against a decline in HRQoL. However, little is known about this relationship for people after total knee replacement (TKR), who often elect to have surgery due to a decline in HRQoL. This association may also differ for younger versus older adults since HRQoL declines with age. Therefore, the purpose of this study was to examine the association of a change in PA from at least 1 year prior to TKR to 1 year after TKR, stratified by older and younger adults, with a change in HRQoL after TKR over the same time frame.

NUMBER OF SUBJECTS: Four hundred twenty-one participants with a unilateral or bilateral TKR in the Osteoarthritis Initiative (OAI).

MATERIALS/METHODS: The exposure was a change in self-reported PA from at least 1-year before to 1 year after TKR. We quantified PA using established categories from the Physical Activity Scale for the Elderly (PASE) as Low PA of 94 or less, Moderate PA of 95 to 146, High PA of 147 to 206, Very High PA of 207 or greater. Next, we classified study participants who stayed in the same category or went up 1 or more PA levels as Increased/Maintained PA, and those who went down 1 or more levels as Decreased PA. We stratified younger and older adults by the median age of 68. Our primary outcome was a change in HRQoL before TKR to after TKR which we quantified using 12-item Short Form Survey Physical Component Summary (PCS). We dichotomized PCS scores using the minimal clinically important difference of 2; less than −2 Decline HRQoL and −2 or greater Maintained HRQoL. We calculated odds ratios and 95% confidence intervals (95% CI) to examine the association between change in PA with change in HRQoL in older and younger adults adjusted for age, body mass index (BMI), sex, race (white/other), education (some college or more/no college), income ($50 000 or more/less than $50 000), marital status (married/other), smoking status (current/other), comorbidity on Charlson Comorbidity Index (1 or more/less than 1), depression on Center for Epidemiological Studies Depression scale (16 or more/less than 16), and average knee pain within the last 30 days on a visual analog scale (3 or more/less than 3).

RESULTS: A total of 220 participants had complete PASE and PCS data (61% female; mean ± SD age, 64 ± 8 years; BMI, 29.9 ± 4.8 kg/m^2). Older adults who Increased/Maintained PA after TKR had 71% (0.10%, 0.82%) lower odds of a Decline in HRQoL compared to those who Decreased PA after TKR. Increased/Maintained PA was not associated with Decline in HRQoL in younger adults (odds ratio = 0.53; 0.25, 1.1). Of 33 younger and 79 older adults who Increased/Maintained PA, 21%, and 15% had a decline in HRQoL, respectively. Of 33 younger and 37 older adults who Decreased PA 21% and 35% had a decline in HRQoL, respectively.

CONCLUSIONS: For older adults, increasing and/or maintaining PA after TKR was associated with lower odds of a decline in HRQoL.

CLINICAL RELEVANCE: Addressing PA during rehabilitation after TKR may have a moderate to large protective effect against a decline in HRQoL in older adults.

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OPL19

THE RELATIONSHIP BETWEEN HEALTH CARE UTILIZATION AND CHANGES IN SELF-REPORTED PAIN AND DISABILITY: IS MORE BETTER?

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PURPOSE/HYPOTHESIS: The purpose of this study was to evaluate the association between improvement in disability at 1 year and health care utilization over 1 year, for patients seeking treatment for subacromial pain syndrome. Our hypothesis was that greater amounts of shoulder-related health care utilization (costs and visits) would be associated with greater improvements in self-reported pain and disability.

NUMBER OF SUBJECTS: One hundred four subjects receiving care for subacromial pain syndrome.

MATERIALS/METHODS: This was a secondary analysis of a cohort of patients with shoulder pain that participated in a randomized controlled trial. Medical costs and visits for the 1-year period following enrollment were abstracted for each subject from the Military Health System Data Repository, a comprehensive claims database managed by the U.S. Defense Health Agency. Using a 2-step cluster, patients were categorized into 2 groups based on 1-year responder status on the Shoulder Pain and Disability Index (SPADI group 1, large changes; group 2, small changes). A generalized linear model, with Poisson regression for skewed distribution of health care data, was used to compare costs and visits between the responder groups. Estimated marginal means with 95% confidence intervals were reported, and significant set at $\alpha = .05$.

RESULTS: The 2 groups of responders were based on SPADI changes from baseline to 1 year (1) large change (mean, 46.83 points) and (2) small change (mean, 7.1 points). There was no significant difference in mean shoulder-related health care utilization between the large-change group (costs, $1556; 95% CI: $958, $2156 to visits, 5.75; 95% CI: 4.12, 7.38) and the small-change group (costs, $1293; 95% CI: $795, $1792 to visits, 7.84; 95% CI: 5.88, 9.80). Demographic variables and number of comorbidities between the 2 groups of responders were not significantly different. More care did not necessarily result in better outcomes.

CONCLUSIONS: Total health care utilization was no different between patients with minimal improvements in disability compared to those with large improvement. The number of shoulder visits and shoulder medical expenditures were not able to predict improvement in pain and disability, suggesting that noncare variables may have a greater influence on outcomes in this patient population. In other words, more care did not result in greater improvements in disability. Treatment was not discontinued when outcomes reached a plateau, which should be evaluated in the future, and could bias the results.

CLINICAL RELEVANCE: The results of this study indicate that the amount of treatment alone may be poorly associated with outcomes, and other factors merit further investigation when considering components of value-based care.

OPL20

PROGNOSTIC AND MODERATING ROLE OF RESILIENCE AND RISK FACTORS IN PATIENTS RECEIVING A COGNITIVE-BEHAVIORAL-BASED PHYSICAL THERAPY INTERVENTION AFTER LUMBAR SPINE SURGERY

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PURPOSE/HYPOTHESIS: Cognitive-behavioral-based physical therapy (CBPT) approaches have been developed to target risk factors for improved outcomes. Individual responses to CBPT may be impacted by baseline psychological status such as resilience. The purpose of this study was to explore the prognostic and moderating influence of resilience, self-efficacy, and fear of movement on 12-month physical function, pain, social support and physical activity after lumbar spine surgery.

NUMBER OF SUBJECTS: Two hundred forty-eight patients (mean ± SD age, 62.2 ± 11.9 years; 51% female) who underwent spine surgery for a degenerative lumbar condition.

MATERIALS/METHODS: This is an exploratory analysis from a randomized trial comparing a postoperative CBPT (n = 124) and education program (n = 124). The primary results of the trial showed no difference in 12-month outcomes in intent-to-treat analyses, but did show superiority of CBPT in an intervention completers only analysis. Participants completed validated questionnaires at 6 weeks (baseline) and 12 months after surgery for physical function (PROMIS Physical Function), pain interference (PROMIS Pain Interference), back pain intensity (numeric rating scale), social health (PROMIS Ability to Participate in Social Roles and Activities), and physical activity (accelerometer step counts). Psychological factors measured at baseline were resilience (Brief Resilience Scale), self-efficacy (Pain Self-Efficacy Questionnaire), and fear of movement (Tampa Scale of Kinesiophobia). Separate multivariable regressions were conducted for each outcome and psychological factor using all patient data. Separate moderated regressions tested the interaction between psychological factor and intervention using data from intervention completers only (n = 179). Covariates in analyses included age, sex, study site, fusion status, and baseline outcome score. Semi-partial correlations were examined.

RESULTS: In multivariable models, resilience was associated with all 12-month outcomes ($r = -0.16$ to -0.14 and 0.12 to 0.23, $P<.05$). Self-efficacy was associated with 12-month physical function ($r = 0.17$, $P = .002$), pain interference ($r = -0.14$, $P = .01$), back pain intensity ($r = -0.12$, $P = .03$), and social health ($r = 0.17$, $P = .003$). Fear of movement was associated with 12-month back pain intensity ($r = 0.12$, $P = .03$) and social health ($r = -0.14$, $P = .01$). None of the psychological factors moderated the effect of CBPT on 12-month outcomes ($P>.05$).

CONCLUSIONS: Early postoperative resilience, self-efficacy, and fear of movement are important prognostic factors for pain-related outcomes after lumbar spine surgery.

CLINICAL RELEVANCE: Along with fear of movement, positive psychological factors such as resilience and self-efficacy are key determinants of postoperative outcomes in patients with degenerative spine conditions. Further work is needed for developing intervention strategies for enhancing resilience.

OPL21

COMPARISON OF PATIENT-REPORTED SYMPTOMS, TENDON STRUCTURE, MECHANICAL PROPERTIES, AND FUNCTION BETWEEN PATIENTS WITH INSERTIONAL AND MIDPORTION ACHILLES TENDINOPATHY

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PURPOSE/HYPOTHESIS: Achilles tendinopathy can occur at the calcaneal insertion or within the midportion of the Achilles tendon. Symptoms are often similar and tendinosis, which is quantified with measures of tendon thickness, is a feature in both presentations. However, insertional Achilles tendinopathy is notoriously recalcitrant to treatment. The purpose of this study was to examine if there are differences between individuals with insertional and midportion Achilles tendinopathy that might relate to differences in patient outcomes.

NUMBER OF SUBJECTS: Individuals with insertional (I) (n = 21) and midportion (M) (n = 28) Achilles tendinopathy with verified tendinosis were included.

MATERIALS/METHODS: Patient symptoms were evaluated with the Victorian Institute of Sport Assessment-Achilles (VISA-A) questionnaire, the Foot

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and Ankle Outcome Score-Quality of Life subscale (FAOS-QOL), and Tampa Scale of Kinesiophobia (TSK). Tendon morphology was quantified using B-mode ultrasound imaging. Achilles tendon mechanical properties were measured with continuous shear wave elastography (cSWE). Lower leg function was evaluated with the heel-rise endurance test.

RESULTS: Twenty-eight (10 female, 21% with bilateral symptoms; mean ± SD age, 53 ± 15 years) individuals with midportion and 21 (14 female, 14% with bilateral symptoms; age, 52 ± 14 years) with insertional tendinopathy were included. The insertional group had larger proportion of women and higher BMI with no other differences in demographics. Both groups had substantial degree of symptoms (VISA-A: M, 58.5; I, 43), with significant differences (P = .006-.024) between the groups in FAOS-QOL (M, 50; I, 37.5) and TSK (M, 38; I, 40). The injured tendon had higher shear modulus (limb symmetry index [LSI]: M, 109%; I, 108%), lower viscosity (LSI: M, 89%; I, 93%), and was thicker (LSI: M, 147%; I, 125%) with no significant difference between the groups. Both groups had significant deficit in heel-rise work (LSI: M, 87%; I, 66%), but the insertional group had significantly (P<.05) greater deficit and more pain with the heel-rise test.

CONCLUSIONS: Patients with insertional Achilles tendinopathy had more symptoms and functional deficits than patients with midportion Achilles tendinopathy, but the Achilles tendon's structure and mechanical properties were affected similarly.

CLINICAL RELEVANCE: There may be other factors that relate to the greater degree of symptoms and functional impairments found in patients with insertional Achilles tendinopathy compared to midportion Achilles tendinopathy. This includes factors such as additional pathological features (eg, calcification, retrocalcaneal bursitis), personal factors, comorbidities, central sensitization, or differences in how the tendon is loaded during functional activities. These factors need to be considered when designing interventions.

OPL22

CLINICAL INTERPRETATION OF THE NECK FUNCTIONAL STATUS COMPUTER ADAPTIVE TEST

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PURPOSE/HYPOTHESIS: (1) Assess reliability of point estimates and change scores of the neck functional status computer adaptive test (NCAT) at different levels of confidence; (2) identify thresholds of clinically important improvement using distribution and anchor-based estimates; and (3) construct a functional staging model to facilitate clinical interpretation of the NCAT scores.

NUMBER OF SUBJECTS: Patients (n = 250 741) experiencing nonspecific neck pain aged 14 to 89 who started a physical therapy episode of care between January 1, 2016 to December 31, 2017, completed the NCAT at admission, and were discharged from therapy.

MATERIALS/METHODS: Reliability of point estimates was calculated using NCAT data collected at admission. Reliability estimates of individual functional status (FS) scores were based on the standard errors of measurement (SEMs) associated with the final estimate of FS obtained from the intake NCAT. Minimal detectable improvement (MDI) was estimated using 1-tailed confidence intervals (CIs) at 90% and 95% levels of confidence. We calculated CIs for the full range of scores and by quartiles of NCAT scores at admission. Distribution and anchor-based estimates of important improvement were assessed using data from patients who completed both the NCAT and the global rating of change scale at discharge. Finally, we developed a functional staging model by defining 5 hierarchical functional stages and the expected performance of patients at each stage. Cut scores were derived based on the difficulty of items and their response categories.

RESULTS: Our primary sample included 250 741 patients who completed the NCAT at admission (mean ± SD age, 54 ± 16 years; 65% women). Of these, 169 039 patients (67%) also completed the NCAT at discharge. The scale-level reliability of the NCAT was 0.91. SEMs were stable across the measurement continuum ranging from 3.7 to 3.9 points (minimum to maximum scores, 0-100), which corresponds to 6.1 to 6.4 points at the 90% confidence level. MDI at the 90% CI ranged between 6.6 and 7.0 points. One half SD of baseline scores was 6.2 points. Overall minimal clinically important improvement (MCII) was 8.1, with estimates ranging from 15 to 4 FS points from the lowest to the top quartile of baseline NCAT scores, respectively. Thus, greater change was needed to achieve MCII for patients with lower baseline functional status. The percent of patients stratified at intake into functional stages 1 to 5 (lowest to highest functioning) were 4%, 12%, 49%, 32%, and 3%, respectively. The majority of patients (61%) demonstrated functional staging change during treatment, with 1%, 4%, 25%, 48%, and 22% categorized into stages 1 to 5, respectively.

CONCLUSIONS: This study provided a set of estimates helpful in clinical interpretation of FS scores derived by the Neck Functional Status CAT.

CLINICAL RELEVANCE: Results will allow clinicians to assess and interpret meaningful functional progress of patients with neck impairments.

OPL23

IS THERE A DIFFERENCE IN UTILIZATION AND OUTCOMES FOR PATIENTS WITH LOW BACK PAIN WHO HAVE BEEN TREATED BY A PHYSICAL THERAPIST VERSUS A PHYSICAL THERAPIST AND PHYSICAL THERAPIST ASSISTANT?

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PURPOSE/HYPOTHESIS: The purpose of this retrospective observational study was to compare differences in clinical outcome and utilization of care among patients with low back pain (LBP) who were treated by a physical therapist only (PT) versus a physical therapist and physical therapist assistant team (PT+PTA).

NUMBER OF SUBJECTS: One thousand eight hundred fifty-four patients with low back pain.

MATERIALS/METHODS: All patients with a complaint of LBP from July 1, 2017 to April 30, 2018, who were not Medicare beneficiaries were included. Patients treated by PT (n = 1673) and PT+PTA (n = 181) were analyzed for differences on the basis of age, initial Modified Low Back Disability Questionnaire (MDQ) score and MDQ change score, initial numeric pain score (NPS) and NPS change score, number of visits, and length of stay (LOS) of physical therapy episode. Patients' change scores that were less than 6 points on the MDQ were categorized as a "failure to progress." Data were collected from the Intermountain Health care electronic medical record (EMR) and from Rehabilitation Outcomes Management System (ROMS). Differences between the groups was determined using Welch's t test to account for unequal sample sizes between the groups.

RESULTS: Groups were similar in age, admit MDQ score and admit pain score. Average age in the PT group, 43.2 years; PT+PTA group, 42.7 years old. The average MDQ score on initial in the PT group was 33.6% and the PT+ PTA group was 36.7%. Average pain score on initial in the PT group was 5.0 and the PT+ PTA group was 5.4. MDQ change ("outcome difference") was not significant, t = 1.9249, P = .0555. Average length of stay (LOS) for the PT+PTA group was 42.85 days, the PT group LOS was 34.14 days. Visits PT+PTA group averaged 7.97 visits per episode, versus PT group of 5.6 visits. Both length of stay (P = .0133) and visits (P<.001) were significant with Welch's t test pain change in the PT+PTA group was 1.73 and in the PT group was 1.8. The difference in pain change was not

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significant (P = .7319). Failure to progress in the PTA group was 38% (69 patients) and PT only group was 30.6% (512 patients). The difference in failure to progress was significant (P = .0383).
CONCLUSIONS: In this retrospective observational study, a higher proportion of patients with LBP treated by a PT achieved a meaningful clinical improvement compared to the proportion of patients treated by PT+PTA. In addition, patients managed by a PT had a significantly shorter LOS and fewer visits compared to patients managed by PT+PTA.
CLINICAL RELEVANCE: The volume of patients who receive physical therapy for complaints of LBP is large. From a value-based health care prospective, more research is needed to determine when and where PTAs may or may not be helpful along the continuum of care for patients with primary complaint of LBP. This retrospective review of outcomes data shows increased utilization of visits and increased failure to progress when a combined approach of PT and PTA is utilized versus PT only in the treatment of this patient population.

OPL24

PERIOSTEAL ELECTRICAL DRY NEEDLING AS AN ADJUNCT TO EXERCISE AND MANUAL THERAPY FOR KNEE OSTEOARTHRITIS: A MULTICENTER RANDOMIZED CLINICAL TRIAL

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PURPOSE/HYPOTHESIS: Manual therapy, exercise and acupuncture have been found to be moderately effective for knee osteoarthritis (OA) when applied in isolation. No previous study has investigated the combination of the effectiveness of electroacupuncture or electrical dry needling in addition to manual therapy and exercise in patients with knee OA. Therefore, the purpose of this trial was to compare the effects of adding electrical dry needling into a manual therapy and exercise program on pain, stiffness, function, and disability in individuals with painful knee OA.
NUMBER OF SUBJECTS: Two hundred forty-two.
MATERIALS/METHODS: Two hundred forty-two participants (n = 242) with painful knee OA were randomized to receive 6 weeks of electrical dry needling, manual therapy and exercise (n = 121) or manual therapy and exercise (n = 121). The primary outcome was related-disability as assessed by the Western Ontario and McMaster Universities (WOMAC) Osteoarthritis Index at 3 months. Secondary outcomes were the numeric pain rating scale, WOMAC subscales, medication intake, and the global rating of change (GROC).
RESULTS: Individuals receiving the combination of electrical dry needling, manual therapy and exercise experienced significantly greater improvements in related disability (WOMAC: F = 35.504, P<.001) than those receiving manual therapy and exercise alone at 6 weeks and 3 months. Patients receiving electrical dry needling were 1.7 times more likely to have completely stopped taking medication for their pain at 3 months than individuals receiving manual therapy and exercise (OR = 1.6; 95% CI: 1.24, 2.01; P = .001). Based on the cutoff score of greater than or equal to +5 on the GROC, significantly (χ^2 = 14.887, P<.001) more patients (n = 91, 75%) within the dry needling group achieved a successful outcome compared to the manual therapy and exercise group (n = 22, 18%) at 3 months. Effect sizes were large (SMD greater than 0.82) for all outcome measures in favor of the electrical dry needling group at 3 months.
CONCLUSIONS: The inclusion of electrical dry needling into a manual therapy and exercise program was more effective for improving pain, stiffness, function, related disability, and medication intake than the application of manual therapy and exercise alone in individuals with painful knee OA.
CLINICAL RELEVANCE: To our knowledge, this study is the first randomized clinical trial comparing the effectiveness of manual therapy and exercise plus electrical dry needling to manual therapy and exercise alone in patients with painful knee OA. The results suggest that a mean of 9 sessions of manual therapy and exercise plus electrical dry needling, using a 9-point standardized protocol targeting the knee locally at a frequency of 1 to 2 times per week over 6 weeks, resulted in greater improvements in pain, stiffness, function, related disability, and medication intake than manual therapy and exercise alone. For the primary outcome of related-disability (WOMAC), between-groups effect sizes were large at 3 months in favor of the dry needling group.

OPL25

ELECTRICAL DRY NEEDLING AS AN ADJUNCT TO EXERCISE, MANUAL THERAPY, AND ULTRASOUND FOR PLANTAR FASCIITIS: A MULTICENTER RANDOMIZED CLINICAL TRIAL

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PURPOSE/HYPOTHESIS: The purpose of this trial was to compare the effects of adding electrical dry needling into a program of manual therapy, exercise and ultrasound on pain, function and related disability in individuals with PF.
NUMBER OF SUBJECTS: One hundred eleven.
MATERIALS/METHODS: One hundred eleven participants with PF were randomized to receive electrical dry needling, manual therapy, exercise and ultrasound (n = 58) or manual therapy, exercise and ultrasound (n = 53). The primary outcome was first-step pain in the morning as measured by the numeric pain-rating scale (NPRS). Secondary outcomes included resting foot pain (NPRS), pain during activity (NPRS), the Lower Extremity Functional Scale (LEFS), the Foot Functional Index (FFI), medication intake, and the global rating of change (GROC). The treatment period was 4 weeks with follow-up assessments at 1 week, 4 weeks, and 3 months after the first treatment session. Both groups received 6 sessions of impairment-based manual therapy directed to the lower limb, self-stretching of the plantar fascia and the Achilles tendon, strengthening exercises for the intrinsic muscles of the foot, and therapeutic ultrasound. In addition, the dry needling group also received 6 sessions of electrical dry needling using a standardized 8-point protocol for 20 minutes. The primary aim was examined with a 2-way mixed-model analysis of covariance (ANCOVA).
RESULTS: The 2-by-4 ANCOVA revealed that individuals with PF who received electrical dry needling, manual therapy, exercise and ultrasound experienced significantly greater improvements in first-step morning pain (F = 22.021, P<.001), resting foot pain (F = 23.931, P<.001), pain during activity (F = 7.629, P = .007), LEFS (F = 13.081, P<.001), FFI Pain Subscale (F = 13.547, P<.001), FFI Disability Subscale (F = 8.746, P = .004), and FFI Total Score (F = 10.65, P<.001) than those who received manual therapy, exercise and ultrasound at 3 months. No differences in FFI Activity Limitation Subscale (F = 2.687, P = .104) were observed. Based on the cutoff score of +5 or greater on the GROC, significantly (χ^2 = 45.582, P<.001) more patients within the electrical dry needling group (n = 45, 78%) achieved a successful outcome compared to the manual therapy, exercise and ultrasound group (n = 11, 21%). Effect sizes ranged from medium to large (0.53).

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CONCLUSIONS: The inclusion of electrical dry needling into a program of manual therapy, exercise and ultrasound was more effective for improving pain, function and related disability than the application of manual therapy, exercise and ultrasound alone in individuals with PF.
CLINICAL RELEVANCE: To our knowledge, this study is the first randomized clinical trial investigating the effectiveness of electrical dry needling combined with manual therapy, exercise and ultrasound in patients with PF.

OPL26

IS THERE AN ASSOCIATION BETWEEN DEMOGRAPHIC AND PSYCHOSOCIAL PROFILES AND PAIN PROCESSING MECHANISMS AMONG HEALTHY ADULTS?

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PURPOSE/HYPOTHESIS: Certain demographic and psychosocial characteristics influence pain neurophysiology. This study aims to investigate the collective relationship of these variables as predictors of individual pain processing mechanisms and overall pain experience.
NUMBER OF SUBJECTS: Thirty-two healthy participants between 18 and 65 years of age were recruited and signed informed consent approved by RWJBH and SU Institutional Review Boards.
MATERIALS/METHODS: Latent psychosocial factors assessed were anxiety, depression, and pain catastrophizing. Pain processing mechanisms were measured through Quantitative Sensory Tests (QST) using mechanical pressure algometer to assess for pain threshold through Pressure Pain Threshold (PPT) test, pain sensitivity through Temporal Summation (TS) test, and pain modulation through Conditioned Pain Modulation (CPM) test. Demographic factors examined were age, sex, race, and ethnicity.
RESULTS: Correlation coefficients were used to analyze relationships between QST, demographic and psychosocial profiles. Moderate association was found between PPT and sex ($r = 0.52$, $P = .002$); with fair association between PPT and race ($r = 0.45$, $P = .011$), and PPT and ethnicity ($r = 0.41$, $P = .019$). Large shared variance seen between PPT and sex and moderate between race and ethnicity. Stepwise regression analysis revealed only sex ($F_{1,30} = 11.05$, $P = .002$) and race ($F_{1,29} = 11.19$, $P = .007$) are significant predictors of PPT, with 25% of variance in PPT explained by sex alone and 40% of variance is explained by both sex and race ($F_{2,29} = 11.19$, $P<.01$). No latent psychosocial variables were captured among participants and no other associations were found between these factors and QST.
CONCLUSIONS: This study provides novel evidence on the collective influence of various demographic factors that contribute to levels of pain threshold, sensitivity, and modulation. Ethnicity showed fair correlation with PPT but unseen with regression analysis. This variable needs to be accounted for as a covariate in the assessment of individual pain measures and evaluation of pain report. Temporal summation and CPM appear to be insensitive to demographic and psychosocial factors and may be useful for objective clinical assessment of individual pain processing mechanisms.
CLINICAL RELEVANCE: Consideration of complex interplay among variables that significantly contribute to pain etiology is crucial in understanding individual pain perception and response which contribute to overall pain experience. Furthermore, integration of QST in patient examination to assess the activity and integrity of central pain processing structures may provide trajectory in the creation and assessment of interventional strategies and treatment outcomes in various patient population especially those with painful musculoskeletal conditions or receiving pain management.

OPL27

PREDICTION OF CANCELLATIONS TO ENHANCE CARE DELIVERY FOR MUSCULOSKELETAL CONDITIONS: A PRELIMINARY ANALYSIS

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PURPOSE/HYPOTHESIS: Recent practice guidelines advocate for nonpharmacological treatment of musculoskeletal pain and health services research supports early physical therapy for decreasing opioid use. Limitations in physical therapy delivery may present a barrier for implementing practice guidelines at appropriate scale. Significant burdens are placed on the health care system when patients fail to attend scheduled appointments. In the context of musculoskeletal conditions there are limited resources available for a growing need of nonpharmacological services. In response this study aimed to develop a preliminary risk prediction model for patients not attending a scheduled appointment.
NUMBER OF SUBJECTS: A nationally representative sample (n = 452443) of patients seeking outpatient physical therapy were analyzed from the ATI Patient Outcomes Registry.
MATERIALS/METHODS: Patients included in this analysis were at least 18 years of age, had at least one scheduled visit for a single episode of care. Patients were excluded if condition code was: headache, lymphedema, neurological, pelvic floor, TMJ, or vestibular. Patients were also excluded if they did not meet realistic age, height, weight, and BMI parameters. A cancellation was defined as a visit that was scheduled but had a final status of "canceled" or "pending" instead of "completed." Demographic and clinical characteristics from the electronic record were used as predictors. We then developed a multivariable logistic regression model to better understand factors associated with cancellations. A generalized estimating equation approach was used to account for repeated visits within patients and analyses were stratified by insurance type.
RESULTS: The cohort was 59% female with a median age of 55 years (IQR, 41-66 years) and had a median of 2 comorbidities (IQR, 1-4 years). The most common primary body regions were lower extremity (37%), lumbar spine (29%), upper extremity (20%), and cervical spine (14%). Primary payer classes were commercial insurance (58%), Medicare (19%), worker's compensation (11%), and Medicaid (9%). Individual level predictors for first cancellation were age, sex, BMI, smoking status, reporting night sweats or night pain, visit day of week, visit number, state of residency, and primary body region. The predicted probability of cancellations ranged from 15% to more than 60% depending on the number of visits and payer. There was also variability in the probability of cancellation by state and insurance status (commercial, 10%-29%; Medicare, 8%-28%). The C statistics for these models were 0.63 and 0.60 for commercial and Medicare payers, respectively.
CONCLUSIONS: Our initial model to characterize cancellations indicated reasonable accuracy. Additional research is needed to investigate ways to improve predictive accuracy before used in practice settings.
CLINICAL RELEVANCE: These analyses suggest there may be opportunities to improve efficiencies in delivering nonpharmacological treatments for musculoskeletal conditions by predicting cancellations for physical therapy.

OPL28

A DESCRIPTIVE ANALYSIS OF A STAGED ALGORITHM FOR REHABILITATION IN PATIENTS SEEKING DIRECT ACCESS TO PHYSICAL THERAPY FOR SHOULDER DISORDERS

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PURPOSE/HYPOTHESIS: Standardized care is advocated to decrease unwanted variability in clinical practice in an effort to improve patient outcomes and decrease cost of care. Treatment based approaches to date based on pathoanatomic diagnoses or impairments alone do not account for and a given patient's symptoms. More specific approaches which provide the ability to account for patients' presentation is needed. Therefore, the purpose of this analysis was to describe the initial efforts to standardize diagnosis and symptom classification and concurrent short term patient outcomes for patients seeking direct access to physical therapy for shoulder disorders.

NUMBER OF SUBJECTS: Patients (mean ± SD age, 48.2 ± 13 years) seeking physical therapy for shoulder (n = 137101 female) complaints via direct access to physical therapy.

MATERIALS/METHODS: Patients' demographic data, visits, numeric pain rating (0-10), and Pennsylvania Shoulder Score (PSS) were queried from the ATI Patient Outcomes Registry. All patients were treated by physical therapists who participated in a 6-hour training program aimed to standardize pathoanatomic diagnoses, assessment of patient symptoms, and provide matched manual therapy within an exercise based approach for neck disorders. Clinicians were instructed to classify patients based on patient outcome measure and pain as high (disability of 50% or greater and pain of 7 or greater), moderate high (30%-49% disability and pain 4-6), or low (disability of 29% or less and pain of 3 or less). Treatment based diagnoses groupings were used based on the published STAR schema for shoulder pain including rotator cuff disorders, shoulder instability, frozen shoulder, and other disorders. A chi-square and separate univariate ANOVAs were used to compare group differences for age, sex, PSS change, and PT utilization via visits between STAR symptom state groups and diagnoses.

RESULTS: Across high (24), moderate (67), and low (48) disability groups as well as rotator cuff (75), instability (17), frozen shoulder (25), or other diagnoses (20) attended similar numbers of PT visits (10.4 ± 5.1) and episode of care (55.7 ± 15.6 days, $P>.05$) via direct access. Patients with classified as high disability displayed significantly greater disability (PSS, 48 ± 15) and pain (7.3 ± 2.2) compared to those classified as moderate (PSS, 58 ± 16; pain, 4.3 ± 2.7), and low disability (PSS, 77 ± 17; pain, 1.9 ± 1.3; $P<.01$). There were no other significant differences between diagnoses or symptom groups for disability or pain or for age, BMI, sex distribution, or PSS change score ($P>.05$).

CONCLUSIONS: Preliminary results suggest that a standardized approach for shoulder complaints shows promise for short term response for patients seeking care via direct access. Future study is warranted to further evaluate program effectiveness.

CLINICAL RELEVANCE: A standardized approach to classification and rehabilitation for patients with shoulder pain appears to yield consistent, clinically important short term change in functional outcomes.

OPL29

SCAPULAR MOVEMENT IMPAIRMENTS IN INDIVIDUALS WITH SUBACROMIAL PAIN SYNDROME BASED ON SCAPULAR ASSISTANCE TEST AND SCAPULA REPOSITION TEST OUTCOMES

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PURPOSE/HYPOTHESIS: The Scapular Assistance (SAT) and Scapula Reposition (SRT) tests are symptom modification tests proposed to identify scapular movement contributions to the presence of shoulder pain, yet whether individuals who have positive results on these tests have greater scapular movement impairments is unknown. The purpose of this study was to determine whether impairments in scapular muscle force generation, mobility, or muscle length are greater in individuals with subacromial pain syndrome (SPS) who have positive results on the SAT or SRT compared to those who test negative.

NUMBER OF SUBJECTS: Sixty subjects (mean age, 36.6 years; 37 male; median Penn Shoulder Score, 71.6/100).

MATERIALS/METHODS: Scapular upward rotation active and passive range of motion (ROM) (intraclass correlation coefficient [ICC] = 0.92-0.94) and posterior tilt active and passive ROM (ICC = 0.90-0.92) during maximal arm elevation were assessed in the scapular plane using a modified digital inclinometer. Maximal isometric force was assessed in the manual muscle test positions for the middle trapezius (ICC = 0.94), lower trapezius (ICC = 0.95), and serratus anterior (ICC = 0.96) using a handheld dynamometer (kilograms) and normalized by body weight. Pectoralis minor muscle length (ICC = 0.99) was assessed with a tape measure (centimeters) and normalized by body height. A reduction in pain by 2 points or greater was considered positive for the SAT and SRT. Mann-Whitney *U* tests were used to assess for differences in the dependent variables between groups based on SAT and SRT results ($\alpha = .05$).

RESULTS: There was a statistically significant difference ($P = .023$) in pectoralis minor muscle length based on the result of the SAT. Individuals who had a positive test had decreased muscle length (median, 8.75; interquartile range [IQR], 8.32-9.28) compared to those who tested negative (median, 9.46; IQR, 8.78-10.14; MDC, 0.18). No significant differences ($P>.05$) in scapular upward rotation or posterior tilt, or muscle force generation were present based on the result of either test.

CONCLUSIONS: A positive SAT was associated with greater pectoralis minor muscle length impairment, but not scapular muscle strength or mobility. The SAT may be helpful in identifying pectoralis minor muscle length contribution to SPS. The SRT result did not identify greater impairments in any of the variables assessed. Other factors not examined in the current study, such as motor control, may affect the outcome of these tests and may warrant investigation.

CLINICAL RELEVANCE: These tests may not differentiate the magnitude of scapular movement impairments in individuals with SPS, if differences do exist. The lack of meaningful differences between positive and negative test results suggest that therapists may not be able to rely on the magnitude of impairments to drive treatment choices. However, future study is necessary to determine the effectiveness of treatment focused on scapular movement related impairments based on the results of the SAT and SRT.

OPL30

VIDEO-BASED MOTION-ANALYSIS USE: A SURVEY OF ORTHOPAEDIC PHYSICAL THERAPISTS

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PURPOSE/HYPOTHESIS: Motion analysis is a tool for physical therapists (PTs) to assess and optimize movement. Video-based motion-analysis (VBMA) is available for smartphones/tablets and require little to no equipment/cost. Research in this topic is limited. The purpose of this study is to explore the use of VBMA in orthopaedic PTs.

NUMBER OF SUBJECTS: Four hundred seventy-seven.

MATERIALS/METHODS: An 18-question multiple-choice online survey was sent to Orthopaedic Section members. Study sample included licensed PTs, practicing 4 hours per week or more treating primarily orthopaedic injuries. The survey was vetted through a survey expert and focus group (11 PTs). Questions included: frequency of VBMA use, reasons for use, potential facilitators/barriers, device/apps used, patients seen, weekly practice hours, time spent with patients, use of without aides/assistants, certifications, and demographics. More than 1 answer was allowed in some responses (eg, device used, reasons for use, and barriers to use).

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RESULTS: Two hundred twenty-eight respondents (47.8%) use VBMA. Of those who use VBMA, 208 (91.2%) use it for 1% to 25% of their caseload, 132 (57.9%) use their personal device, 98 (43.0%) use a patient device, and 90 (39.5%) use a clinic-issued device; 209 (91.7%) chose visual feedback, 208 (91.2%) analysis of movement, and 118 (51.8%) assessment of progress as reasons for VBMA use; 121 (53.1%) use a camera on a tablet/phone; 103 (45.2%) use a VBMA app. Apps most frequently used: Hudl/Technique (47, 45.6%), Coach's Eye (23, 22.3%), and Dartfish (15, 14.6%). Barriers to use: lack of device/equipment (233, 48.8%), time restraint (232, 48.6%), and unfamiliarity with device/equipment (153, 32.1%). Significant differences were found with age, years of experience, certification, and postprofessional training. Those younger (40.6 versus 43.2 years old, $P = .014$) and with 20 years or fewer of experience (52.5% with 20 years or fewer versus 37.4% with greater than 20 years, $P = .004$) were more likely to use VBMA. Orthopaedic clinical specialists (OCS) were more likely to use (113/210) versus those who were not (115/267) (53.8% versus 43.1%, $P = .025$); 24/36 (66.7%) Orthopaedic Residency graduates were more likely to use versus 204/439 (46.5%) nonresidency graduates who did not ($P = .029$); 26/40 (65%) Fellows of the American Academy of Orthopaedic Manual Physical Therapists were also more likely to use versus 202/437 (46.2%) who were not ($P = .035$). Time spent with patients, geographic region, delegation to assistants/aides, practice setting, or terminal degree did not predict VBMA use.

CONCLUSIONS: The majority of respondents do not use VBMA. Of those using VBMA, most use it for 25% or less of their caseload. Those younger, with less years of experience, are OCS, and are Residency or Fellowship-trained were more likely to use VBMA. Generalizability to other PTs outside the Orthopaedic Section is limited. Future research should explore validity/reliability of VBMA and patient outcomes with use of VBMA.

CLINICAL RELEVANCE: PTs can use this information to explore the use of VBMA in clinical practice. PTs can also use this information to educate colleagues who are not using VBMA.

OPL31

SHORT- AND LONG-TERM EFFECTS OF SKILL TRAINING VERSUS STRENGTH AND FLEXIBILITY EXERCISE ON KNEE, HIP, AND LUMBAR SPINE KINEMATICS IN PEOPLE WITH CHRONIC LOW BACK PAIN

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PURPOSE/HYPOTHESIS: Repeated use of direction-specific, altered movement patterns during functional activities is an important movement-related mechanism proposed to contribute to chronic low back pain (CLBP) symptoms and limitations. Compared to back-healthy people, the typical altered pattern is greater early lumbar movement during an activity. One goal of treatment, therefore, would be to change these alterations during performance of functional activities. Skill training (ST) is individualized, challenging, and progressive practice to learn or modify motor skills. As such, ST may be more effective at changing altered movement patterns than other types of exercise. Our purpose was to compare the short- and long-term effects of 2 treatments, ST and strength and flexibility exercise (SF), on knee, hip and lumbar spine movement during a functional activity test of picking up an object (PUO).

NUMBER OF SUBJECTS: One hundred twenty-four people with CLBP (45 male; mean ± SD age, 42.6 ± 0.9 years).

MATERIALS/METHODS: As part of a clinical trial, participants were randomized to either 6 weeks of ST or SF. The ST group received individualized training to modify pain-provoking altered movement patterns during functional activities. The SF group received exercises for trunk strength and trunk and limb flexibility. At baseline, posttreatment and 6-month follow-up participants performed a standardized PUO test using their preferred pattern. The 3-D marker coordinate data were collected. Kinematics were calculated. Early (first half of PUO descent) sagittal plane knee, hip and lumbar spine excursion (positive is flexion, negative is extension) were calculated. A mixed-model repeated-measures ANOVA was used to examine Treatment group (Tx), Time and Tx-by-time effects. When an ANOVA was significant ($P<.05$), a priori planned contrasts were examined.

RESULTS: The 2 groups were similar at baseline for knee (ST, 11.1° ± 1.5°; SF, 8.9° ± 1.5°; $P = .31$), hip (ST, 21.2° ± 1.0°; SF, 20.8° ± 1.0°; $P = .81$), and lumbar (ST, 11.3° ± 0.5°; SF, 11.2° ± 0.5°; $P = .88$) early excursion. ST group: significant changes were found in knee (18.6° ± 1.5°, $P<.01$), hip (10.8° ± 1.0°, $P<.01$), and lumbar (−2.0° ± 0.4°, $P<.01$) early excursion from baseline to posttreatment; no significant changes ($P = .22$) were found from posttreatment to follow-up. SF group: there were no significant changes ($P = .38$) for knee, hip, and lumbar excursion across time points.

CONCLUSIONS: The ST group changed their movement patterns after treatment and changes were maintained at 6-month follow-up. There were no significant changes in the SF group movement patterns after treatment or at follow-up.

CLINICAL RELEVANCE: In people with CLBP, ST was more effective than SF at changing and maintaining change to knee, hip, and lumbar spine movement patterns during a functional activity. If the short-term and, more importantly, the long-term goal of rehabilitation is to improve altered movement patterns contributing to symptoms and limitations in function, our data suggest ST is superior to SF.

OPL32

DOES MULTIDIMENSIONAL HEALTH ASSESSMENT USING PROMIS SCALES ENHANCE CLINICAL DECISION MAKING FOR PATIENTS WITH ORTHOPAEDIC PROBLEMS? A CASE SERIES

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PURPOSE/HYPOTHESIS: To describe proportions of orthopaedic patients that identify 1 of 4 generic health domain scales as their primary health problem using the Patient-Reported Outcomes Measurement Information System (PROMIS). Hypotheses were: (1) that the proportion of patients reporting a primary health domain not commonly assessed at initial evaluation—Fatigue and Self-Efficacy (SE)—would be similar to proportions for Physical Function (PF) and Pain Interference (PI); (2) that PROMIS PF and PI scores would show strong convergent validity, while Fatigue and SE would show low to moderate correlations with PF and PI; and (3) that case descriptions would demonstrate how identifying a patient's primary health domain leads to treatment directed at their primary health problem.

NUMBER OF SUBJECTS: Forty-five.

MATERIALS/METHODS: PROMIS scores were analyzed for 45 consecutive patients over a 3-month period. All patients received physical therapy in a university-based outpatient clinic. Each completed 4 PROMIS scales (PF, PI, Fatigue, SE) at initial evaluation. PROMIS T-scores are normalized to the US population with an average of 50, standard deviation 10. Moderately worse than normal is 0.5 to 1.0 standard deviation from average, and severely worse is greater than 1 standard deviation. A primary health domain—"PF/PI," "fatigue," or "SE"—was ascribed to each patient based on this criteria. Each domain was matched with a specific set of treatments. Proportions of patients for each domain thus represented the frequency of each distinct treatment approach. Pearson correlations for all pairs of PROMIS scales were performed. Correlations above 0.6 demonstrated high convergence, supporting grouping those scales into 1 domain. Lower correlations support using the scales clinically as a separate domains.

RESULTS: Patient age range was 17 to 74 years, average ± SD of 38.3 ± 17.3 years, 80% female. Eighteen had chief complaints in lower extremity, 12 low back, 12 neck, 3 upper extremity. The average ± SD PF T score was 44.0 ± 7.8 (range, 22-60); PI was 59.5 ± 6.9 (range, 47-75); fatigue was 55.2 ± 8.4 (range, 35-74); SE was 44.3 ± 5.4 (range, 32-57). PF/PI and SE were each the primary health domain for 35.6% of the patients, with

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fatigue 28.9%. Convergent validity was strong for PF and PI scores (r = −0.67, P<.01). Fatigue was significantly correlated to PF (r = −0.29, P = .05) and PI (r = 0.42, P<.01) but not SE (r = −0.25, P = .10). The SE scale was significantly correlated to PF (r = 0.31, P = .04) and PI (r = −0.55, P<.01). Three cases link the primary health domain with a distinct approach to treatment.

CONCLUSIONS: The 4 PROMIS scales identified a high proportion of patients (64.5%) with primary problems outside of the typical orthopaedic PF/PI domain. Fatigue and SE are distinct generic health domains that led to different treatment approaches.

CLINICAL RELEVANCE: Generic health domains captured by PROMIS provide a new framework for clinical decision making and patient engagement. The generic health domains are well-aligned with treatments aimed at addressing specific areas of health (PF/PI, fatigue, and SE).

OPL33

DIFFERENTIATING SYMPTOM IRRITABILITY CLASSIFICATION LEVELS WITH 3 PATIENT-REPORTED OUTCOME INSTRUMENTS

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PURPOSE/HYPOTHESIS: Identify specific thresholds for each functional limitation criterion in 3 PRO measures, in order to enhance the differentiation of shoulder symptom irritability classification (SSIC) levels.

NUMBER OF SUBJECTS: One hundred one.

MATERIALS/METHODS: Consecutive subjects with primary complaints of shoulder pain were assessed by pairs of blinded raters (24 raters in total). Raters recorded the shoulder symptom irritability classification level and patients completed 3 separate patient-reported outcome (PRO) measures. Analysis of variance (ANOVA) was used to compare functional disability across different levels of irritability. Receiver operating characteristic (ROC) curve analysis was utilized to derive cutoff scores for 3 PRO instruments. Ordinal regression was utilized to compare strength of PRO instruments in the determination of SSIC.

RESULTS: ANOVA demonstrated significant differences in functional limitation between SSIC groups for all PRO measures with a strong effect (ES, 3.20-6.80). ROC curve analysis determined cutoff scores (high, moderate, low) for the Penn Shoulder Score (PSS) (0-47.9, 48.0-68.5, 68.6-100), American Shoulder and Elbow Surgeons Score (ASES) (0-48.3, 48.4-65.7, 65.8-100), and the Focus On Therapeutic Outcomes Functional Score (FOTO FS) (0-47.0, 47.1-61.9, 62.0-100). The PSS total score and the ASES total score both were significantly related to SSIC with parameter estimates of −0.072 (95% CI: −0.038, −0.106; P<.001) and −0.030 (95% CI: −0.002, −0.058; P = .033), respectively. However, the PSS Pain Subscale was significantly related to SSIC (P<.001), while the ASES Pain Subscale was not (P = .584).

CONCLUSIONS: Functional limitation varies across different levels of shoulder symptom irritability. The PRO cutoff scores show promising results in helping to differentiate levels of symptom irritability. Furthermore, these results demonstrate that the best PRO measure to help determine shoulder symptom irritability is the PSS, as it has the strongest relationship with rater SSIC selection.

CLINICAL RELEVANCE: This is the first study to determine cutoff scores of 3 commonly utilized PRO measures to help inform judgment about irritability. These data also provide evidence of the importance of functional limitation status in the SSIC system, especially when differentiating between high shoulder symptom irritability and moderate shoulder symptom irritability. Furthermore, it provides evidence that the Penn Shoulder Scale may be more influential, with regard to pain and function subscales, than other patient-reported outcome measures in influencing the classification of shoulder symptom irritability.

OPL34

THE SEVERITY OF PREFRACTURE BASIS MOBILITY LOSS AT THE TIME OF ACUTE HOSPITAL DISCHARGE FOR HIP FRACTURE IS ASSOCIATED WITH 30-DAY MORTALITY: A 1-YEAR NATIONWIDE COHORT STUDY OF 5147 DANISH PATIENTS

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PURPOSE/HYPOTHESIS: Early mobilization is monitored in most national hip fracture (HF) registries and included as mandatory in enhanced HF recovery programs. However, knowledge of the importance of acute hospital recovery in relation to achievement of the prefracture basic mobility status, considered an important first step of rehabilitation from HF, is sparse. At the same time, critics say that achievement of the prefracture level is just a matter of length of stay (LOS). We, therefore, examined if the severity of prefracture basic mobility loss at hospital discharge was associated with 30-day postdischarge mortality after a first time HF.

NUMBER OF SUBJECTS: Using the nationwide Danish Multidisciplinary Hip Fracture Database (DMHFD) from January 2015 through December 2015, we included 5147 patients 65 years or older (70% women) who had surgery for a first time HF at 1 of the 25 hospitals treating HF patients in Denmark.

MATERIALS/METHODS: The Cumulated Ambulation Score (CAS) being an obligatory DMHFD score was recorded at prefracture (questionnaire) and objectively at discharge. The CAS evaluates the ability of patients to get in and out of bed, sit to stand to sit from a chair with arms, and walk with or without an assistive device, with a score of 0 to 6 points (6 points indicating an independent basic mobility status and 0 points a completely bedridden patient). The severity of prefracture CAS-points lost (from 1-6 points) at discharge was entered into Cox regression analyses, adjusted by sex, age, BMI, Charlson Comorbidity Index, type of fracture, residential status, and LOS.

RESULTS: The mean LOS for the 60% (n = 3097) of patients who had not regained their prefracture CAS level at discharge was 9.5 days compared to 8.5 days for the 2050 who did. In adjusted analyses, the risk of 30-day mortality hazard ratio (95% CI) was 2.7 (1.9, 3.8) times higher if CAS was not regained, and increased with increasing loss of CAS points. Thus, the risk of death hazard ratio (95% CI) was 1.3 (0.7, 2.2), 1.7 (0.99, 2.9), 2.6 (1.7, 3.8), 4.2 (2.6, 7.0), 5.1 (2.7, 9.7), and 12.3 (7.0, 21.5) times higher for patients who respectively lost 1, 2, 3, 4, 5, and 6 CAS points, compared to no loss.

CONCLUSIONS: In this large national HF registry study, we found that the severity of prefracture basic mobility loss upon acute hospital discharge was strongly associated with 30-day postdischarge mortality in the adjusted analysis including LOS. Further, the analysis indicates that it's not only a matter of the complete regain of the prefracture CAS level since less CAS points lost during the early rehabilitation the more patients seem to survive.

CLINICAL RELEVANCE: Physical therapist should include the full recovery of the prefracture basic mobility status as an important first step rehabilitation goal for patients with hip fracture. We suggest that the reliable and well-validated CAS score be used for that purpose.

OPL35

A SPECIFIC PROTOCOL OF AUTOLOGOUS BONE MARROW CONCENTRATE AND PLATELET PRODUCTS VERSUS EXERCISE THERAPY FOR SYMPTOMATIC KNEE OSTEOARTHRITIS: A RANDOMIZED CONTROLLED TRIAL WITH A 2-YEAR FOLLOW-UP

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PURPOSE/HYPOTHESIS: Current common treatment options for symptomatic knee osteoarthritis (OA), including pharmacological therapies, exercise, and arthroplasty, often have short-term or unsatisfactory results. Autologous biologic therapies, such as platelet-rich plasma and bone marrow concentrate (BMC), have demonstrated promise as a treatment option for knee OA. The purpose of this study was to compare exercise therapy to autologous bone marrow concentrate and platelet products for knee OA treatment.

NUMBER OF SUBJECTS: Fifty.

MATERIALS/METHODS: Patients with symptomatic knee OA (Kellgren-Lawrence grades 2-3) were randomized into either an exercise therapy group or injection of autologous BMC and platelet products. The exercise group partook in 3 months of physical therapy (PT) consisting of an initial visit with a home exercise program (HEP) and another visit at 6 weeks for an upgraded HEP. Patients in the exercise group were then evaluated and could then crossover to BMC treatment after 3 months. Clinical outcomes were documented at baseline and at 1, 3, 6, 12, and 24 months, including the Knee Society Score of Assessment and Function (KSS), Visual Analogue Scale (VAS), Short Form-12 scales (SF-12), and Lower Extremity Activity Scale (LEAS).

RESULTS: There were no significant differences in baseline clinical scores or demographics. Three months of exercise resulted in significant improvements in LEAS (P = .015) and ROM (P = .022) only, but to a lesser degree than the treatment group. All patients in the exercise group crossed over to receive BMC treatment after 3 months. After pooling the treatment group with the crossover group, the KSS-knee score and LEAS were significantly improved after receiving treatment compared to performing exercise. After BMC, all metrics improved significantly across time (KSS knee score, KSS function score, SF physical, and LEAS, P<.001; ROM, P = .003), except for SF-12 mental scores (P = .061). After BMC treatment, patients' clinical outcome scores (except SF-12 mental), were significantly improved through the 2-year follow-up compared to baseline. No serious adverse events were reported.

CONCLUSIONS: The use of image-guided percutaneous BMC with platelet products yielded better results than exercise therapy as an effective alternative therapy for patients with symptomatic moderate to moderate-to-severe osteoarthritis of the knee.

CLINICAL RELEVANCE: Patients in the treatment group experienced increased activity levels (shown by LEAS), improved stability, pain, function and range of motion of the knee (KSS knee score, KSS function score, and SF physical) compared to 3 months of exercise therapy. Exercise therapy provided improvements in ROM and activity levels, but to a lesser degree than BMC treatment. Significant improvements in pain and functionality were maintained through 2 years of follow-up after receiving BMC treatment.

OPL36

KINEMATIC MECHANISMS OF SCAPULOTHORACIC UPWARD ROTATION

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PURPOSE/HYPOTHESIS: Scapulothoracic (ST) upward rotation (UR) serves many important roles in shoulder function including maximizing range of motion and deltoid length-tension relationships. Mechanically, ST UR cannot occur without sternoclavicular (SC) and acromioclavicular (AC) motion. In particular ST UR has been proposed to occur due to AC UR, SC posterior rotation, and SC elevation (ie, "component motions"). However, the kinematic mechanisms by which this occurs remains unclear. The purpose of this study was to investigate the relative contributions of AC UR, SC posterior rotation, and AC UR for producing ST UR.

NUMBER OF SUBJECTS: Thirty participants with current shoulder pain and 30 without a history of shoulder pain.

MATERIALS/METHODS: Shoulder complex kinematics were calculated for a dynamic trial of unloaded scapular plane abduction using single plane fluoroscopy and 2-D/3-D shape matching. Relative kinematics (SC, AC, SC) were described according to published recommendations. Finite helical displacements describing SC, AC, and ST motion were calculated at 30° intervals of humerothoracic (HT) elevation (30°-60°, 60°-90°, 90°-120°). A coupling function was derived to estimate ST UR from its component motions for each interval of HT elevation as a function of the acromioclavicular internal rotation angle. This angle represents the primary offset between the clavicular and scapular anatomical axes and has been theorized to be the predominant factor in defining the coupling relationships. The accuracy of the coupling function for predicting the actual ST UR was described using RMS error and the R^2 from linear regression. The relative contribution (or importance) of each component motion to producing ST UR was calculated as a proportion of the actual ST UR displacement. The effects of HT interval and group membership on proportional contributions were statistically assessed using 2-factor mixed-model ANOVAs for each HT interval.

RESULTS: The coupling function resulted in RMS errors of 1.2° to 2.8° and R^2 values of 0.80 to 0.90. During the first interval of motion (30°-60°), AC UR was the predominant contributor to ST UR (84%), while SC posterior rotation and SC elevation had a combined contribution of approximately 10%. During the second interval of motion (60°-90°), the proportional contribution from AC UR significantly decreased to 42% (P<.01) while that of SC posterior rotation increased significantly to 32% (P<.01). During the final interval of motion (90°-120°), the proportional contributions due to AC UR and SC posterior rotation remained stable at 37% and 34%, respectively. The proportional contribution due to SC elevation remained small throughout all intervals of motion (8%-10%).

CONCLUSIONS: ST UR can be validly estimated from its component motions using the coupling function. AC UR and SC posterior rotation are the primary contributors to ST UR, while SC elevation does not contribute substantially.

CLINICAL RELEVANCE: Knowledge of proportional contributions is crucial for understanding how ST UR is produced, which can help inform movement-based diagnostic classifications and the selection of targeted exercise interventions.

OPL37

PATIENT-CENTERED OUTCOMES: DOMAIN IMPORTANCE PREDICTS HEALTH CARE UTILIZATION FOLLOWING PHYSICAL THERAPY

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PURPOSE/HYPOTHESIS: Patients commonly seek health care to reduce pain intensity, fatigue, emotional distress, and pain interference. We previously identified 3 subgroups defined by how patients rate importance of improvement in these domains. The aim of this study was to determine whether patient-determined domain importance subgroup predicted health care utilization subsequent to an episode of physical therapy for musculoskeletal pain.

NUMBER OF SUBJECTS: Two hundred forty-six patients with knee, shoulder, back or neck pain seeking physical therapy that provided complete 12-month outcome data in the Orthopaedic Physical Therapy Investigative Network's (OPT-IN) Optimal Screening for Prediction of Referral and Outcome (OSPRO) study.

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MATERIALS/METHODS: At initial evaluation, patients completed a demographic and health history questionnaire, numeric pain rating scale, region specific disability measure and Charlson comorbidity index (CCI). We used the Patient Centered Outcome Questionnaire (PCOQ) to assess importance of improvements in pain intensity, fatigue, emotional distress, and pain interference with treatment. Patients also completed the OSPRO Yellow Flag (OSPRO-YF) assessment tool, which evaluates pain-related psychological distress. At 1 year, patients reported use of the following health care services for their pain condition in the time since discharge from physical therapy: opioids, injections, surgery, diagnostic tests/imaging, or emergency room visits. We developed separate logistic regression models to test whether subgroup membership predicted use of any additional health care, and utilization of specific services during the follow-up period. Age, sex, CCI, pain intensity, disability, chronicity, anatomical region, insurance status and OSPRO-YF scores were covariates.
RESULTS: The largest subgroup was "function and pain focused" FP (n = 105, 43%) followed by "multifocused" MF (n = 93, 38%) and "pain only focused" PO (n = 48, 20%). With MF as the reference group, PO had higher adjusted odds (95% CI) of medication use (aOR = 4.4; 1.6, 12.3), injection (aOR = 5.6; 1.6, 19.0) and surgery (aOR = 6.8; 1.3, 35.0) while FP had lower odds of medication use (aOR = 0.3; 0.1, 0.9). OSPRO-YF was not a significant predictor in any multivariate model.
CONCLUSIONS: Patients focused on improvements in pain have greater use of pain medication, injection and surgery after an episode of physical therapy compared to those focusing on multiple domains. Patient-determined outcome domain importance might be a better predictor for health care utilization subsequent to an episode of physical therapy than pain-related psychological distress.
CLINICAL RELEVANCE: As frontline providers, physical therapists must be able to identify patients who are at risk for escalation of care. Assessing the importance of outcome domains using the PCOQ may help to better identify those at risk for escalation of care following physical therapy. In particular awareness of patients that are focused primarily on pain relief may lead to management strategies that effectively limit unnecessary escalation of care.

OPL38

PATIENT SUBGROUPING TO INFORM TREATMENT PATHWAY DEVELOPMENT FOR A COMPREHENSIVE OSTEOARTHRITIS CARE PROGRAM

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PURPOSE/HYPOTHESIS: This study identifies common patient subgroups presenting to a new Comprehensive Osteoarthritis (OA) Care Program in a large, academic health system. Results will inform the development of treatment pathways delivered by physical therapists that offer tailored OA care.
NUMBER OF SUBJECTS: Two hundred forty-six program participants (female: n = 184, 74.8%) with knee (n = 194, 79%) or hip (n = 52, 21%) OA.
MATERIALS/METHODS: Orthopaedic surgeons referred patients with knee or hip OA to the program if they were not immediate candidates for joint arthroplasty. At initial evaluation, we collected demographic information, numeric pain rating scale and joint-specific disability measure (KOOS Jr or HOOS Jr). Participants also completed the OSPRO-Yellow Flag Assessment Tool, which evaluates 3 domains of pain-related psychological distress (ie, negative mood, negative coping, and positive affect/coping). We used hierarchical agglomerative cluster analysis to identify patient subgroups clustering on age, BMI, pain intensity, disability and psychological distress domains. Discriminant function analysis determined the strongest individual predictors of subgroup membership.
RESULTS: We identified 4 patient subgroups: (1) low psychological distress (n = 99, 40.2%), (2) high psychological distress (n = 50, 20.3%), (3) poor coping skills (n = 46, 18.7%) and (4) high BMI (n = 51, 20.7%). Subgroup 1 was young, with below average BMI, pain intensity, disability and psychological distress. Subgroup 2 was older, had lower BMI and above average pain, disability and psychological distress. Subgroup 3 had average age and BMI, with above average function, pain, negative mood and fear avoidance. However, subgroup 3 had below average positive affect/coping. Subgroup 4 was younger than average and had significantly elevated BMI, with above average disability, pain, and psychological distress. The discriminant function test was significant (Wilks' $\lambda = .07$, $P<.001$) indicating that measures adequately discriminated between the subgroups, accounting for 79.2% of the variance. Positive affect/coping, BMI and disability (in order) were the strongest determinants of subgroup membership.
CONCLUSIONS: We identified 4 distinct patient subgroups presenting to the comprehensive OA care program. Positive affect/coping, BMI and disability at initial evaluation may be most informative for allocating patients to these subgroups.
CLINICAL RELEVANCE: A comprehensive OA care program may optimize outcomes by building distinct treatment pathways for common subgroups. Low touch, education-based pathways may be most appropriate for participants with low psychological distress. Alternatively, those with high psychological distress may require pathways that improve cognitive behavioral health and pain coping, with greater patient-provider interaction. Participants with poor coping skills might benefit most from treatments that improve resilience and confidence in self-management. Finally, participants with high BMI might require pathways focused on weight loss, nutrition, behavioral health and lifestyle management.

OPL39

SUPRASPINATUS STRESS AND STRAIN ACROSS ARM ELEVATION

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PURPOSE/HYPOTHESIS: Rotator cuff disease is a common condition contributing to shoulder pain and progressing to rotator cuff tears. Most cuff tears originate in the supraspinatus. The majority of these injuries are "cumulative trauma, wear and tear" injuries with presumed origin from excess stress or strain to the supraspinatus tendon. While much theory has been proposed, there is no data available regarding how stress and strain in the supraspinatus tendon changes across the range of arm elevation motion. As in vivo measurements are invasive, advanced musculoskeletal modeling provides an opportunity to investigate this issue. The purpose of this investigation was to describe stress and strain in the supraspinatus using a finite element shoulder musculoskeletal model incorporating simulated elevation motion.
NUMBER OF SUBJECTS: Forty-eight-year-old woman, single-subject analysis.
MATERIALS/METHODS: A model was developed by imaging the right shoulder (3-T MRI 3-D gradient recalled echo sequence, T1-VIBE with water excitation, 0.6-mm isotropic resolution). Mimics software was used to manually segment the humerus, scapula, coracoacromial ligament, and supraspinatus musculotendinous structures, which were then reconstructed to 3-D models. Models were subsequently meshed using tetrahedral elements. Finite element analysis was performed using FEBio. The supraspinatus tendon was modeled as an incompressible fiber-reinforced hyperelastic material using 1 fiber group and a Mooney-Rivlen ground matrix, based on material properties described in previous literature. A prescribed, active, 50% supraspinatus contraction force was used throughout the simulated motion. Previous average kinematics during a functional reach task

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incorporating bone-fixed tracking in healthy subjects were simulated. The humeral head was centered in the glenoid throughout the motion. Supraspinatus stress and strain data and location of peak stress and strain were determined at 30°, 60°, 90°, and 120° of motion during the functional reach.

RESULTS: Throughout the range of motion, locations of peak stress corresponded to areas of the supraspinatus where tears commonly initiate, including a peak stress on the joint side of the posterior supraspinatus. Both stress and strain progressively increased (100% and 200%, respectively) across the motion. Additionally, the supraspinatus musculotendinous structures underwent substantial visible torsional deformation progressively with arm elevation.

CONCLUSIONS: A computational model using subject-specific geometry and precise 3-D kinematics can provide insight into internal tendon stresses and strains that cannot otherwise be measured. Further model development is ongoing to investigate relative effects of differing subject geometries, altered motion, and other factors related to cumulative trauma to the supraspinatus.

CLINICAL RELEVANCE: Supraspinatus tendon stress and torsional deformation should be further investigated to develop the best approaches to prevent and treat rotator cuff disease. Preliminary data from a single subject suggests torsional rather than compressive mechanisms may be more critical.

OPL40

HIGH-PERFORMING PHYSICAL THERAPISTS CONSISTENTLY USE SKILLED INTERVENTIONS FOR PATIENTS WITH LOW BACK PAIN DESPITE BASELINE DISABILITY

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PURPOSE/HYPOTHESIS: Guideline adherent care for an episode of physical therapy for low back pain (LBP) has been suggested as an average 3 active (ie, exercise-based) to 1 passive (ie, modalities, manual therapy after the first 14 days) current procedural terminology (CPT) codes. However, clinical trials have demonstrated added benefit of utilizing manual therapy within an exercise-based approach, depending on patient status. Thus, guideline adherent care may inadvertently discount appropriate use of manual therapy as it does not consider patient status. The purpose of this study was to compare use of skilled (ie, active, manual) units per visit (SPV) between high and low performing physical therapists (PTs) across levels of baseline patient disability per modified Oswestry Disability Index (ODI).

NUMBER OF SUBJECTS: Patients with LBP (n = 28 902) from the ATI Patient Outcomes Registry treated by high and low performing PTs.

MATERIALS/METHODS: A risk-adjusted performance measure (RPM) was calculated for PTs relative to predicted ODI change across an episode of care, controlling for sex, body mass index (BMI), payer, chronicity, baseline ODI and Veteran's Rand 12-Item Health Survey (VR12). High performing PTs were classified by an RPM indicating ODI change significantly greater than expected, while low performing PTs were classified by an RPM indicating ODI change significantly less than expected using 95% confidence intervals (95% CI). All patients with LBP (n = 139 476 patients, 2845 PTs) were divided into quartiles by initial ODI. Linear regression estimated SPV for patients treated by high (n = 13 604 patients, 281 PTs) and low (n = 15 298 patients, 297 PTs) performing PTs, controlling for sex, payer, age, BMI and VR12. Comparisons between groups across baseline ODI quartiles were made via least squares means for SPV using 95% CI.

RESULTS: High (H) performing PTs demonstrated consistently high SPV across levels of baseline ODI, while low (L) performing PTs significantly decreased the use of SPV as baseline ODI increased (Q1: H, 3.90; 95% CI: 3.85, 3.95; L, 3.84; 95% CI: 3.78, 3.90; Q2: H, 3.91; 95% CI: 3.86, 3.96; L, 3.78; 95% CI: 3.73, 3.83; Q3: H, 3.92; 95% CI: 3.86, 3.97; L, 3.64; 95% CI: 3.59, 3.69; Q4: H, 3.89; 95% CI: 3.84, 3.95; L, .3.44; 95% CI: 3.39, 3.49). Total units per visit was the same between groups, with low performing PTs using more modalities for patients with higher baseline disability.

CONCLUSIONS: Physical therapists with the highest RPM for ODI change consistently use more SPV across levels of patient disability compared to the lowest performing PTs, particularly in the most disabled patients. This suggests that PTs who get the most improvement in ODI, regardless of patient disability display a treatment signature of more exercise-based and manual therapy interventions compared to lower performing PTs. Future studies should consider these results when defining and evaluating guideline adherent care.

CLINICAL RELEVANCE: Consistent use of exercise-based and manual therapy care for patients with LBP is associated with greater risk-adjusted ODI change, despite baseline patient disability.

OPL41

USE OF INTERMOUNTAIN HEALTHCARE'S REHABILITATION OUTCOMES MANAGEMENT SYSTEM TO QUANTIFY PATIENT OUTCOMES IN A PRIVATE PRACTICE SETTING: A BRIEF LOOK AT BEFORE AND AFTER IMPLEMENTATION

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PURPOSE: The cost of musculoskeletal pain in the United States is a major concern and a growing burden on society. Multiple options for intervention and the complexities associated with the treatment of pain add to this burden and have led to a push for value-based care. The use of validated patient-reported outcome measures (PROMs) is a cornerstone of new care models and assists clinicians in effectively tracking treatment effect. A true measure of the impact of an intervention or condition requires at least 2 completed data points or outcome scores. Most often, outcomes are collected at initial encounter, at a 30-day or predetermined progress point and at discharge. Not all clinicians or facilities have a set standard for outcomes collection but leave this up to the discretion of the clinician. The purpose of this report is to demonstrate the need for a systematic implementation of outcomes collection in clinical practice to truly measure value in physical therapy care for painful musculoskeletal conditions.

DESCRIPTION: A sample extraction of retrospective data using 1117 patients discharged between June 2014 and June 2015 in a single private practice physical therapy center through electronic medical records were accessed. All patients diagnosed with nonsurgical conditions of the hip, knee, ankle and shoulder with documented initial scores for validated patient reported outcome tools were included. In this data set, despite documented goals attained at discharge, only 425 (38%) had successful collection of outcomes as measured by 2 or more reported scores. Failure to collect follow-up outcomes renders knowledge of patient success or meaningful change equivocal. Adoption of a systematic collection of PROMs was implemented using Intermountain Healthcare's Rehabilitation Outcomes Management System (ROMS) in September 2016. Follow-up data extraction of 2067 discharged patients between September 2016 and January 2018 resulted in 1865 (90%) successful collection of outcomes on 2 or more occasions.

SUMMARY OF USE: The simple implementation of a systematic collection of PROMS into the work flow resulted in marked improvement in compliance and utilization. Despite the best intention of the clinician eliminating the discretionary option of outcomes collection enhanced performance and improved satisfaction for all stakeholders.

IMPORTANCE TO MEMBERS: This brief pilot comparison of data clearly demonstrates that structured systematic collection of outcomes is easily implemented when adopted into the clinic work flow. Use of these tools consistently can also promote overall quality enhancement and guide clinical development and peer engagement. The need for consistent outcomes collection and reporting in physical therapy care is paramount at this time of increased health care costs.

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OPL42

DOES JOINT HYPERMOBILITY EXACERBATE PAIN, FUNCTIONAL DISABILITY, AND GAIT CHANGES IN ADOLESCENTS WITH JUVENILE FIBROMYALGIA?

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PURPOSE/HYPOTHESIS: Juvenile fibromyalgia (JFM) is a rheumatic condition characterized by musculoskeletal pain, tender points, fatigue, and impaired physical function. Adolescents with JFM demonstrate altered biomechanics during gait and jump landing compared to healthy adolescents which may exacerbate pain in this cohort. Adolescents with joint hypermobility (HM) also demonstrate gait adaptations, with greater knee extension at midstance. Though joint HM is common in adolescents with JFM, and HM is associated with many JFM-related symptoms, it is unknown if HM further exacerbates symptoms or alters biomechanics in JFM. The purpose of this study was to evaluate the effect of HM on pain, functional disability, and gait kinematics in subjects with JFM. The hypothesis tested was that HM subjects would demonstrate greater pain and functional disability and greater hip extension, knee extension and knee abduction angles during midstance compared to non-HM subjects.

NUMBER OF SUBJECTS: Twenty-four female subjects with JFM were categorized as HM (n = 10; mean ± SD age, 15.3 ± 1.6 years) or non-HM (n = 14; age, 15.3 ± 1.5 years) based on the Beighton-Horan Laxity Scale (BHLS).

MATERIALS/METHODS: A BHLS was performed by a trained investigator on each subject to determine joint mobility status (HM, BHLS of 4 or greater; non-HM, 3 or less). Pain and functional disability were measured via the visual analog scale (VAS) and Functional Disability Index (FDI). Three-dimensional motion analysis was used to capture gait kinematics at peak knee extension during the midstance phase of gait. Due to unknown limb dominance, 1 limb from each subject was randomly selected for analysis. Mann-Whitney *U* tests were performed to assess the effect of joint mobility on discrete measures of pain, functional disability and frontal and sagittal plane gait kinematics ($P<.05$).

RESULTS: There were no significant differences in VAS (HM, 6.88 ± 1.20; non-HM, 6.30 ± 1.05; Cohen's $d = 0.51$) and FDI (HM, 28.79 ± 7.52; non-HM, 24.70 ± 7.32; Cohen's $d = 0.55$) scores between groups ($P\geq.94$). There were no significant differences in frontal and sagittal plane hip (Cohen's $d\leq0.13$), knee (Cohen's $d\leq0.27$) and ankle (Cohen's $d\leq0.25$) kinematics during midstance between groups ($P\geq.24$).

CONCLUSIONS: This preliminary analysis showed that HM did not appear to exacerbate pain, functional disability or lower extremity kinematics in adolescents with JFM. Gait, a primal movement task may not expose movement deficits, whereas more dynamic tasks, such as jump landing, may be more sensitive to the effects of HM on lower extremity kinematics in this cohort. Future work will also examine whether HM negatively affects response to neuromuscular training focused on enhancement of movement skills and physical activity engagement.

CLINICAL RELEVANCE: Joint HM is associated with pain and altered biomechanics in other populations. Despite the limited effect of HM on pain, functional disability and gait kinematics in this small sample of subjects with JFM, it may be valuable to further assess joint mobility in adolescents with JFM as the role of HM in JFM is not fully understood.

OPL43

RELATIONSHIP BETWEEN OCCUPATIONAL HEALTH OUTCOME OF THE STARTBACK TOOL, OSWESTRY, AND RETURN TO WORK FOR PATIENTS WITH LOW BACK PAIN

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PURPOSE/HYPOTHESIS: Occupational low back pain (LBP) has a large impact on the individual worker, employers and those responsible for paying the associated medical costs. One approach to improving treatment outcomes is to identify patients at risk for a poor outcome. The STarT Back Tool (SBT) was designed to categorize patients based on high, medium or low risk to predict future disability for patients with LBP. The purpose of this retrospective study was to examine the relationship between the SBT, Modified Oswestry Disability Index (mODI) and Return to Work status (RTW) from 2 occupational health PT clinics over a 2-year period. This study was conducted due to limited research applying the SBT to an occupational health population.

NUMBER OF SUBJECTS: Two hundred twenty-three individuals with the primary complaint of LBP caused by a work-related injury.

MATERIALS/METHODS: Patients must have completed a SBT upon initial evaluation, a mODI upon initial and final visits, and had a minimum of 3 PT visits to be included in the study. The mODI is a 10-item questionnaire with a scale from 0 to 100 with the lower score indicating less disability. The minimum clinically important difference (MCID) has been described as the smallest change in a scale that is meaningful to patients. For this study a successful outcome was measured by the following MCID criteria: mODI of 6% or greater. RTW status was successful if an individual returned to performing their regular preinjury work duties. The patient was unsuccessful if they did not return back to regular duties during this episode of care, was on modified duty or assigned to a different job.

RESULTS: The mean age of patients was 38.3 ± 14.3 years and 65% were men. The SBT categorized 29.1% as high risk, 62.7% as medium risk, and 8.1% as low risk. The mean mODI scores for each group were: 26.5 ± 22.4 high risk; 20.3 ± 14.0 medium risk; 18.6 ± 11.1 low risk. Almost 82% of patients in the high risk group met the mODI MCID. In the medium and low risk groups, 88.6 and 88.9% of patients respectively met the mODI MCID. The high risk group had the greatest number of individuals that were unable to return to regular work duties at 29.2%. The medium risk group had 20.0% and the low risk group had 5.5% that were unable to return to regular work duties.

CONCLUSIONS: This is one of the first investigations to examine outcome data in an Occupational Health PT setting using the SBT, mODI and RTW. The descriptive data revealed the high risk population had the greatest number of patients that were unsuccessful returning to their regular work duties. Further research is needed applying the SBT to this population. Additional research should examine the reasons for failure to return to work and identify further prognostic factors in order to improve treatment outcomes for patients with occupational LBP injuries.

CLINICAL RELEVANCE: In this patient population, the SBT could provide an opportunity to identify patients who could benefit from the most directed treatment for improved outcomes and return work duties.

OPL44

EFFECTIVENESS OF PHYSICAL THERAPY TREATMENT IN ADDITION TO USUAL PODIATRY MANAGEMENT OF PLANTAR HEEL PAIN: A RANDOMIZED CLINICAL TRIAL

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PURPOSE/HYPOTHESIS: Many patients seek care from a podiatrist for plantar heel pain (PHP), while few of these patients are also seen by a physical therapist. Physical therapists provide treatment that is not a part of usual podiatric care that may result in additional improvement in function and pain. The purpose of this study was to examine the additional

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benefit of physical therapy treatment to usual podiatric care in individuals with PHP.

NUMBER OF SUBJECTS: Ninety-five individuals (mean ± SD age, 50 ± 11 years; 75% female) that presented to a podiatrist and were diagnosed with PHP.

MATERIALS/METHODS: Eligible individuals were randomized to receive usual podiatric care (uPOD) or usual podiatric care plus physical therapy treatment (uPOD+PT). In both treatment groups, podiatrists and physical therapists intervened pragmatically. The primary outcome was change in foot and ankle ability measure (FAAM) at 6 months. Secondary outcomes included change in numeric pain rating scale (NPRS), patient-reported success, 6-week and 1-year FAAM outcomes. Patient-reported success was achieved by reporting 1 of the top 2 rankings on the global rating of change scale. Primary analysis was intention-to-treat (ITT) using analysis by covariance adjusted to baseline scores, and a secondary per-protocol (PP) analysis was performed analyzing only those who completed treatment ($P<.05$).

RESULTS: ITT analysis included all 95 participants, and the PP analysis included 79. Both groups demonstrated significant improvements in FAAM and NPRS at 6 weeks, 6 months, and 1 year. The between-group difference (mean; 95% CI) in primary outcome of 6-month change in FAAM was not significant in the ITT analysis (4.5; –1.7, 10.8), but in the PP analysis, uPOD+PT improved more than uPOD (7.7; 2.1, 13.3). In the ITT analysis, there were no between-group differences in 6-week (3.5; –1.6, 8.5) and 1-year FAAM (4.3; –1, 9.6), or 6-month NPRS (1.3; 0.6, 2.1); but, greater NPRS changes in uPOD+PT at 6 weeks (0.9; 0.3, 1.4) and 1 year (1.5; 0.6, 2.5). In the PP analysis, there were no differences between groups in FAAM at 6 weeks (5.1; –0.7, 11), but greater improvement in uPOD+PT for the FAAM at 1 year (5.5; 0.1, 10.8), and for the NPRS at 6 weeks (0.9; 0.2, 1.6), 6 months (1.3; 0.6, 2.1) and 1 year (1.3; 0.6, 2.1). When comparing the PP analysis to the ITT analysis, the participants that achieved success at 6 months in the uPOD+PT group increased from 64.6% to 84.4%, whereas the uPOD group success rate did not change substantially from 57.4%.

CONCLUSIONS: Physical therapy treatment can improve outcomes, including a greater influence on pain than function, of usual podiatric care for PHP especially if treatment is completed.

CLINICAL RELEVANCE: Collaboration between podiatrists and physical therapists can improve patient outcomes and determination of a patient's ability/willingness to complete treatment is an important consideration in achieving a good outcome with physical therapy treatment.

OPL45

A STUDY OF THE ACCURACY OF PHYSICAL THERAPISTS PALPATING THE LONG HEAD OF THE BICEPS TENDON

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PURPOSE/HYPOTHESIS: Shoulder pain due to LHBT tendinopathy can be debilitating and is often difficult to treat. The accurate diagnosis of LHBT pathology can be difficult and often involves a combination of special tests and palpation. Tendon needling has been shown to be effective in the treatment of tendinopathies. Physical therapy based interventions such as dry needling requires a certain degree of accuracy with regards to palpation of the LHBT. The ability of physical therapists (PTs) to accurately palpate the LHBT remains unknown. The aim of this study was to conduct a prospective single blinded study to determine if PTs are accurate in palpating the LHBT with the use of ultrasound as the gold standard.

NUMBER OF SUBJECTS: Two PTs and 32 asymptomatic participants (11 female) with a mean ± SD age of 24.3 ± 1.9 years, and a body mass index of 23.5 ± 1.9 kg/m^2 were consented into the study.

MATERIALS/METHODS: Two PTs palpated the LHBT within the intertubercular groove of the humerus on the bilateral shoulders of all participants in 2 test positions (position 1: supine, 90° of elbow flexion, 0° of shoulder abduction, 20° of medial rotation; position 2: supine, 90° of elbow flexion, 30° of shoulder abduction, and rotation per examiner preference). Examiner order and shoulder position were randomized for each participant. Once the examiner had their palpating finger on LHBT, the position was marked by taping a disposable 18-gauge needle on the skin, parallel to the biceps tendon over the intertubercular groove. A radiologist blinded to the palpation order then evaluated the shoulder sonographically to assess the position of the needle in relation to the underlying LHBT and intertubercular groove. The needle placement relative to the groove was graded as being inside (within 2 mm of the border) or outside of the groove. The distance from the needle to either the medial or lateral border of the groove was also recorded in millimeters using an unpaired t test with a 95% confidence interval. Accuracy was determined by percent accuracy. The magnitude of the distance between the needle placement and the intertubercular groove was compared between the 2 positions using an independent t test.

RESULTS: Overall accuracy rate was 45.7% (117/256) with the accuracy of position 1, 49.2% (63/128) being slightly higher than position 2, 42.2% (54/128). Overall, missed palpations (either medial or lateral to the border of the intertubercular groove) were localized 7.5 ± 4.7 mm in position 1 and 8.3 ± 4.6 mm in position 2 with 78.5% of misses occurring medially in position 1 and 93.3% of misses occurring medially in position 2.

CONCLUSIONS: The results of this study did not support 1 position being significantly more accurate over another for LHBT palpation. Further research is necessary to determine the best position to optimally examine and treat the LHBT.

CLINICAL RELEVANCE: The overall accuracy of PTs ability to palpate the biceps tendon was 40.7% higher than that of physicians in a similar study. The accuracy of PTs palpating the LHBT is hypothesized to increase in symptomatic individuals.

OPL46

MEASURING PROCESS COMPLIANCE WITH THE LOW BACK PAIN TREATMENT-BASED CLASSIFICATION SYSTEM: A QUALITY IMPROVEMENT INITIATIVE

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PURPOSE/HYPOTHESIS: Implementing evidence-based practice is vital to improving health care quality. Systems for classifying and directing treatment for low back pain (LBP) exist, but once classification systems are implemented there is limited evidence on therapists' compliance. Implementation is a cyclical process requiring assessment, measurement and improvement. The purpose of this quality improvement (QI) study was to develop a measure for compliance with the treatment-based classification (TBC) system and to assess the effect of compliance on failure-to-progress (FTP) rates for patients with LBP.

NUMBER OF SUBJECTS: Patients with 3+ visits for LBP in the fourth quarter of 2017, n = 151.

MATERIALS/METHODS: Therapists were educated on TBC through online modules at the start of 2017. A Quality Review Tool (QRT) was developed in Excel to standardize the chart audit and was piloted on 20 charts with 5 test reviewers. Following refinement of the QRT, 7 reviewers completed a 90-minute audit training. Each reviewer then completed 21 to 22 patient chart reviews using the electronic health record. Reviewers' clinical questions were resolved with group consensus. Compliance was de-

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fined as a therapist making a correct classification and matching the first treatment to that classification. Pearson chi-square was used to measure the association between classification and compliance, as well as compliance and FTP rate. The FTP rate is the proportion of patients that do not achieve the minimal clinical important difference of 6 points on the Modified Low Back Disability Questionnaire. Results for each clinic were compiled and disseminated to clinic managers.

RESULTS: Eighty-six charts (57.0%) were compliant with classification and matched treatment. Forty-four charts (29.1%) were "incomplete" because testing integral to the TBC algorithm was missing (eg, nerve root compression testing). When a therapist classified a patient as specific-exercise the chart was more likely to be compliant compared to manipulation, stabilization or traction groups ($\chi^2_4 = 10.06$, $P = .04$). A compliant chart was not associated with lower FTP ($\chi^2_1 = 1.30$, $P = .25$), though the study was underpowered for this analysis ($d = 0.1$). However, compared to the previous year, FTP decreased from 32.5% of patients with LBP (n = 1592) in 2016 to 29.3% (n = 1362) in 2017 following the implementation of TBC education and the QRT.

CONCLUSIONS: In this 1-year QI cycle, the compliance rate of 57% is consistent with other research auditing compliance to standard care processes. Confirmation bias in the PT evaluation process is suspected to have contributed to the high proportion of incomplete charts (29.1%). Overall FTP rates improved with this QI initiative compared to the previous year.

CLINICAL RELEVANCE: Other research has shown a benefit when TBC is applied. Compliance with TBC can be measured with the QRT and improvement in compliance may lead to improved clinical outcomes for patients with LBP. Implementing a thorough evaluation process to limit confirmation bias is an important next step to improve the quality of LBP care.

OPL47

KINEMATICS OF THE SHOULDER, TRUNK, PELVIS, AND HIP WHILE REACHING FORWARD TO PROGRESSIVELY DISTANT TARGETS

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PURPOSE/HYPOTHESIS: Reaching is an important activity involving the upper limb and has been most commonly studied within the context of the "functional reach test." The contribution of various body regions has not been reported during reaching towards progressively distant targets. Understanding the differences in kinematics during forward reaching towards targets at different distance provides a basis for assessing functional movement in clinical situations. The purpose of this study was to describe the kinematics of the shoulder, trunk, pelvis, and hip during forward reach. Our hypotheses were that reaching to a target at shoulder height would involve angular movements at the shoulder, trunk, pelvis and hip and that the movements would increase significantly as the target became more distant.

NUMBER OF SUBJECTS: Twelve healthy men (mean ± SD age, 25.7 ± 3.4 years) participated in a protocol approved by the Institutional Review Board at Campbell University.

MATERIALS/METHODS: Surface palpation identified 22 anatomical sites throughout the trunk, bilateral upper and lower extremities prior to receiving a spherical reflective marker. Another marker, which served as a target, was placed on a vertical pole which was mounted on wheels and adjusted to the target position for each trial. A baseline position was established by having the participant stand and flex both shoulders with palms together until achieving 90° of shoulder flexion. The point where the middle fingers of both hands met served as the starting point for the vertical pole that served as the reach target. Two trials were performed for each condition. Participants stood and performed unilateral forward reaching at baseline position, and baseline plus 5%, 10%, 15%, and 20% of body height. Motion was captured via a 12-camera infrared system at 500 Hz and analyzed within BTS Smart Performance software (BTS Bioengineering, Brooklyn, NY).

RESULTS: Sagittal and transverse plane motions demonstrated high reliability between trials at each target distance (ICC = 0.716-0.977). Shoulder flexion and horizontal abduction were major contributors to forward reaching with components of trunk flexion and left trunk rotation at all target distances. Pelvic tilt, left pelvis rotation, hip extension and hip external rotation made notable contributions at the furthest targets. All motions became more pronounced as target distance increased ($P<.001$).

CONCLUSIONS: Kinematic analysis demonstrated that right forward reaching requires shoulder flexion and horizontal abduction, trunk flexion and left rotation, pelvic anterior tilt and left rotation, and right hip external rotation and extension. The contribution of each body region to forward reaching became more pronounced as the target became more distant.

CLINICAL RELEVANCE: Standing forward reaching with 1 upper extremity involves motions of the shoulder, trunk, pelvis, and hip. Each component motion increases with further target distances. Knowledge of normal forward reaching kinematics may be useful in identifying abnormalities in movement within clinical populations.

OPL48

FUNCTIONAL RECOVERY OF PATIENTS WITH FULL-THICKNESS ROTATOR CUFF TEARS DISCHARGED FROM PHYSICAL THERAPY

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PURPOSE/HYPOTHESIS: To determine the functional recovery of patients with full thickness rotator cuff tears (FT-RCT) after discharge from physical therapy (PT) compared to healthy controls without shoulder pain.

NUMBER OF SUBJECTS: Individuals with imaging evidence of a FT-RCT (n = 11; 5 male; 7 dominant shoulder; mean ± SD age, 66 ± 7 years) and 11 age-, sex-, and arm–dominance matched controls without shoulder pain or FT-RCT.

MATERIALS/METHODS: Participants attended 1 session. Participants with FT-RCT were evaluated at discharge from PT; number of sessions and length were recorded. Each treating PT discharged patients based on satisfactory symptoms and function. Overall rating of PT efficacy was determined with the global rating of change (GROC; 14pt) and Patient Acceptable Symptom State (PASS; yes/no). Self-reported shoulder function was measured using the Pennsylvania Shoulder Score (PENN, 0-100, 100 as full function). Active range of motion (ROM) in scapular plane elevation (scaption), internal and external rotation were measured. Shoulder strength in scaption and external rotation were measured with a handheld dynamometer, normalized to body weight (BW). Shoulder performance was assessed with time of 20 repetitions on 2 tasks; reaching a target 10% higher than participant height, and reaching the back of the head by externally rotating and abducting the shoulder. Outcomes were compared between groups using an independent t test.

RESULTS: On average, patients attended 12 PT sessions over 8 weeks. At discharge, 8/11 (73%) patients reported a moderate or greater change in symptoms on the GROC, but only 4/11 (36%) considered their symptoms acceptable on the PASS. The FT-RCT group had a lower PENN score (mean difference [MD], –17.5 points; $P<.01$); internal rotation ROM (MD, –10.7°; $P<.01$), scaption strength (MD, –4% BW; $P<.01$) and external rotation strength (MD, –3% BW; $P = .04$) compared to controls. No differences between groups were found for scaption ROM (MD, –10.5°; $P = .09$), external rotation ROM (MD, –9.4°; $P = .09$); and performance tests (reach overhead MD, 1.9 seconds; $P = .20$; reach back of the head MD, 3.2 seconds; $P = .14$).

CONCLUSIONS: Despite reporting moderate change in symptoms (GROC), the FT-RCT group had lower perception of upper extremity function, and

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impairment in scaption and external rotation shoulder strength and internal rotation ROM compared to controls. These persistent impairments may explain the low PASS rate. There were no between groups differences in functional performance, suggesting that patients with FT-RCT may employ compensatory movement patterns. These findings need to be confirmed in a larger representative sample.

CLINICAL RELEVANCE: Clinician must be aware that patients' perception of change in their symptom/condition may not fully characterized clinical and functional outcomes of patients with FT-RCT. These impairments may contribute to the low rate of satisfactory symptom state. Understanding the impact of clinical impairments on acceptable symptoms, perceived function, and functional performance is necessary to maximize recovery of patients with FT-RCT.

OPL49

DEVELOPMENT AND IMPLEMENTATION OF A COMPREHENSIVE LIFESTYLE AND BEHAVIORAL HEALTH MANAGEMENT PROGRAM FOR OSTEOARTHRITIS: A NEW ROLE FOR PHYSICAL THERAPISTS

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PURPOSE: Innovative models of osteoarthritis (OA) care are needed that more effectively address the physical, behavioral, and psychological characteristics that contribute to persistent pain and disability for individuals with OA. This presentation will introduce physical therapists to a novel care pathway (a "joint health program", or JHP) that provides longitudinal, comprehensive management of hip and knee osteoarthritis (OA). In the JHP, physical therapists with specialized training in cognitive behavioral therapy function as the central provider (ie, the Primary Osteoarthritis Provider, or POP) that coordinates and delivers interventions focused on physical activity, lifestyle modification and behavioral health.

DESCRIPTION: Patients with hip or knee OA who were not immediate candidates for total joint arthroplasty were referred to the JHP by orthopaedic surgeons following clinical evaluation. The POP then performed a comprehensive assessment of the patient's physical function, psychological health, nutrition, and patient-specific goals to develop an individualized plan of care. The POP provided longitudinal treatments according to a collaboratively developed of plan of care, and the POP coordinated care with core partners including nutritionists, behavioral health specialists and referring orthopaedic providers based on evaluation findings, subsequent progress and shared decision making. Between clinic visits, the POP contacted the patient frequently via phone calls and electronic health record (EHR) messaging to maximize interaction and moderate utilization. Patients who reached their personalized goals discontinued clinic visits but remained in the program and were followed remotely using phone calls and EHR messaging over the course of a year to monitor progress and prevent relapse.

SUMMARY OF USE: This presentation will provide an in-depth review of the JHP including its development, implementation, structure, and payment redesign strategies. We will also discuss challenges to implementing this program in a large academic medical center. Finally, we will present preliminary program results supporting the JHP's ability to improve patient function, reduce pain, and decrease psychological distress.

IMPORTANCE TO MEMBERS: Comprehensive behavioral health, lifestyle management and physical activity interventions provided by a physical therapist can provide significant improvements in disability and psychological distress for individuals with hip or knee OA. Physical therapists are uniquely qualified to function as central providers in this new role. Ongoing implementation of the JHP will focus on capturing follow-up data to assess cost-effectiveness of the program. We will also identify tailored treatment pathways within the program that optimize value of care for patients with OA. This program is responsive to value-based payments initiatives that have expanded in orthopaedics and in the health care industry at-large.

OPL50

ASSOCIATION OF COMORBIDITY WITH REHABILITATION USE IN OLDER ADULTS WITH BACK PAIN

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PURPOSE/HYPOTHESIS: Examine the association between number and type of comorbidities with use of rehabilitation service among older adults with back pain.

NUMBER OF SUBJECTS: Eight thousand three hundred forty-four Medicare Beneficiaries participating in round 5 in 2015 of the nationally representative National Health and Aging Trends Study (NHATS).

MATERIALS/METHODS: NHATS is a cohort of older adults with annual interviews. We included community dwelling older adults who reported bothersome back pain in the prior month at round 5. We excluded participants who were nonambulatory (requires wheelchair/scooter). We used 12 self-reported chronic conditions; including depression, anxiety, and arthritis. We categorized the number of conditions as 0 to 1, 2 to 3, and 4 or greater. Individual conditions were dichotomous variables. We examined combinations of depression, anxiety, and arthritis. We used round 6 data to ascertain self-reported use of rehabilitation services in the prior year (between rounds 5 and 6). The primary outcome was any rehabilitation use (yes/no). A secondary outcome was rehabilitation use to improve back function (yes/no). Descriptive statistics characterized the cohort and rehabilitation use. We used weighted logistic regression to examine the association of comorbidities with use of rehabilitation services in the following year. All models were adjusted for age, sex, race, education, body mass index, Medicaid status, Medicare Supplement status, and smoking.

RESULTS: In 2015, 2443 (29%) participants reported bothersome back pain. This sample was mostly female (n = 1503, 62%), white (n = 1722, 70%), and 70 to 79 years old (n = 1175, 48%). Most had multiple comorbidities: 18.4% (95% confidence interval [CI]: 16.5%, 20.6%) had 0 to 1 other health conditions, 44.1% (95% CI: 41.6%, 46.7%) had 2 to 3, and 37.5% (95% CI: 35.3%, 39.6%) had 4 or greater. Use of any rehabilitation services was 25.0% (95% CI: 22.8%, 27.4%). Those with 4 or greater comorbidities had more than twice the odds of using rehabilitation services versus those with 0 to 1 (odds ratio [OR] = 2.10; 95% CI: 1.31, 3.53). Individuals with arthritis were more than twice as likely to receive rehabilitation services (OR = 2.11; 95% CI: 1.54, 2.89), but there was no significant association of either depression or anxiety with rehabilitation use. Depression combined with arthritis was associated with greater likelihood of rehabilitation use (OR = 1.64; 95% CI: 1.08, 2.50). Rehabilitation use to specifically improve back function was 10.4% (95% CI: 8.8%, 12.1%). Similar patterns were found for associations between each comorbidity variable and rehabilitation to improve back function.

CONCLUSIONS: Among older adults with back pain, those with 4 or more comorbidities and those with arthritis were more likely to report using rehabilitation services in the next year. Depression and anxiety were not associated with rehabilitation use.

CLINICAL RELEVANCE: Depression and anxiety are well established prognostic factors for back pain. Using a nationally representative sample, our study suggests there may be underuse of rehabilitation services for Medicare Beneficiaries with back pain and comorbid depression and anxiety.

OPL51

HIP JOINT MUSCLE FORCES DURING GAIT ARE ASSOCIATED WITH HIP JOINT SYMPTOMS AND CARTILAGE HEALTH IN PATIENTS WITH FEMOROACETABULAR IMPINGEMENT SYNDROME

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PURPOSE/HYPOTHESIS: Patients with femoroacetabular impingement syndrome (FAIS) possess abnormal hip joint morphology and exhibit altered hip joint mechanics, severe pain and disability as well as altered cartilage composition compared to asymptomatic controls. The purposes of this study were to assess: (1) the effects of FAI on hip joint muscle forces during gait and (2) the potential link between muscle forces, patient reported outcomes and cartilage health in FAI patients.

NUMBER OF SUBJECTS: Twenty-four presurgical FAI patients and 24 age, sex, and BMI-matched controls.

MATERIALS/METHODS: OpenSim was used to perform musculoskeletal simulations of gait (speed of 1.35 m/s). Muscle forces during the stance phase (initial contact to toe-off) were estimated for the gluteus maximus, gluteus medius, gluteus minimus, adductors, sartorius, iliopsoas, piriformis, rectus femoris, vasti and hamstrings using computed muscle control. All participants completed the Hip disability and Osteoarthritis Outcome Score (HOOS) in order to assess hip joint pain and function on a 0-to-100-point scale, where 0 indicates severe pain or dysfunction and 100 indicates no pain or dysfunction. FAI patients underwent MR-imaging of the surgical hip joint in order to perform T1rho and T2 mapping of the acetabular and femoral cartilage. Higher T1rho and T2 values indicate altered cartilage composition and are considered hallmarks of early cartilage disease. Independent *t* tests were used to assess group differences in HOOS subscores. A MANOVA was used to assess the effects of FAI on peak muscle force production. Partial correlation coefficients (r), adjusting for age, sex, and BMI, were used to determine the associations between peak muscle forces, HOOS subscores, acetabular and femoral T1rho and T2 values within FAI patients.

RESULTS: Compared to controls, FAI patients reported worse pain (P<.001) and function (P<.001) and exhibited lower Vasti force (P = .01) during loading response and higher Sartorius force (P<.01) during terminal stance. Within FAI patients, lower Gluteus Medius, Gluteus Minimus, Sartorius and Iliopsoas forces were associated with worse pain (r = 0.44-0.63, P = .002-.05) and function (r = 0.48-0.70, P = 0-.03). Lower Rectus Femoris and Vasti forces were associated with higher T1ρ values (r = −0.46 to −0.58, P = .006-.04) within the superomedial and anterior femur. Lower Gluteus Medius and Vasti forces were associated with higher T2 values (r = −0.44 to −0.48, P = .03-.05) within the anterior and posterior femur. Lower Vasti and Iliopsoas forces were associated with higher T2 values (r = −0.45 to −0.47, P = .03-.04) within the posterior and anterior-superior acetabulum.

CONCLUSIONS: FAI patients ambulate with abnormal hip joint muscle forces. Lower hip joint muscle forces are associated with hip joint symptoms and cartilage health within FAI patients.

CLINICAL RELEVANCE: Our findings suggest abnormal muscle forces are produced during gait in FAI patients. These results may help clinicians to develop better intervention programs for the FAI population.

OPL52

CHARACTERIZATION OF SAGITTAL PLANE JOINT DEMANDS DURING A TRIPLE HOP TASK: IMPLICATIONS FOR CLINICAL INTERPRETATION

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PURPOSE/HYPOTHESIS: Triple hop is commonly used to assess lower extremity function to determine functional strength and neuromuscular control following anterior cruciate ligament (ACL) injury and reconstruction. Previous studies assessing a modified triple hop indicate that it does not preferentially load the knee, confounding interpretation distance hopped measures as they apply to knee recovery. This study compares ankle, knee and hip sagittal plane demands during deceleration and propulsion phases of a triple hop performed according to the clinical testing procedures.

NUMBER OF SUBJECTS: Eighty-one female athletes (age, 14-23 years); no history of lower extremity surgery or recent injury

MATERIALS/METHODS: Kinematics and kinetics were collected using 3-D motion analysis during a triple hop task for distance (dominant leg). Joint kinematics and net joint moments (inverse dynamics) were used to calculate joint power. Joint demands were characterized by range of motion (ROM), moment impulse (extMI: area under the extensor moment-time curve), and power absorption (pAb) and generation (pGn) (work: area under the power-time curve) during deceleration (foot contact to peak knee flexion) and propulsion (peak knee flexion to toe-off) phases of the second hop. Three trials were averaged. Mixed-design MANOVA was used to compare kinematics and kinetics between joint (ankle, knee, and hip) and phase (deceleration and propulsion).

RESULTS: During deceleration, ROM was greater at knee (36.2° ± 6.4°) than hip (11.3° ± 3.6°, P<.01) and ankle (29.3° ± 9.5°, P<.01). extMI was greater at knee (0.24 ± 0.08, P<.01) and hip (0.26 ± 0.09, P<.01) than ankle (0.19 ± 0.06). Knee pAb (0.83 ± 0.30) was greater than ankle (0.70 ± 0.3, P = .04) and hip (0.30 ± 0.2, P<.01). During propulsion, knee ROM (34.5° ± 7.7°) was greater than ankle (14.7° ± 8°, P<.01). extMI was different between all joints (0.31 ± 0.05, 0.19 ± 0.05, and 0.08 ± 0.07 for the ankle, knee, and hip, respectively; all, P<.01). Ankle pGn was greater (0.84 ± 0.13) than knee (0.57 ± 0.19, P<.01) and hip (0.32 ± 0.26, P<.01). When comparing between phases, knee ROM was greater (P = .05) and ankle (P<.01) in deceleration, hip ROM was greater (P<.01) in propulsion. Knee (P<.01) and hip (P<.01) extMI was greater in deceleration and ankle was greater (P<.01) in propulsion. Knee pAb was greater (P<.01) in deceleration and ankle (P<.01) and hip (P<.01) pGn greater in propulsion.

CONCLUSIONS: Despite similar extMI to the hip, ROM and pAb were the greatest at the knee during deceleration. The demands at the knee were greater in deceleration than propulsion. These data suggest that the knee is preferentially loaded in this phase. During propulsion, extMI and pGn at the ankle were 39% and 33% greater, respectively at the ankle than knee indicating a greater contribution from the ankle.

CLINICAL RELEVANCE: Even though the demands at the knee are large during deceleration, the predominant role of the ankle for propulsion may allow for large hop distances despite knee impairments. The outcome measure, distance hopped, may not be most sensitive to knee joint impairments.

OPL53

RADIOGRAPHIC INDICES OF METATARSAL BONE STRENGTH IN PATIENTS WITH LOWER EXTREMITY AMPUTATION DUE TO CRITICAL LIMB ISCHEMIA

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PURPOSE/HYPOTHESIS: Peripheral arterial disease (PAD) can progress to critical limb ischemia (CLI) and ultimately require a lower extremity amputation (LEA). It is not well known if bone strength is impacted by PAD and CLI prior to LEA. The purpose of this study is to determine radiographic indices of metatarsal bone strength in individuals with LEA due to CLI. We tested the null hypothesis that LEA due to CLI will have no discernable impact on radiographically-derived geometric indices of metatarsal bone strength.

NUMBER OF SUBJECTS: Ten participants (50% women) who had a transtibial LEA due to CLI after a history of PAD were studied. Three participants had diabetes mellitus (DM) and peripheral neuropathy (PN). All participants had a long history of smoking.

MATERIALS/METHODS: We performed a cross-sectional (n = 10) and serial

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longitudinal (n = 5) cohort analysis. Participants were included if they had a standard dorso-plantar foot radiograph within the previous 3 years prior to LEA due to CLI. From foot radiographs, the outer periosteal and inner endosteal diameters were measured at distal (25%), middle (50%), and proximal (75%) sites along the second and fifth metatarsal diaphyseal shafts. Outer and inner diameters were used to calculate the buckling ratio (BR) and average cortical wall thickness (Ct.Th) as indices of bone strength. An increasing BR or decreasing Ct.Th indicate decreasing metatarsal bone strength and elevated fracture risk. All 10 participants had at least a single foot radiograph an average of 42 weeks prior to LEA, while 5 participants (3 women) had longitudinal radiographs (average interval of 37 weeks). The earliest and latest radiographic indices were compared using a 2-tailed paired *t* test ($\alpha = .05$) with Bonferroni correction for multiple comparisons.

RESULTS: Mean ± SD age of participants: 60 ± 14 years. BR and Ct.Th at the distal, middle and proximal sites averaged 3.2 and 1.2 mm, 2.2 and 2.1 mm, and 2.5 and 2.2 mm, respectively, in the second metatarsal; 3.9 and 1.2 mm, 2.1 and 2.6 mm, and 2.5 and 2.8 mm, respectively, in the fifth metatarsal. In 5 participants with 2 radiographs, BR increased 18% to 25% and 32% to 45% in the second and fifth metatarsal, respectively due to an average decrease of 15% to 37% in Ct.Th in both distal and proximal metaphyseal-diaphyseal region sites ($P<.04$). There were no significant changes in BR or Ct.Th in the middle diaphyseal site in second or fifth metatarsal, $P>.05$).

CONCLUSIONS: Metatarsal bone strength is decreased due to cortical osteolysis in the second and fifth metatarsal prior to LEA. BR is increased and Ct.Th decreased in the distal and proximal metaphyseal-diaphyseal regions but not in the middle diaphyseal regions prior to LEA. Since our sample size was small, these preliminary findings require further investigation.

CLINICAL RELEVANCE: Physical therapists should recognize that patients with LEA due to CLI and PAD may have an accelerated cortical bone osteolysis with reduced foot bone strength, therefore may be at increased risk for metatarsal fracture.

OPL54

FEAR BELIEFS AND LOW BACK PAIN–RELATED DISABILITY HELP EXPLAIN IMMEDIATE RESPONSE TO NEUROMUSCULAR ELECTRICAL STIMULATION IN ADULTS WITH LOW BACK PAIN

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PURPOSE/HYPOTHESIS: With chronic low back pain (LBP) there is a reduced capacity to recruit multifidi muscles during exercises. Further, exercises alone may be insufficient for inducing multifidi muscle activity changes. Low back neuromuscular electrical stimulation (NMES) may be considered as an adjunct treatment. The purpose of this study was to explore relationships between immediate changes in multifidi muscle activity following low back NMES and the following factors: LBP intensity, LBP-related disability, and fear-avoidance beliefs, in patients with chronic LBP. We hypothesized greater LBP intensity, higher fear-beliefs, and more LBP-related disability, would be independent contributors to reduced change in multifidi muscle activity from baseline (ie, pre-NMES) to immediately post-NMES.

NUMBER OF SUBJECTS: Sixty patients (58.3% female), aged 18 years or older (median, 31 years) with LBP of 3 months or longer, were recruited from an outpatient physical therapy clinic. Individuals with a pacemaker, spinal fracture, or who had received prior low back surgery and/or NMES were excluded.

MATERIALS/METHODS: Participants rated their LBP intensity and completed 2 reliable self-report measures (*a*) the modified Oswestry Disability Questionnaire (OSW) and (*b*) the Fear-Avoidance Beliefs Questionnaire (FABQ), which is comprised of 2 subscales: physical activity (PA) and work (W). Using an ultrasound imaging procedure with previously established reliability, L3-4 and L4-5 multifidus muscle images were obtained and percent thickness change (ie, multifidi muscle activity) was determined before and after low back NMES for each side for each level. Regression modeling ($P \leq .05$) was used to explore relationships between average change in multifidi muscle activity across levels (the dependent variable) and the following outcome measures: LBP intensity, OSW, and FABQ-PA and FABQ-W, after controlling for NMES intensity, as higher NMES intensities have been shown to evoke greater muscle activation improvements in other muscle groups.

RESULTS: Fear-avoidance beliefs related to physical activity were the strongest predictor of immediate multifidi muscle response to NMES, with greater fear beliefs resulting in less multifidi muscle activity change (change in $R^2 = 0.14$, $P = .003$). LBP-related disability was also an independent predictor of multifidi muscle activity response to NMES, with greater disability associated with less change in multifidi muscle activity (change in $R^2 = 0.08$, $P = .013$). NMES intensity, average LBP intensity, and the FABQ-W were not predictors for immediate response of the multifidi to NMES.

CONCLUSIONS: Results suggest patient-specific psychosocial factors: ie, physical activity fear beliefs, should be considered when evaluating multifidi muscle response to low back NMES among patients with chronic LBP.

CLINICAL RELEVANCE: Results align with prior research among adults with LBP suggesting patient-specific psychosocial factors are important considerations when tailoring and evaluating response to physical therapy interventions, such as NMES.

OPL55

THE USE OF GRADED NECK STRENGTHENING AND PROPRIOCEPTIVE EXERCISES WITHIN A MULTIMODAL PROGRAM TO IMPROVE NECK FLEXOR ENDURANCE AND FUNCTION IN PATIENTS WITH CERVICOGENIC HEADACHE: 2 CASE REPORTS

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BACKGROUND AND PURPOSE: Current evidence and literature advocates for a course of manual therapy and exercise to treat those with cervicogenic headaches, however the choice and dosage of exercises has rarely been described. As well, strengthening of the deep cervical flexors can reproduce symptoms in a patient with more irritable symptoms. Two cases are presented that describe the reasoning process and graded approach to prescribing nonpainful exercises meant to improve neck flexor endurance and head-neck control in those suffering from cervicogenic headache.

CASE DESCRIPTION: Case 1: a 34-year-old man reported disabling headaches following cycling, which affected his ability to work. His Neck Disability Index (NDI) was 28%, while his Headache Disability Index (HDI) scored 52. He exhibited limited cervical active range of motion (AROM), positive cervical flexion rotation test (CFRT), symptom reproduction with upper extremity (UE) strength testing, and a Neck Flexor Endurance Test (NFET) of 17 seconds. Over 8 visits, the patient was treated with a multimodal approach that included strengthening and proprioceptive exercises for the head and neck, without provocation of symptoms. Case 2: a 30-year-old woman reported severe headaches that caused nausea following a motor-vehicle accident 16 months prior along with neck and left UE pain. An upper cervical ligamentous and cranial nerve exam was performed and deemed normal. Her NDI was 46% and her HDI was 76%. On exam, cervical AROM was limited and reproduced her headache, neck and left UE pain. She exhibited signs of adverse neural tension in the upper extremities, especially on the left side. As well, she exhibited a positive CFRT and an NFET of 3 seconds which reproduced her symptoms. This patient was treated similarly to case 1, over 12 visits.

OUTCOMES: Case 1: following a multimodal approach of manual therapy and strengthening and proprioceptive exercises, the patient reported a global rating of change (GROC) of 6+, an NDI of 14% and an HDI of 17. His NFET improved to 34 seconds and he was able to return to competitive

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cycling without complaints of neck or headache symptoms. Case 2: following a course of therapy that was similar to case 1, the patient reported a GROC score of 6+, an NDI of 18% and an HDI of 24. As well, her NFET improved to 26 seconds without provocation of symptoms. She returned to her job, reaching her prior level of function, including a nonprovocative UE strengthening regimen.

DISCUSSION: These case reports present the strategy of strengthening the neck and upper quarter region through a graded exercise regimen that was meant to avoid provocation of headache or neck pain symptoms. This progression is described in detail with attention on avoidance of symptom reproduction, within a multimodal physical therapy approach to improve function and NFET results, while decreasing headache intensity and frequency in those with cervicogenic headache.

OPL56

CERVICAL MUSCLE VOLUME IN INDIVIDUALS WITH IDIOPATHIC NECK PAIN: A MAGNETIC RESONANCE IMAGING STUDY

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PURPOSE/HYPOTHESIS: Movement dysfunction in individuals with neck pain suggests a contribution from cervical muscles. Imaging studies show that muscle cross-sectional area and muscle fat infiltration (MFI) differ between individuals with chronic neck pain and asymptomatic controls. However, the majority of magnetic resonance imaging (MRI) studies have investigated individuals with whiplash-associated disorder. Only 1 MRI study included individuals with idiopathic neck pain. It was limited to specific spinal levels and females only, and reported poor age matching of controls. Therefore there is a need for improved understanding of muscle morphology in individuals with idiopathic neck pain. The aim of this study was to determine if there are differences between individuals with chronic idiopathic neck pain and asymptomatic age and sex-matched controls in cervical muscle volume and MFI across multiple cervical muscles and spinal levels.

NUMBER OF SUBJECTS: Twenty individuals with chronic idiopathic neck pain greater than 3 months (mean ± SD age, 38.3 ± 10.3 years; 13 female) and 17 asymptomatic controls (age, 38.6 ± 11.2 years; 11 female).

MATERIALS/METHODS: The volume of bilateral levator scapula, semispinalis capitus, multifidus and semispinalis cervicis, semispinalis capitus, splenius cervicis and splenius capitus, and sternocleidomastoid from C3-T1 were obtained from 3-D models of the neck muscles constructed from measures of cross-sectional area quantified using MRI. Pixel intensities from the T1- and T2-weighted images determined MFI percent within muscle. Muscle volume, MFI volume and relative muscle volume (without MFI) were calculated. Linear mixed regression models determined differences between groups in muscle volume, MFI and relative volume, adjusting for age, sex, body mass index, spinal level, and side (left/right).

RESULTS: Individual muscle groups at each spinal level were examined separately as overall models demonstrated interactions between muscle, spinal level and group. There were no differences in muscle, MFI or relative volumes between groups for any muscle except semispinalis capitus, which had lower muscle volumes ($F = 5.6$, $P = .024$; post hoc mean differences at individual spinal levels ranging from 55 to 88 mm^3, $P<.05$) and higher fat volumes ($F = 5.2$, $P = .03$; 23 to 48 mm^3, $P\leq.009$) at all spinal levels between C3 and C6 in individuals with pain, however, relative volume did not reach significance.

CONCLUSIONS: This study found less muscle volume and greater MFI volume in semispinalis capitus in individuals with chronic idiopathic neck pain compared to asymptomatic matched controls. However, no other cervical muscles measured demonstrated any between-group differences.

CLINICAL RELEVANCE: Differences in cervical musculature between individuals with chronic idiopathic neck pain and asymptomatic controls appear minimal. However, differences in the semispinalis capitus may partially explain movement dysfunction specifically related to the actions of this muscle, ie, cervical extension and rotation and maintaining the lordosis of the cervical spine.

OPL57

THE INFLUENCE OF HIP PAIN ON MUSCLE PERFORMANCE IN DANCERS

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PURPOSE/HYPOTHESIS: Improved understanding of hip pathology in the young, active population has contributed to increasing research investigating femoroacetabular impingement and anterior hip pain. However, little information exists regarding the influence of hip pain on muscle performance in dancers. This study examined whether differences exist in core muscle endurance, cardinal plane hip or dance-relevant position muscle force production via handheld dynamometry (HHD), standing turnout range of motion (ROM), and hip special tests in dancers with hip pain while dancing compared to dancers without hip pain. It was anticipated that between group differences would exist, namely that dancers without hip pain would show greater core endurance and HHD values in certain dance-relevant positions.

NUMBER OF SUBJECTS: Fifty-eight preprofessional and professional dancers across the United States who were 18 to 45 years old, dancing for 3 or more years and dancing for 20 or more hours per week with 1 year or greater within the preprofessional program or professional company, and had the technical ability to hold dance relevant positions tested at a 90° angle; who had no prior hip surgery, acute radicular lumbar pathology, or limitation in upper or lower extremity weight bearing due to existing injury. Both male and female subjects were included.

MATERIALS/METHODS: Subjects were dichotomized into "control" and "pain" groups based on a visual analog scale (VAS) rating 25 or greater during 1 or more dance-specific movements in the preparticipation questionnaire (control, n = 35; painful, n = 23). Subjects underwent core endurance plank testing, standing turnout measures, hip special tests, and HHD 'make' tests for cardinal plane hip and dance-relevant muscle force production. Dance-relevant muscle force production was assessed using a novel HHD stabilizing device.

RESULTS: No significant differences emerged between the 2 groups for any HHD (cardinal plane or dance-relevant), or core endurance measures. However, the painful group showed significantly greater right standing turnout measures.

CONCLUSIONS: The finding that static, isometric testing, even in combined, triplanar motion, did not highlight differences between groups is clinically significant, as dynamic muscular imbalances or compensatory strategies might account for true differences. Further study into the differentiating factors of hip pain in dancers is warranted, with emphasis on undertsanding the role of excessive ROM and potential strength imbalances unique to dancers.

CLINICAL RELEVANCE: The study findings reinforce the need for further investigation of potential risk factors in the development of hip pathology in the artistic athlete. As the breadth of understanding of the hip continually expands, the need for appropriate management strategies to minimize deleterious effects of repetitive, competitive training grows increasingly relevant. Development of dance-specific physical performance assessments and broadly implemented HHD testing is warranted to establish a baseline of physical capability to mitigate the risks associated with highly repetitive, physically demanding feats typical of dance.

OPL58

THE ASSOCIATION BETWEEN CHRONIC NONARTHRITIC PERIPHERAL JOINT PAIN AND MULTIPLE SLEEP COMPLAINTS: A SECONDARY DATA ANALYSIS OF A NATIONAL CROSS-SECTIONAL SURVEY

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PURPOSE/HYPOTHESIS: There is significant evidence to indicates that sleep and pain are related in a bidirectional way for some chronic pain diagnoses (eg, rheumatoid arthritis and fibromyalgia). While there is research regarding the link between sleep and arthritic joint pain, there is limited literature available regarding the association between sleep and chronic nonarthritic peripheral joint pain (CNAJP). The purpose of this study is to examine the strength association between prevalent sleep complaints and CNAJP.

NUMBER OF SUBJECTS: Five thousand three hundred twenty-one subjects from the 2015 National Health Interview Survey (NHIS) Adult Sample data set were analyzed.

MATERIALS/METHODS: Subjects were included in the analysis if they were aged 18 years or older and interviewed for the 2015 NHIS in the United States. Subjects were excluded if they had a previous diagnosis of osteoarthritis, rheumatoid arthritis, lupus, fibromyalgia or a history of cancer. Further, participants were excluded if data were missing regarding joint pain status, sleep complaints, or any of the exclusion criteria. The NHIS is an annual cross-sectional household interview survey of the civilian noninstitutionalized population living in the United States. Data specific to the NHIS format and sample design are described elsewhere. Data were analyzed using SAS software, Version 9.4 (SAS Institute, Inc, Cary, NC). Individuals were determined to have CNAJP if they had peripheral joint pain lasting 3 months or longer. Sleep complaint information available was quality was short sleep (getting less than 6 hours of sleep per day on average), having trouble falling asleep, or having trouble staying asleep. Descriptive statistics and odds ratios (ORs) were calculated for the association between prevalent sleep complaints and prevalent CNAJP. Descriptive statistics were assessed for confounding using chi-square tests for categorical variables. Logistic regression was used to determine the strength of the association of between prevalent CNAJP and prevalent sleep complaints.

RESULTS: Main results indicate that the presence of at least 1 sleep complaint is associated with a 51% increase in the odds of the individual having prevalent chronic joint pain (OR = 1.51; 95% CI: 1.33, 1.70) in the adjusted model. All sleep complaints were associated with a significant increase in the odds of prevalent CNAJP when looking at each individual sleep complaint after adjustment, however, the largest OR was observed for short sleep (OR = 1.31; 95% CI: 1.11, 1.56).

CONCLUSIONS: A significant association exists between the presence of sleep complaints and prevalent CNAJP. Among sleep complaints, short sleep appears to have the strongest association, even after adjusting for confounders and other prevalent sleep complaints.

CLINICAL RELEVANCE: These results underline the importance of assessing and addressing sleep complaints in this population. Future research should focus on determining if a bidirectional relationship exists in this population similar to rheumatoid arthritis and fibromyalgia.

OPL59

ASSOCIATIONS BETWEEN FREQUENCY AND TIMING OF INTERIM PATIENT-REPORT OUTCOME MEASURES AND FUNCTIONAL STATUS AT DISCHARGE FROM PHYSICAL THERAPY FOR COMMON MUSCULOSKELETAL IMPAIRMENTS

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PURPOSE/HYPOTHESIS: Assess associations between frequency and timing of interim functional status (FS) patient-reported outcome measure (PROM) during the episode of care and FS at discharge, for patients with either neck, low back, shoulder, or knee impairments. We hypothesized that at least 1 early interim surveys will be associated with better FS outcomes compared to no or late interim surveys.

NUMBER OF SUBJECTS: Secondary analysis of data from a large sample (n = 532 815) of adult patients meeting the inclusion criteria admitted to physical therapy services and completed FS PROMs at admission for either neck, lumbar, shoulder, or knee impairments during 2016.

MATERIALS/METHODS: To minimize potential for patient selection bias, 2 a priori inclusion criteria at the clinician level were set; having a completion rate of 50% or higher and having at least 10 complete episodes. We tested associations between frequency and timing (admission to first interim PROM) with FS outcomes, controlling for patient characteristics known to be associated with outcomes, and for episode duration expected to impact the potential of interim survey administration, for each impairment using 3-level hierarchical linear regressions with patients nested within clinicians and clinics. Inverse probability weighing (IPW) analyses assessed potential selection bias for those patients with missing outcomes data.

RESULTS: For patients with complete outcomes data at admission and discharge (n = 410 809, 77%), a first interim PROM administered within the first 2 weeks was associated with an addition of 4.6, 4.3, 4.2, and 4.0 FS points at discharge compared to having on interim survey (P<.001), for neck, lumbar, shoulder, and knee impairments, respectively. A first interim survey administered during the third or fourth week, or during the fifth week or later, was associated with 1.4 to 1.7, and 0.5 to 0.8 additional FS points at discharge (P<.001), respectively. Additional interim surveys (2 or more) contributed to slightly higher outcomes compared to having only 1 interim survey, especially with shorter timing to first interim. IPW did not impact results.

CONCLUSIONS: At least 1 interim PROM assessment in addition to intake and discharge, administered within the first 2 weeks after intake was associated with higher FS outcomes for patients with common musculoskeletal conditions treated in rehabilitation.

CLINICAL RELEVANCE: Enhancing value of care in today's alternative health care reimbursement systems using PROM data is important. Although we cannot establish causal inference, results should encourage physical therapists to administer at least 1 interim PROM survey within 2 weeks after intake to maximize treatment outcomes. This is the first study to provide physical therapists with information on associations between intensity of PROM administration during routine everyday clinical practice and FS outcomes.

OPL60

PATIENT-DEFINED OUTCOMES DIFFER BY AGE FOR INDIVIDUALS WITH MUSCULOSKELETAL PAIN

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PURPOSE/HYPOTHESIS: Pain is a highly variable experience necessitating a patient centered approach. Older adults report less pain related distress and better quality of life than younger and middle age adults. However, the influence of age on patient-defined outcomes for individuals with musculoskeletal pain is not established. The purpose of this study was to determine age related differences in (1) desired, successful, and expected levels for multiple outcome domains and (2) the importance of improvement in each outcome domain.

NUMBER OF SUBJECTS: Six hundred nine individuals with musculoskeletal pain (63.3% female, 17.2% with neck pain, 37.8% with low back pain, 23.8% with shoulder pain, 21.2% with knee pain, 41.5% 18 to 39 years old, 30.7% 40 to 56 years old, 27.7% 57 to 75 years old).

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MATERIALS/METHODS: This is a secondary analysis of the Optimal Screening for Prediction of Referral and Outcome cross sectional and longitudinal cohorts. Individuals seeking physical therapy for nonsurgical neck, low back, shoulder, and knee pain who completed the Patient Centered Outcome Questionnaire (PCOQ) at the initial evaluation were included in this analysis. The PCOQ is a 5-item questionnaire in which patients rate their desired, successful, and expected level of the domains of pain, fatigue, emotional distress, and interference using a 101-point numeric rating scale (0, none to 100, worst imaginable). The PCOQ further assesses the importance attached to improvement in each domain with a 101-point numeric rating scale (0, not important to 100, most important). A 3-way ANOVA examined PCOQ domains by a priori determined age categories (18-39, 40-56, 57-75 years), sex, and anatomical location.
RESULTS: An age-by-sex-by-anatomical location interaction was not observed for any of the domains of interest ($P>.05$). Significant age by anatomical location interactions were observed for desired levels of pain ($P = .02$) and interference ($P = .03$). Younger and older adults with neck pain desired lower pain than middle age adults with neck pain ($P = .01$) and younger adults with neck pain desired lower interference than middle age adults with neck pain ($P = .02$). A main effect for age was observed with older adults indicating higher importance for change in fatigue ($P<.01$) and emotional distress ($P = .01$) than younger adults regardless of anatomical location. Age-related differences in treatment success criteria or expectations were not observed for any anatomical location ($P>.05$).
CONCLUSIONS: Patient-centered approaches to managing patients with musculoskeletal pain necessitate accounting for individual variability attributed to age. Our findings suggest younger and older adults with neck pain desire lower pain and interference than middle age individuals. Furthermore, older adults may value changes in fatigue and emotional distress, even though these are not typical treatment targets for physical therapy encounters.
CLINICAL RELEVANCE: Physical therapists treating patients with musculoskeletal pain should be aware of age related differences in desired outcomes and importance of outcomes for patients with musculoskeletal pain.

OPL61

TREADMILL GAIT RETRAINING IMPROVES KNEE JOINT POSITION SENSE IN WOMEN WITH KNEE HYPEREXTENSION GAIT PATTERN

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PURPOSE/HYPOTHESIS: Knee hyperextension (KH), condition mainly seen in women, can result in abnormal loading patterns than could initiate degenerative cartilage changes. KH, defined as knee extension greater than 5°, is associated with a ground reaction force vector that acts anterior to the knee placing substantial increased contact stress on the tibiofemoral articular cartilage. Studies show that proficiency controlling KH after gait training can be transferred to overground walking and retained 8 months after training. Changes in motor function have been associated to changes in joint position sense (JPS) when learning locomotor tasks. Given the critical role of proprioception in the control of walking, the purpose of this study was to investigate the efficacy of gait retraining in improving knee JPS in women with KH. We hypothesized that knee JPS would improve after training.
NUMBER OF SUBJECTS: Eleven women (mean ± SD) aged 23 ± 4 years with KH greater than 5.5° at rest and walking.
MATERIALS/METHODS: Kinematic data during treadmill walking and knee JPS were collected using 3-D motion analysis (Optotrak) and calculated using Visual3D (C-Motion). Walking data were collected at pre and posttraining (2-5 days after training). For JPS testing, participants were asked to stand on limb to be tested, close their eyes, position the knee to a "target" position (15° of flexion), and maintain the "target" position for 5 seconds. After resuming the starting position, subjects were asked to reproduce the "target" position. Three trials were performed. Knee joint angle data were collected for 1 second when participants held the position perceived as the target. Peak knee flexion values were used to calculate the overall error (root-mean-square error, RMSE) to compare success in achieving the target position. Subjects participated in a supervised treadmill gait training program twice a week for 3 weeks for correction of sagittal alignment of the knee with the greatest amount of extension. During each session, subjects walked on an instrumented treadmill (Gaitway Kistler) at 1.3 m/s walking speed for three 8-minute intervals with 5-minute rest periods. Feedback was provided at the second, fourth, and sixth minute of each 8-minute session using 3 specific cues: "too little" (less than 0° extension), "good" (0°-5° flexion), "too much" (greater than 5° flexion). Kinematic data were collected (20 seconds) at the beginning and end of each training session. Peak knee extension for 20 gait cycles and knee JPS overall error, collected at pre and posttraining, were compare using repeated measures ANOVA (SAS Version 9.4).
RESULTS: Peak knee extension at rest and during walking at pretraining was 8.2° ± 2° and 10.3° ± 5°, respectively. There was a significant reduction in knee extension between walking at pretraining and posttraining ($P<.05$) and knee JPS overall error scores ($P<.05$).
CONCLUSIONS: Study showed that knee sagittal plane alignment and knee joint position sense can be influenced with gait training in women with KH.
CLINICAL RELEVANCE: Proficiency controlling knee kinematics after gait retraining program can influence knee joint position sense.

OPL62

THORACIC SPINE MANIPULATION IN PATIENTS WITH CERVICAL RADICULOPATHY: A RANDOMIZED CONTROLLED TRIAL

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PURPOSE/HYPOTHESIS: To compare the immediate and short-term effects of thoracic manipulation to those of a sham thoracic manipulation in patients with cervical radiculopathy (CRAD). We hypothesized that patients randomized to receive thoracic manipulation will have less pain and disability, and greater cervical spine range of motion and deep neck flexor muscle endurance compared to those receiving sham manipulation.
NUMBER OF SUBJECTS: Subjects (n = 43) were randomized to receive either a thoracic spine manipulation (n = 22) or a sham manipulation (n = 21).
MATERIALS/METHODS: Participants with CRAD were randomized to receive manipulation (n = 22) or sham manipulation (n = 21) of the thoracic spine. Outcomes were measured at baseline, immediately and 48 to 72 hours after manipulation. Repeated-measures ANOVA assessed the primary outcome of neck and upper extremity pain (numeric pain rating scale [NPRS]), and secondary outcomes of the neck disability index (NDI), cervical range of motion (ROM), and deep neck flexor endurance. Post hoc independent *t* test assessed difference between groups at the 2 follow-ups. Chi-square tests assessed the primary outcome of perceived success with the global rating of change scale (GROC), and secondary outcomes of numbness, tingling and symptom distribution via centralization, and beliefs about receiving the manipulation treatment.
RESULTS: Significant 2-way interactions were found for neck and upper extremity pain, cervical ROM, NDI, and deep neck flexor endurance ($P = .02$). Post hoc analysis showed that the manipulation group had lower neck pain ($P<.01$), better cervical range of motion ($P<.01$), lower NDI score ($P<.01$), and longer deep neck flexor endurance ($P = .02$) compared to sham manipulation group. Further, the chi-square analysis showed

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that a greater proportion of participants in the manipulation group reported moderate change on the GROC (P = .01) and centralization of symptoms (P<.01). More participants in the manipulation group believed they received an active treatment as compared to the sham manipulation group (90% versus 57%, P = .01).

CONCLUSIONS: Patients with CRAD treated with 1 session of thoracic manipulation experienced lower neck pain and disability, and greater perceived recovery, CROM and the deep neck flexor endurance compared to those treated with a sham manipulation. These between group differences were maintained for up to 72 hours after the manipulation treatment.

CLINICAL RELEVANCE: Thoracic manipulation in patients with CRAD is an effective early treatment option, and may serve as a segway to more direct manipulative techniques to the cervical spine and neurodynamic system.

OPL63

PHYSICAL ACTIVITY AND PHYSICAL FUNCTION BEFORE AND AFTER TOTAL KNEE ARTHROPLASTY

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PURPOSE/HYPOTHESIS: Pain and function improve after total knee arthroplasty (TKA), but it is not clear whether physical activity also improves. The aims of this study were to (1) determine if steps per day or time spent in moderate to vigorous physical activity (MVPA) improves after TKA and (2) determine if physical activity was associated with functional measures. Given the consistent improvements in function and pain after TKA, we hypothesized that physical activity would increase 6 months after TKA and improvements in activity would be associated with the change in pain and function. We anticipated that individuals with greater gains in function would also show the greatest improvements in physical activity.

NUMBER OF SUBJECTS: Forty-five individuals scheduled for unilateral TKA participated in this longitudinal, prospective cohort study.

MATERIALS/METHODS: Participants were tested 2 to 4 weeks prior to TKA and 6 months after TKA. A triaxial accelerometer (Actigraph GT3X Pensacola, FL) was worn for 7 consecutive days. Steps per day were averaged across valid days and time spent in MVPA was quantified as the number of minutes spent in 2020 or more activity counts. The 6-minute walk test, timed up-and-go, and 30-second chair-stand test were performed at both testing sessions. Changes in function and accelerometer-based physical activity were compared before and 6 months after TKA with paired t tests. The relationships between MVPA and steps per day with function were assessed using preoperative, postoperative, and change scores.

RESULTS: The average ± SD age was 65 ± 7 years, BMI was 32.6 ± 7.5 kg/m^2, and 62% of subjects were female. Average wear time before surgery was 6.7 ± 0.9 days and 14.5 ± 1.8 hours per day. Average wear time at follow-up after surgery was 6.4 ± 0.9 days and 14.2 ± 1.8 hours per day. There was no change in MVPA (2.8 minutes per day; P = .20) or steps per day (166 steps; P = .59) after TKA, but all functional measures significantly improved. Age and BMI were not related to physical activity before TKA, but there was a weak correlation between BMI and steps per day after TKA (r = −0.34, P = .027). There were several correlations between MVPA and function at the postoperative time point, but not before TKA. Better scores on the 6MW, TUG, and 30-CST were correlated with a greater number of steps per day before and after TKA. Change in function was not correlated with change in any measure of physical activity.

CONCLUSIONS: After TKA, individuals show large improvements in function, but do not improve in objective measures of physical activity. Although individuals with better function may also have higher levels of activity before and after TKA, change in function did not correlate with change in activity.

CLINICAL RELEVANCE: Surgical interventions that reduce pain and rehabilitation that focuses on physical impairments and functional deficits do not have an effect on a patient's physical activity. Interventions that target behavioral change are warranted for this population.

OPL64

A PILOT STUDY OF PATIENT-DEFINED OUTCOMES FOR SEEKING ADDITIONAL HEALTH CARE AFTER AN EPISODE OF PHYSICAL THERAPY

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PURPOSE/HYPOTHESIS: Patient-centered models of treatment delivery provide an alternative approach to evaluating clinical outcomes. Patient's perspectives of desired, expected, and successful outcomes differ based on the clinical outcome of interest and may explain additional care seeking following an episode of care, despite meeting predetermined success criteria (eg, minimal clinically important difference [MCID]). The purpose of this pilot study was to investigate what patient defined levels for pain relief, fatigue emotional distress, and interference with activities of daily living (ADLs) would prohibit seeking additional health care.

NUMBER OF SUBJECTS: A convenience sample of 25 patients referred to outpatient physical therapy with musculoskeletal pain complaints.

MATERIALS/METHODS: Patients completed a Patient Centered Outcome Questionnaire (PCOQ) prior to their initial evaluation. The PCOQ uses separate 11-point numeric rating scales (0, none to 10, worst imaginable) to assess usual, desired, successful, and expected levels of the domains of pain, fatigue, emotional distress, and interference. The PCOQ was modified to include an item specific to the level of each domain at which patients would stop seeking additional care following physical therapy. Pearson correlations assessed associations between this "stopping level" and other patient-defined criteria for desired, success, and expected levels for the individual domains.

RESULTS: Patients reported mean usual levels of pain as 4.4 ± 2.4, fatigue as 3.7 ± 2.6, emotional distress as 2.4 ± 2.3, and interference as 4.1 ± 2.7. Patient defined mean desired, expected, and successful pain as 0.45 ± 0.74, 1.0 ± 1.4, 1.3 ± 1.2, fatigue as 0.55 ± 1.0, 1.4 ± 1.7, 1.3 ± 1.2 emotional distress as 0.32 ± 0.84, 0.59 ± 1.0, 0.68 ± 0.99, and interference as 0.5 ± 1.1, 0.71 ± 1.2, 1.0 ± 1.2. Patients reported that they would cease seeking additional care when they achieved mean pain 1.5 ± 1.8, fatigue 2.1 ± 2.5, emotional distress 1.5 ± 1.7, and interference 1.2 ± 1.6. Correlations demonstrated significant moderate associations (P<.01) between "stopping level" and patient expectation for domains of fatigue (r = 0.60) and emotional distress (r = 0.64), as well patient success criteria in the emotional distress (r = 0.61) domain.

CONCLUSIONS: Patients may continue to seek care until they meet self- defined expectation or success criteria for fatigue and emotional distress. These findings add to our prior findings by suggesting patients may require changes larger than MCID before stopping to seek additional care.

CLINICAL RELEVANCE: Individuals seeking outpatient physical therapy would likely cease additional intervention once their success and expectation criteria are met, instead of continuing to seek care until desired levels are met. Furthermore, these findings suggest that monitoring fatigue and emotional distress may help determine if additional care will be sought after receiving physical therapy.

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SPL1

INDICATORS OF MUSCULOSKELETAL AND CARDIOVASCULAR FATIGUE IN A WOMEN'S DIVISION I COLLEGIATE SOCCER TEAM ACROSS A SEASON

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PURPOSE/HYPOTHESIS: Soccer is the second most popular sport among female collegiate athletes. An increase in participation has resulted in a rise in injury rates, particularly speculated to be due to training-related factors. Consequently, there has been an interest in identifying indicators of fatigue related to performance that may also serve as risk factors for injury. The purpose of this study was to determine fatigue trends, using noninvasive measures of fatigue, across a season in women's collegiate soccer players. We hypothesized that fatigue measures such as maximum heart rate and Rating of Perceived Exertion (RPE) would increase, and countermovement jump (CMJ) height would decrease as the season progressed. We also expected changes in number of accelerations/decelerations and total distance covered during matches as the season proceeded.

NUMBER OF SUBJECTS: Seventeen.

MATERIALS/METHODS: A cross-sectional, repeated-measures design was employed. Seventeen NCAA Division I women's soccer players completed a countermovement jump test and fatigue assessment scale each week before and after games. POLAR heart rate monitors and actigraphs were worn during games to track heart rate and distance information. Injury and illness records were obtained from the team's certified athletic trainer at the end of the season. Fatigue measures including RPE, CMJ, minimum (HRmin) and maximum (HRmax) heart rate, time in heart rate zones, total distance, maximum speed and accelerations/decelerations were compared over 3 time points: early (T1), mid (T2), and late (T3) season.

RESULTS: We found that HRmax significantly increased between T1 and T3 (201.6 ± 10.0 bpm versus 208.8 ± 7.6 bpm, $P<.03$) and between T2 and T3 (204.1 ± 8.5 bpm versus 208.8 ± 7.6 bpm, $P<.05$). We also observed significant decreases in CMJ values between T1 and T2 (12.8 ± 1.5 inches versus 12.0 ± 1.6 inches, $P<.05$) and T1 and T3 (12.8 ± 1.6 inches versus 11.6 ± 1.6 inches, $P<.03$), respectively. RPE significantly increased from T1 to T3 (4.7 ± 0.8 versus 5.5 ± 0.9, $P<.03$) and from T2 to T3 (5.1 ± 0.8 versus 5.5 ± 0.9, $P<.05$), respectively. All other variables measured did not change significantly over the season ($P>.05$).

CONCLUSIONS: As the season progressed, the soccer players' fatigue increased as indicated by elevated HRmax, decreased CMJ test heights and increased RPEs. Our study can be used as preliminary evidence for using these measures to evaluate trends of fatigue over a season and evidence for structuring training load over a season.

CLINICAL RELEVANCE: Our study emphasizes the need for thoughtful preparation before and during a Division I women's collegiate soccer season regarding increased fatigue levels. This may include educating athletes, coaches, strength/conditioning and sports medicine professionals of the need for targeted musculoskeletal loading and cardiovascular training periodization. Future studies should examine the relationships between these measures and injury risk.

SPL2

FEMALES EXPERIENCE GREATER SPEED-DEPENDENT INCREASES IN LOADING RATE THAN MALES DURING TREADMILL RUNNING

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PURPOSE/HYPOTHESIS: Up to 79% of runners get injured every year. In addition, female runners have a higher risk of developing running-related injuries (RRI) than male runners. Kinetics risk factors for RRI include high rates of loading (ROL) and tibial impact shocks (TIS). Previous research is not clear whether females demonstrate higher ROL and TIS. While most runners use a variety of running speeds during their training, not much is known about how running speed affects kinetic risk factors. The purpose of this study was to investigate the effect of sex and speed on kinetic risk factors for RRI during running.

NUMBER OF SUBJECTS: Thirty-seven healthy runners (17 male, 19 female; mean ± SD age, 23 ± 3 years). All subjects were free of neuromuscular or musculoskeletal injury in the past 6 months, had no history of lower limb surgery, and ran at least 10 miles per week.

MATERIALS/METHODS: Participants ran on a treadmill at 3 speeds: their preferred long slow distance (LSD) speed, LSD+15%, and LSD+30%. Vertical ground reaction force (Newtons) and TIS ($m \cdot s^{-2}$) were measured with a pressure treadmill and a triaxial accelerometer, respectively. Average ROL ($N \cdot kg^{-1}$) and TIS (grams) were calculated from 10 strides at each speed. ROL was normalized to body mass. A MANOVA was used to determine the effect of sex (male/female) and speed (LSD, LSD+15%, LSD+30%) on ROL and TIS. ANOVAs were used to investigate interactions and main effects for each RRI risk factor, *t* tests were

used to compare pairwise differences between sex and speed during post hoc testing for each RRI risk factor.

RESULTS: There was a significant effect of sex and speed on kinetic risk factors (MANOVA, $P = .003$). The individual ANOVAs showed significant interaction effects of sex and speed on ROL ($P = .001$) but not on TIS ($P = .197$). Pairwise comparisons showed that only females exhibited a greater ROL at LSD+30% (232 ± 61) than at LSD (206 ± 42, $P = .001$) and LSD+15% (210 ± 41, $P = .001$). ROL for males did not differ among speeds (LSD, 214 ± 38; LSD+15%, 221 ± 39; LSD+30%, 218 ± 35). Significant main effects for speed were found for ROL ($P = .001$) and TIS ($P = .001$). ROL at LSD+30% (225 ± 9) was greater than at LSD (210 ± 7, $P = .001$) and at LSD+15% (216 ± 7, $P = .023$). TIS at LSD+30% (6.7 ± 0.3) were greater than TIS at LSD (5.1 ± 0.3, $P = .001$) and at LSD+15% (5.9 ± 0.3, $P = .001$). TIS at LSD+15% were also greater than TIS at LSD ($P = .001$). The ANOVA main effects for sex indicated that ROL and TIS did not differ between males and females.

CONCLUSIONS: Females exhibited a significantly greater increase in ROL when going from LSD and LSD+15% to LSD+30% speed whereas males did not. In addition, kinetic RRI risk factors increased with running speed but did not differ between males and females.

CLINICAL RELEVANCE: Females exhibit a greater rate of increase in ROL as running speeds increase, where males do not. Given that ROL is a purported RRI risk factor, females might be at greater risk of developing RRI than males when running at faster speeds, which may partially explain why females have higher rates of RRI than males.

SPL3

TRAINING RUGBY ATHLETES WITH AN EXTERNAL FOCUS PROMOTES MORE AUTOMATIC ADAPTATIONS IN LANDING FORCES

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PURPOSE/HYPOTHESIS: Landing with high impact forces may be a risk factor for ACL injury. Verbal instruction to reduce impact forces is recommended for ACL injury prevention. Instructions can promote an internal (focus on body movements) or external (focus on movement effect) attentional focus. Training with an external focus may result in better retention/transfer and promote greater automaticity for various tasks. The purpose of this study was to compare the effects of movement training incorporating instructions promoting an internal or external focus. We hypothesized that athletes who trained with an external focus would demonstrate a greater reduction in landing forces following training. We also anticipated that the training adaptations would be less affected by a secondary cognitive task for the athletes that trained with an external focus (indicative of greater automaticity).

NUMBER OF SUBJECTS: Twenty-two (12 male, 10 female) uninjured high school rugby athletes.

MATERIALS/METHODS: Upon enrollment, athletes were randomly allocated to groups that would receive instructions promoting an internal (FoAin group) or external (FoAex group) focus. During an initial testing session, forces were recorded during drop landings using a force platform (baseline condition). Following the initial testing session, athletes completed 4 training sessions where they were given instructions intended to reduce landing forces. The FoAin group was instructed: "focus on bending your knees when you land," and the FoAex group was instructed: "focus on landing softly." Following the training program, the athletes completed a follow-up testing session where they performed drop landings without (retention condition) and with a secondary cognitive task (dual-task condition). The secondary cognitive task (counting backward) assessed automaticity by limiting the athletes' ability to attend to their movement. A mixed-model ANOVA with a between-factor of group (FoAin, FoAex) and a within-factor of condition (baseline, retention, dual-task) was conducted with the landing forces as the dependent variable.

RESULTS: There was a group-by-condition interaction ($P = .01$). The groups exhibited a similar decrease in landing forces for the retention condition versus baseline, as the FoAin group demonstrated a 33.3% reduction and the FoAex group demonstrated a 30.8% reduction. The interaction effect appeared to reflect a difference in the response to the secondary cognitive task, as the FoAin group demonstrated a 25.0% increase in landing forces for the dual-task condition relative to the retention condition, whereas the FoAex group only demonstrated a 3.7% increase.

CONCLUSIONS: Athletes that trained with an external focus were better able to maintain changes in their landings mechanics when they could not fully attend to their movement (greater automaticity).

CLINICAL RELEVANCE: Movement training with an external focus may result in more robust adaptations in landing mechanics.

SPL4

INERTIAL SENSORS DETECT ASYMMETRIES IN SHANK ANGULAR VELOCITY DURING WALKING FAST AND RUNNING IN INDIVIDUALS WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Wearable inertial sensors have shown to detect asymmetries in shank angular velocity (SAV) during walking in individuals with anterior cruciate ligament reconstruction (ACLR). These SAV asymmetries are strongly related to limb asymmetries in knee extensor moments during walking, which may be attributed to quadriceps weakness. However, asymmetries in SAV during running and how they relate to self-reported knee function are still unknown in individuals with ACLR. This study aimed to (1) investigate SAV asymmetries at different gait speeds in individuals with ACLR, and (2) determine the relationship between SAV and self-reported knee function at 4 months after ACLR.

NUMBER OF SUBJECTS: Thirteen ACLR subjects (mean ± SD age, 26.23 ± 7.83 years) and 16 healthy controls (age, 27.75 ± 5.21 years).

MATERIALS/METHODS: This is part of an ongoing prospective longitudinal study. Testing took place in clinical settings at 4 months post surgery. Two wireless inertial sensors were attached bilaterally on the shanks, 5 cm above the lateral malleoli. Subjects were instructed to walk, walk fast, and run at a self-selected speed for each, along a 12-m straight walkway. SAV was calculated bilaterally at loading response phase, which was identified as the first negative SAV peak after heel strike in the sagittal plane of gyroscope signals. The average SAV was calculated for each limb. Self-reported knee function was assessed using the International Knee Documentation Committee 2000 (IKDC 2000). The magnitude of SAV limb asymmetry in healthy controls was calculated and used to define limits of meaningful SAV limb asymmetry in ACLR individuals. Paired t tests were used to assess SAV limb symmetry during gait. Pearson's correlation was used to examine the relationship between SAV and the IKDC 2000.

RESULTS: SAV was significantly smaller for the involved limb compared to the uninvolved limb during walking ($P = .002$), walking fast ($P<.001$), and running ($P<.0001$). From controls, the smallest meaningful SAV asymmetries were 0.13, 0.20, and 0.26 rad/s for walk, walk fast, and run, respectively. Accordingly, ACLR participants showed meaningful SAV asymmetries during walking (0.18 ± 0.17 rad/s), walking fast (0.49 ± 0.31 rad/s), and running (0.72 ± 0.35 rad/s). SAV interlimb differences during walking fast and running were moderately correlated with the IKDC 2000 ($r = -0.52$, $P = .03$ and $r = -0.58$, $P = .02$, respectively).

CONCLUSIONS: At 4 months postsurgery, ACLR subjects exhibited significant and meaningful SAV asymmetries, which were more evident during walking fast and running compared to walking. ACLR participants with higher SAV asymmetries during walking fast and running showed lower self-reported knee function.

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CLINICAL RELEVANCE: Wireless inertial sensors are an inexpensive and practical tool to detect gait asymmetries post ACLR. Implementing these sensors in clinical practice will offer an objective measurement, in addition to visual observation, to monitor normalization of gait during rehabilitation after ACLR.

SPL5

LIMB PREFERENCE IMPACTS STRENGTH AND JUMPING LIMB SYMMETRY INDEX VALUES FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Following anterior cruciate ligament reconstruction (ACL-R) a clinical goal is to obtain symmetrical performance between limbs. Individuals have a dominant limb or preferred limb when performing tasks like kicking a ball or jumping from 1 leg. Performance between limbs is characterized by some asymmetry, but limb preference is not often considered when making return to activity decisions following ACL-R. The purpose of this study was to determine if limb preference has an effect on quadriceps strength or single-leg forward hop distance limb symmetry index (LSI) values following ACL-R. We hypothesized that limb preference will have a significant effect on quadriceps strength and single limb forward hop LSI values.

NUMBER OF SUBJECTS: Thirty-nine individuals with ACL-R (14 male, 25 female; mean ± SD age, 20.2 ± 5.1 years; height, 173.9 ± 9.6 cm; mass, 71.1 ± 13.9 kg; time since surgery, 5.7 ± 1.1 months; limb injured, 19 preferred and 20 nonpreferred). Inclusion criteria included age of 14 to 35 years, primary unilateral ACL-R in the past 4 to 12 months, and cleared by medical provider to participate in physical and jumping activities. Exclusion criteria included current pregnancy or inability to give consent.

MATERIALS/METHODS: Outcome measures were obtained on both limbs with the uninvolved tested prior to the involved limb. The preferred limb for performing a unilateral jump (eg, layup) was self-identified by participants. An isokinetic dynamometer was used to obtain maximum quadriceps isometric peak torque (Newton meters). Next, participants performed a single-leg hop for distance (centimeters). LSI was calculated for each outcome variable using both maximal MVIC, and distance hopped (LSI = involved/uninvolved). Independent *t* tests were performed and statistical significance was set at priori $P<.05$. Effect sizes were calculated to interpret magnitude of differences.

RESULTS: There was no significant difference ($P = .34$, $d = 0.31$) in quadriceps LSI values between groups (preferred limb injured 82.8% ± 20.5%, nonpreferred injured 76.7% ± 19.5%). There was a significant difference ($P = .04$, $d = 0.70$) in single limb hop for distance LSI between groups (preferred injured 94.1% ± 12.6%, nonpreferred injured 83.4% ± 14.1%).

CONCLUSIONS: Limb preference impacted both quadriceps strength and forward hop distance LSI values. The magnitude of the effect for quadriceps strength was small ($d = 0.31$), but medium ($d = 0.70$) for single-leg forward hop LSI. It is possible that limb preference needs to be task specific, such as asking preferred jumping limb or perceived stronger limb.

CLINICAL RELEVANCE: Limb preference is typically not considered when considering return to activity decisions. Results suggest limb preference influences LSI values. The current recommended protocol of 90% LSI prior to returning to sport after ACL injury should consider the influence of limb preference.

SPL6

NORMALIZED ISOMETRIC SHOULDER STRENGTH PREDICTS BALL VELOCITY IN YOUTH BASEBALL PLAYERS

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PURPOSE/HYPOTHESIS: Evaluation of upper extremity muscle strength is an integral part of physical assessment and injury prevention in baseball players, however minimal data exists in youth populations. Changes in anthropometric measures, inherent in physically developing athletes, have been shown to impact strength measures but normalization methodology is rarely reported. The purposes of this study were to (1) compare 5 different methods for normalizing isometric shoulder strength and (2) examine the relationship between normalized shoulder strength and ball velocity in a cohort of youth baseball players.

NUMBER OF SUBJECTS: Male youth baseball players (n = 159; mean ± SD age, 11.1 ± 1.1 years) actively participating in organized baseball were included in this study.

MATERIALS/METHODS: Baseline and follow-up weight, height and bilateral ulnar length measurements were assessed followed by isometric strength in both the dominant (D) and nondominant (ND) shoulders. Strength measures included scaption and external rotation (ER) at 0° of shoulder abduction in the seated position, followed by ER and internal rotation (IR) at 90° in the prone position. Ball velocity was assessed as a measure of throwing performance. Intraclass correlation coefficients (ICC), standard errors of measurement (SEM), and minimal detectable change (MDC_{95}) were calculated for all strength measures. Repeated measures analyses of variance (ANOVA) were conducted comparing strength changes at 2 time points after normalizing to 5 separate anthropometric measures including weight, height, body mass index, torque and percent of ND shoulder strength. Linear regression models were used to examine the relationships between normalized isometric shoulder strength and ball velocity. Statistical significance was set a priori at $\alpha = .05$.

RESULTS: Torque, defined as the measure of shoulder strength multiplied by the corresponding ulnar length, was the only method that demonstrated excellent reliability ($ICC_{2,1}$ = 0.98-0.99) and detected significant changes in shoulder strength for each of the 4 measures tested (SEM, 0.39-0.69 Nm). Modest but significant correlations were observed between ball velocity and scaption torque ($R^2 = 0.27$, $P<.001$) as well as ER torque at 0° ($R^2 = 0.23$, $P<.001$).

CONCLUSIONS: The torque normalization method demonstrated the most consistent measurement properties for assessing isometric shoulder strength in youth baseball players. In addition, ulnar length was the most stable and reliable anthropometric measure we evaluated. Lastly, normalized isometric shoulder scaption strength was the most significant predictor of ball velocity, followed by ER strength at 0° in this population.

CLINICAL RELEVANCE: Measuring ulnar length is a reliable, timely and cost-effective way to normalize shoulder strength in youth baseball players. Consistently normalizing strength measures allows clinicians to assess shoulder strength and throwing performance irrespective of an athlete's physical growth and development over time.

SPL7

ASSOCIATION BETWEEN FUNCTIONAL HOP TEST PERFORMANCE AND QUADRICEPS STRENGTH IN PATIENTS RECOVERING FROM ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Quadriceps muscle weakness is common after anterior cruciate ligament reconstruction (ACLR) and may present itself during functional movements common in sport. It has been suggested that hop testing can be used to estimate quadriceps strength; however, small studies investigating this relationship have led to inconclusive findings. The purpose of this study was to determine the relationship between functional hop test performance and quadriceps strength following ACLR.
NUMBER OF SUBJECTS: Three hundred eighty-seven individuals (mean ± SD age, 23.9 ± 10.3 years; 208 male) who underwent unilateral ACLR 8.3 ± 3.2 months prior to testing.
MATERIALS/METHODS: All measures were obtained as part of routine clinical care within a single institution and stored within an electronic database. Records were extracted for all individuals that performed isokinetic quadriceps strength testing and at least 1 hop test within a single clinic visit. Functional hop tests included the vertical hop, vertical 4 hop, horizontal hop, and horizontal crossover 4 hop. The distance in centimeters of each hop was recorded for each limb across 3 trials, and the average of each was used in the analysis. Quadriceps strength for each limb was defined as the peak torque for knee extension (60°/s) normalized to body mass. Pairwise Pearson correlations were used to assess the relationships between each of the 4 hop tests and quadriceps strength. Potential confounders (age, sex, and time since ACLR) were explored through linear regression.
RESULTS: Quadriceps strength showed statistically significant but weak to moderate correlations with each of the functional hop tests; similar correlations were shown for both the involved and uninvolved limbs respectively: vertical hop (r = 0.41 and 0.39), vertical 4 hop (r = 0.31 and 0.36), horizontal hop (r = 0.39 and 0.33), and crossover 4 hop (r = 0.42 and 0.42) (P<.001). These correlations were not influenced by age, sex, or time since ACLR.
CONCLUSIONS: Relationships between functional hop test performance and quadriceps strength following ACLR are weak to moderate at best. These results indicate that functional hop testing is not solely determined by quadriceps strength, but instead captures a different aspect of the recovery process for individuals post-ACLR.
CLINICAL RELEVANCE: Functional hop testing should not be used as a direct assessment of muscle function when trying to estimate quadriceps strength following ACLR regardless of time since surgery. Instead, more valid measures of muscle strength, such as isokinetic dynamometry, should be used to evaluate quadriceps strength and recovery throughout rehabilitation.

SPL8

PARA-ATHLETES REQUIRE CUSTOMIZED SEATING FOR OPTIMIZED PERFORMANCE AND SAFETY

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PURPOSE: The purpose is to demonstrate Science Meets Practice by sharing an evidence based systematic approach for coordinating seating interventions in adaptive sports equipment for athletes with physical impairments.
DESCRIPTION: Athletes with physical impairments who use wheelchairs, prosthetic limbs, or lower extremity orthoses often participate in adaptive sports from a seated position in specialized equipment. Adaptive technologies vary greatly from one sport to another, and within a given sport, the equipment used by each athlete is significantly different based on the position played or specific competitive event, skill level, and the unique needs of each athlete. Known challenges for seated athletes include skin and soft tissue compromise, postural instability, and upper extremity musculoskeletal injury. Optimized sports performance and safety is facilitated when the athlete receives customized seating interventions for adaptive sports equipment that promote tissue protection, postural support, and upper-limb preservation. Given the realm of physical, physiologic, and functional considerations that must be incorporated into sports technology recommendations, physical therapists are integral stakeholders who work collaboratively with coaches, adaptive instructors, and product manufacturers to identity seating solutions for para athletes ranging from novice participants to elite level competitors. An evidence based systematic approach for identifying athlete needs and coordinating seating interventions for sports will be demonstrated to promote PT awareness of this highly specialized component of adaptive sports medicine.
SUMMARY OF USE: The proposed model for supporting athletes with disabilities with customized seating interventions can be implemented in traditional and nontraditional clinical settings by PT professionals motivated to practice adaptive sports medicine.
IMPORTANCE TO MEMBERS: PT professionals will gain increased awareness of opportunities to apply foundational knowledge and skills to provide highly specialized support to athletes with physical impairments.

SPL9

EFFECTS OF STABLE AND UNSTABLE SURFACES ON THE LOWER EXTREMITY AND TRUNK MUSCLE ACTIVATION DURING THE STAR EXCURSION BALANCE TEST AND Y BALANCE INSTRUMENT IN HEALTHY ADULTS

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PURPOSE/HYPOTHESIS: The Star Excursion Balance Test (SEBT) with its 8 directions has been used as a rehabilitation tool. To improve its efficacy and eliminate same constructs, anterior (A), posterolateral (PL), and posteromedial (PM) directions of the SEBT has been recommended. The Y Balance instrument (YBI) consists of A, PM, and PL directions of the SEBT. It has been developed to eliminate common sources of error and method variations during the SEBT. The kinematic differences between the SEBT and the YBI has been observed previously on stable surface. For same tasks, electromyographic (EMG) activity has been reported to change between various surfaces. The purpose of this study was to compare muscle activation of the lower extremity and trunk muscles during the SEBT and the YBI on stable and unstable surfaces.
NUMBER OF SUBJECTS: Twenty (10 male, 10 female) healthy adults with no history of chronic ankle instability were recruited for the study.
MATERIALS/METHODS: Surface EMG was collected for rectus abdominis, external oblique, erector spinae bilaterally and gluteus maximus, gluteus medius, medial hamstrings, biceps femoris, vastus medialis, rectus femoris, vastus lateralis, anterior tibialis, and medial gastrocnemius on the stance leg, during the A, PL, and PM directions of the SEBT on the floor and using YBI. Unstable surface was introduced using Thera-Band stability trainer. Paired t tests assessed differences in EMG for each direction and each muscle between the stable and unstable surface (SEBT stable versus unstable AND YBI stable versus unstable) and between the SEBT and YBI (SEBT stable versus YBI stable AND SEBT unstable versus YBI unstable) with α = .05.
RESULTS: Significant differences were observed for 12 of 15 muscles between stable and unstable surfaces for 1 or more directions of the SEBT and the YBI. Overall, the muscle activation was higher for the unstable surface compared to the stable surface for both the SEBT and the YBI. On the stable surface, EMG was higher for the SEBT compared to the YBI. No differences in the EMG were observed between the SEBT and the YBI on the unstable surface.
CONCLUSIONS: Adding instability to the surface increased muscle activation during both the SEBT and the YBI. However, on the stable surface, muscle activation was lower for the YBI compared to the SEBT.
CLINICAL RELEVANCE: Introducing an unstable surface could produce more muscle activation. Even though the YBI has been recommended to replace the SEBT, caution should be exercised as both these tasks may not be identical. The subject may use different neuromuscular strategies to accomplish these similar activities.

SPL10

THE INFLUENCE OF FATIGUE AND ANTICIPATION ON JUMP-CUT MOVEMENT PATTERNS IN KNEE BIOMECHANICS

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PURPOSE/HYPOTHESIS: Anterior cruciate ligament (ACL) injuries are very common in athletes, with an increased risk for females. Additionally, contributing factors of anticipation and fatigue have been shown to adversely affect lower extremity biomechanics. This research aims to determine whether differences exist in knee kinematics and kinetics for (1) healthy females and males, (2) pre and post fatigue conditions, (3) anticipated (A) and unanticipated (UA) trials, and/or for any combination of these, during a jump-cut activity. These dysfunctional movement patterns may indicate an increased risk for knee injury.

NUMBER OF SUBJECTS: Forty.

MATERIALS/METHODS: Forty subjects, including 20 males (mean ± SD age, 25.85 ± 3.83 years; height, 72.5 ± 2.7 inches; weight, 190.65 ± 14.2 lb) and 20 females (age, 24.45 ± 2.62 years; height, 65.67 ± 2.54 inches; weight, 139.89 ± 15 lb) participated in the study. Lower extremity kinematics and kinetics were measured using a 3-D electromagnetic system for left and right jump-cut trials. The FAST-FP was used to induce fatigue and consisted of jumping, sprinting, step-ups, and L-drill. Trials with and without knowledge of cut side (Anticipated [A]/Unanticipated [UA]) were performed in the nonfatigued and fatigued states. A repeated-measures ANOVA was used to analyze peak and mean angles, moments and ground reaction force (GRF), with post hoc Tukey tests for significant findings between factors (sex, pre/postfatigue protocol, A/UA).

RESULTS: Significant findings were noted for sex, pre/post fatigue and A/UA conditions. Notable results included higher mean and peak abduction and internal rotation angles for females and post fatigue state; lower mean and peak flexion angles for females; higher mean and peak adduction internal moments post fatigue, and higher peak vertical GRF for the unanticipated condition. Females demonstrated higher mean abduction angles post fatigue and higher peak adduction internal moments post fatigue and without anticipation. Females also had significantly higher LESS scores and remained in knee abduction throughout movements across all conditions. Additionally, a greater number of significant findings were noted for the dominant leg (right).

CONCLUSIONS: Females demonstrated significantly larger knee abduction angles and resultant external moments in all conditions relative to men, especially when fatigued. UA trials demonstrated increased GRF upon landing and an increase in the resultant external abduction moment in both sexes, especially with fatigue. Sex, fatigue state, and A/UA should be considered when designing sports training programs to reduce risky movement patterns.

CLINICAL RELEVANCE: Given the increased incidence of ACL injury and reinjury, physical therapists need to understand that fatigue and lack of anticipation may increase risky movement patterns, especially for females. These results emphasize the need to address these specific conditions during training/rehabilitation to reduce the potential of ACL injury or reinjury.

SPL11

COMPARING STATIC SINGLE-LEG POSTURAL CONTROL OF ATHLETES WHO ARE DEAF OR HARD OF HEARING TO ATHLETES WHO ARE HEARING

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PURPOSE/HYPOTHESIS: Postural control integrates information from the somatosensory, visual, and vestibular systems and is often assessed to monitor an athlete's progress in rehabilitation and concussion management. Disturbances to these systems have been proposed as possible mechanisms for postural control deficiencies. However, postural control of athletes with possible vestibular dysfunction, that is, deaf or hard-of-hearing (D/HoH), has yet to be explored. Therefore, the purpose of this study was to compare static postural control of athletes who are D/HoH to athletes who are hearing.

NUMBER OF SUBJECTS: Thirty-five National Collegiate Athletic Association Division III athletes who are D/HoH (21 male; mean ± SD age, 19.82 ± 1.18 years; height, 1.74 ± 0.09 m; weight, 73.31 ± 10.32 kg) and 22 collegiate club athletes who are hearing (11 male; age, 20.66 ± 1.81 years; height, 1.76 ± 0.08 m; weight, 76.76 ± 15.94 kg) participated in the study.

MATERIALS/METHODS: Participants were instructed to stand on their dominant leg, with eyes open for 20 seconds while hands were kept on hips and nonstance leg, was held in approximately 20° of hip flexion and 45° of knee flexion. Center of pressure (CoP) data were collected on a tri-axial force plate. Total, anteroposterior (AP) and mediolateral (ML) CoP excursion, AP and ML CoP range, sway area, and AP and ML root-mean-square (RMS) were calculated. One-way ANOVAs were performed to test the effects of hearing status on postural control with alpha set a priori at $P \leq .05$.

RESULTS: There was an effect of hearing status on total (hearing, 46.81 ± 8.42 cm; D/HoH, 56.91 ± 21.89 cm; $P = .04$) and ML (hearing, 30.52 ± 5.46 cm; D/HoH, 36.84 ± 13.72 cm; $P = .05$) excursion, AP (hearing, 3.11 ± 0.63 cm; D/HoH, 4.23 ± 2.01 cm; $P = .02$) and ML (hearing, 2.85 ± 0.59 cm; D/HoH, 3.43 ± 1.05 cm; $P = .02$) range, sway area (hearing, 7.49 ± 2.54 cm^2; D/HoH, 11.48 ± 5.53 cm^2; $P < .01$) and ML RMS (hearing, 0.64 ± 0.16 cm; D/HoH, 0.75 ± 0.21 cm; $P = .03$). No effect was observed on AP excursion (hearing, 29.48 ± 6.03 cm; D/HoH, 36.00 ± 14.90 cm; $P = .06$) and AP RMS (hearing, 4.43 ± 3.20 cm; D/HoH, 3.48 ± 2.28 cm; $P = .20$).

CONCLUSIONS: Athletes who are hearing were more stable during a static single-leg, postural control assessment compared to athletes who are D/HoH. These findings suggest that possible sensory differences exist between populations which may influence static postural control. Other assessments that alter the visual, somatosensory, and vestibular sensory systems, such as the modified Clinical Test of Sensory Interaction and Balance, may allow for a more comprehensive postural control evaluation of athletes who are D/HoH. Further research is warranted to understand the role of sex, sport, and degree of hearing loss on postural control.

CLINICAL RELEVANCE: Understanding postural control performance of athletes who are D/HoH will assist clinicians in the management, return-to-play decisions and safety of athletes who are D/HoH.

SPL12

QUADRICEPS STRENGTH FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION COMPARED TO MATCHED UNINJURED CONTROLS: A SYSTEMATIC REVIEW AND META-ANALYSIS

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PURPOSE/HYPOTHESIS: Recovery of quadriceps strength is a critical goal of postoperative rehabilitation following ACL reconstruction (ACL-R). Comparison with the uninjured leg, is often used to determine recovery of quadriceps strength in these individuals and for return-to-play (RTP) decision making. However, limb symmetry may not ensure a return to preinjury levels of activity. Quadriceps weakness may be detected if ACL-R individual are compared with age, sex, activity-matched uninjured individuals. We performed a systematic review and meta-analyses of the literature to assess recovery of quadriceps strength following ACL-R when compared to appropriately matched uninjured individuals.

NUMBER OF SUBJECTS: Not applicable.

MATERIALS/METHODS: Studies published in English language that reported data on peak quadriceps strength measured with a dynamometer in individuals with ACL-R and age, sex, and activity/sports-matched healthy controls were included. Four databases were searched (PubMed, CINAHL, SPORTDiscus, Scopus) and 3 reviewers assessed eligibility of studies. Study quality was assessed using the modified Downs and Black

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scale. Peak quadriceps strength for the ACL-R limb and the uninjured participants was extracted from each study. Standardized Mean Differences (SMD) were calculated for prespecified analyses using random effects models. Heterogeneity was assessed using the I^2 statistic. The study protocol was developed in accordance with PRISMA guidelines and registered on the PROSPERO International Register for systematic reviews (CRD42018083765).

RESULTS: The initial search returned 4133 results. After inclusion and exclusion criteria were applied, eighteen studies were included in the analysis. Irrespective of time point, across all studies, the ACL-R participants (n = 463) had lower quadriceps strength compared to age, sex, activity/sports-matched uninjured controls (n = 437) (SMD, −0.75; −1.10, −0.39; P<.0001, I^2 = 83%). When comparing quadriceps strength in participants who were post-RTP (15 studies), ACL-R participants (n = 394) had lower strength compared to controls (n = 385) (SMD, −0.50; −0.80, −0.21; P = .0009, I^2 = 73%). Of the 18, 4 studies were of good quality (score, 20-25), 13 were of fair quality (score, 15-19), and 1 was of poor quality (score, 14). The results were unchanged on excluding the 1 study of poor quality.

CONCLUSIONS: Athletes who undergo ACL-R potentially return-to-play before complete recovery of quadriceps strength when compared to appropriate uninjured controls. However, the heterogeneity across the studies was high. Subsequent data analyses continues to identify factors that could be related to the heterogeneity and observed results.

CLINICAL RELEVANCE: Athletes may be returning to play without adequate quadriceps strength which may place them at a greater risk of reinjury or posttraumatic osteoarthritis. Future studies and clinicians determining return-to-play criteria should compare ACL-R individuals with appropriately matched uninjured controls.

SPL13

PRIOR HISTORY OF ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IS ASSOCIATED WITH FUTURE ANTERIOR CRUCIATE LIGAMENT INJURY IN FEMALE COLLEGIATE ATHLETES

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PURPOSE/HYPOTHESIS: Injury prevention programs have demonstrated efficacy in reducing the risk of noncontact anterior cruciate ligament (ACL) injuries; therefore identifying athletes at-risk for an ACL injury is warranted. Researchers have attempted to identify athletes at-risk for ACL injury based on DVJ performance; however, findings are equivocal. Two functional tests (FT), the standing long jump (SLJ) and the single-leg, hop (SLH), have shown promise in identifying female collegiate athletes at-risk for a noncontact time-loss lower quadrant (LQ) injury; however, the ability of these tests to discriminate ACL injury risk is unknown. Also unknown is the risk of a subsequent ACL injury based on prior ACLR in a population of female collegiate athletes. The purpose of this prospective cohort study is 2-fold: (1) identify the relative risk (RR) of subsequent ACL injury in a population of female collegiate athletes and (2) determine the ability of a battery of FT to identify athletes at-risk for ACL or LQ injury.

NUMBER OF SUBJECTS: Three hundred sixty female collegiate athletes competing in soccer (n = 118), volleyball (n = 187), and basketball (n = 55) from 3 levels of competition (DII, 31; DIII, 251; NAIA, 78) were followed prospectively.

MATERIALS/METHODS: Athletes reported prior injury history and performed 2 FT: SLJ and SLH during a preseason screening clinic. Mean FT scores were normalized to height. RR of a noncontact time-loss injury (categorized by region/diagnosis) was based on prior ACLR history and FT scores. Risk of injury based on prior ACLR was dichotomized by yes or no. ROC curve analysis did not reveal cutoff scores for each FT; therefore previously published cutoff scores (SLJ, less than 0.80; SLH, less than 0.70) were utilized.

RESULTS: Mean ± SD FT measures were SLJ, 0.81 ± 0.10; R SLH, 0.69 ± 0.11; L SLH, 0.68 ± 0.11. Athletes with prior ACLR were 6 times (RR = 6.5; 95% CI: 1.4, 32.9; P = .007) more likely to experience a noncontact ACL injury during the season. The sensitivity and specificity associated with a new ACL injury based on prior ACLR was 28.6 (95% CI: 3.7, 71.0) and 94.9 (95% CI: 92.1, 97.0) respectively. Suboptimal performance on all 3 FT (SLJ, less than 0.80; [B] SLH less than 0.70) was associated with an almost 2-fold increase in a noncontact time-loss LQ injury (RR = 1.6; 95% CI: 1.1, 2.4; P = .028). There was no association between ACL injury and FT scores.

CONCLUSIONS: Prior history of ACLR was associated with a significantly greater risk of a subsequent ACL injury. FT scores were not associated with ACL injury; however, poor performance on all 3 was associated with an increased risk of a noncontact time-loss LQ.

CLINICAL RELEVANCE: Screening female collegiate athletes with an injury history questionnaire and with FT may help clinicians identify individuals at-risk for future injury.

SPL14

CRITERIA FOR CLEARANCE TO RETURN TO SPORT FOLLOWING PRIMARY ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A SCOPING REVIEW

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PURPOSE/HYPOTHESIS: Determining readiness to return to sport (RTS) after anterior cruciate ligament (ACL) reconstruction is a critical decision for sports medicine professionals to improve performance and reduce the current reinjury risk of up to 1 in 3 athletes sustaining new knee injuries after RTS. The aims of this scoping review were to (1) describe the criteria used to clear athletes to RTS following primary ACL reconstruction, (2) detail how these criteria evolved over time.

NUMBER OF SUBJECTS: Twenty-two thousand nine athletes (mean ± SD age, 25.7 ± 5.3 years; 35.4% female) across 209 studies.

MATERIALS/METHODS: We searched the MEDLINE, Embase, CINAHL, and SPORTDiscus electronic databases using keywords related to ACL and RTS. Two authors independently reviewed titles, abstracts, and full text to determine study inclusion. Data were extracted independently and verified by a second author. Collected data included (1) study demographics and (2) RTS criteria categorized into 7 domains: time, strength, hop testing, clinical examination, patient reported outcomes (PROs), subjective reports, and performance-based criteria.

RESULTS: Time was used in 178 studies (85%)* and in 88 studies (42%) time was the only criterion used to clear athletes to RTS. Various modes of strength testing were reported in 86 studies (41%). Thirteen different hop tests were used in 31 studies (15%). Reporting of which specific limb symmetry indices were utilized was variable for both strength and hop testing. Clinical examination was used in 54 studies (26%); including ligamentous stability (17%), range of motion (14%), effusion (10%), and thigh circumference (4%). PROs were used in 8 studies (4%); while subjective report of pain, knee stability, and readiness to RTS, were used in 17 studies (8%). Performance-based criteria were used in 41 studies (20%); including completion of a specific program (13%), agility (2%), proprioception

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(3%), aerobic endurance (1%), and quality of motion (1%). In studies that used more than 1 RTS criteria: 23% used 2 criteria, 21% used 3 criteria, and 9% used 4 criteria or more. There has been a 32% increase in number of studies reporting RTS criteria since last review on this topic. *All percentages reported reflect a portion of total studies (209).

CONCLUSIONS: Time was the most common criterion used to clear athletes to RTS following primary ACL reconstruction; 4 out of every 5 studies used a time criterion, 2 out of every 5 studies reported a strength criterion. Despite the physical and psychological demand of sport, only 1 in 5 studies used a physical performance-based criterion, and fewer than 1 in 10 studies used an athlete-report criterion.

CLINICAL RELEVANCE: Due to the variability in RTS criteria, sports medicine professionals should be judicious when selecting RTS criteria and examine multiple factors that represent the physical and biopsychosocial demands of sport for their individual athlete. The results of this scoping review suggest that in most studies, the multifactorial aspects of RTS are not considered when clearing athletes to RTS.

SPL15

RETURN TO SCHOOL-AGE COMPETITIVE SPORTS AFTER AN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING A CONTRALATERAL PATELLAR TENDON GRAFT

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PURPOSE/HYPOTHESIS: An anterior cruciate ligament (ACL) tear is a common injury in sports and often requires a reconstruction to get the athlete back to sports or the desired activity level. However, returning to sports at the same level or higher has been reported to be as low as 44%. Factors leading to this low rate of return include range of motion (ROM) and strength asymmetries, poor functional testing, and inadequate psychological readiness. The purpose of this study was to assess the rates at which patients return to the same level or higher, in particular, higher level sports and activities. We hypothesized that patients would be able to return to the same or higher levels after an ACL reconstruction using a contralateral patellar tendon graft (PTG) at a higher rate compared to previously reported studies.

NUMBER OF SUBJECTS: One hundred twenty.

MATERIALS/METHODS: Between 2009 and 2013, 120 school-aged competitive athletes (level 9, twisting, pivoting, jumping sports) underwent an ACL reconstruction using a contralateral PTG were enrolled into the study (76 female, 44 male). Prior to surgery, each patient was seen in the rehabilitation department with goals of having symmetric ROM, minimal swelling, normal gait mechanics, and adequate strength/leg, control. Once this was achieved, surgery was performed. Goals for rehabilitation after surgery were divided between the ACL knee and graft donor knee with the ACL knee focusing on attaining full ROM and swelling reduction, whereas the donor knee was focused on low intensity, high repetition strengthening exercises for tendon regeneration. These rehabilitation principles were followed until symmetry between the knees was attained as measured by goniometric measurement for ROM, quadriceps muscle strength on the Cybex isokinetic test measured at 180°/s and 60°/s, isometric single leg press, and single-leg hop for distance. Once symmetry was attained, each patient was progressed back into the sport they were getting back to while following up for continued testing and subjective outcome measures for activity rating scales.

RESULTS: Of the 120 level 9 athletes, 80% (96) were able to get back to the same level or higher as measured by the activity rating scale. Females were able to get back to the same level or higher at a higher rate at 83% (63/76) compared to males at 75% (33/44). All (100%) of these athletes were able to get back to the same sport at least at a recreational level.

CONCLUSIONS: Return to school-aged competitive level 9 sports following an ACLR using a contralateral PTG can be attained at a high rate for both male and female patients (80%). Dividing the goals of rehabilitation after surgery between 2 knees through a contralateral PTG is a factor to this high percentage as the patient has independent goals with each knee allowing for predictable outcomes.

CLINICAL RELEVANCE: Restoring symmetry following an ACLR can lead to high return to sport rates, which can be predictably done using a contralateral PTG.

SPL16

ISOMETRIC AND ISOKINETIC ASSESSMENTS OF RAPID KNEE EXTENSOR TORQUE DEVELOPMENT ARE SIMILARLY CORRELATED WITH RUN AND JUMP KINETIC ASYMMETRIES IN COLLEGIATE ATHLETES POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Following anterior cruciate ligament reconstruction (ACLR), quadriceps strength and rate of torque development (RTD) are typically measured with an isometric (ISOM) or isokinetic (ISOK) muscle contraction. It is unclear which contraction type is best for measuring quadriceps RTD and how these isolated measurements relate to functional knee joint kinetics. The purpose of this investigation was to assess asymmetries in ISOM and ISOK quadriceps performance and evaluate the relationships between strength, RTD, and running and jumping kinetics following ACLR.

NUMBER OF SUBJECTS: Thirteen Division I athletes (mean ± SD age, 20.7 ± 1.4 years; BMI, 25.9 ± 3.9 kg/m^2; 8 female) 7.6 ± 3.0 months post ACLR.

MATERIALS/METHODS: ISOM assessment consisted of voluntary maximal and rapid torque development at 90° of knee flexion. ISOK evaluation was performed at 60°/s and 240°/s. Variables of interest included: peak torque (ISOMPT, ISOKPT), RTD from onset to 200 milliseconds (ISOMRTD200, ISOKRTD200), and RTD from 20% to 80% of peak torque (ISOMRTD20-80, ISOKRTD20-80). Whole body kinetics and kinematics were recorded during maximal countermovement jumps (CMJ) and treadmill running (RUN). Peak knee extensor moment (PKEM) and rate of knee extensor moment (RKEM) during the takeoff and landing phases of the CMJ were computed. Stance phase PKEM (RUNPKEM) and RKEM from 20% to 80% of peak (RUNRKEM) were averaged over 15 running strides. Wilcoxon signed-ranks tests were used to assess between-limb asymmetries and compare limb symmetry indices (LSI) between ISOM and ISOK variables. Effect sizes (ES) were calculated to quantify the magnitude of the differences. A Spearman correlation was used to evaluate the associations between ISOM and ISOK variables and functional knee joint kinetics.

RESULTS: Significant between-limb differences were detected for all variables of interest ($.001<P<.004$, $0.57<ES<0.62$). ISOM and ISOK peak torque deficits were similar (ISOMPT LSI, 76.3%; ISOKPT LSI, 71.3%; $P = .463$). ISOMRTD200 LSI (57.8%) was less than ISOKRTD200 LSI (71.4%; ES, 0.4; $P = .039$) and ISOMRTD20-80 LSI (49.0%) was less than ISOKRTD20-80 LSI (67.7%; ES, 0.39; $P = .046$). CMJ PKEM and RKEM were significantly correlated with both ISOM and ISOK variables, most strongly with ISOKRTD200 ($r = 0.747$-0.913). RUNPKEM was significantly correlated with ISOMRTD20-80 ($r = 0.771$, $P = .002$), while RUNRKEM was most strongly associated with ISOMRTD20-80 ($r = 0.779$, $P = .002$), and ISOKRTD200 ($r = 0.688$, $P = .009$).

CONCLUSIONS: Quadriceps RTD was more strongly correlated with knee joint kinetics than peak strength. ISOM and ISOK RTD assessments are similarly correlated with functional knee joint kinetic asymmetries following ACLR.

CLINICAL RELEVANCE: To restore knee joint function in athletes post-ACLR, clinicians should emphasize rapid and powerful quadriceps contractions. When assessing quadriceps RTD in patients, both ISOK and ISOM contractions are viable options, but ISOM evaluation may be more discriminative than ISOK testing.

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SPL17

ACTIVATION ASYMMETRIES OF THE VASTUS LATERALIS AND VASTUS MEDIALIS ARE MORE PRONOUNCED THAN RECTUS FEMORIS 4 AND 6 MONTHS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN COLLEGIATE ATHLETES

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PURPOSE/HYPOTHESIS: Muscle morphology and neuromuscular control after anterior cruciate ligament (ACL) injury and surgery varies among the individual quadriceps muscles. Greater atrophy and altered specificity of the uniarticular vasti muscles compared to the biarticular rectus femoris (RF) has been previously reported. Quadriceps muscle specific rate of activation post ACLR has not been investigated, but has important implications for postsurgical intervention and sports performance. The purpose of this study was to analyze the activation patterns of the superficial quadriceps muscles (vastus lateralis [VL], vastus medialis [VM], and RF) in performance of maximal and rapid knee extension contractions, running, and jumping 4 and 6 months post ACLR in elite collegiate athletes.

NUMBER OF SUBJECTS: Eight Division I athletes (5 female; mean ± SD age, 21.3 ± 1.3 years; BMI, 25.0 ± 3.8 kg/m^2) 4.0 ± 1.2 (4M) and 5.9 ± 1.1 months (6M) post surgery.

MATERIALS/METHODS: Athletes completed maximal and rapid isometric knee extension efforts, countermovement jumps (CMJ) and treadmill running while surface electromyography (EMG) of the bilateral VL, RF, and VM were recorded. Rate of activation for each muscle was calculated as the root mean square values (RMS) of the EMG signal from contraction onset to 200 milliseconds during isometric efforts (ISOM-RAPID) and in 0- to 200-millisecond epochs from the initiation of the eccentric (ECC), concentric (CONC), and landing (LAND) phases of the CMJ. During running, rate of EMG rise (RUN) was averaged over 20.1 ± 2.0 strides. Isometric force control (ISOM-FC) was expressed as the coefficient of variation of the filtered RMS signal (500-millisecond window size). Differences between involved (INV) and uninvolved (UN) limbs and between measurement intervals were analyzed using a linear mixed model. Descriptive statistics, including limb symmetry indices (LSI), were calculated for each variable at each interval.

RESULTS: At 4M postop, ECC VL (LSI, 53.4%), ECC VM (LSI, 58.9%), and LAND VL (LSI, 70.4%) were significantly lower in the INV limb ($P \leq .001$), while 6M postsurgery, only ECC VM was significantly reduced (LSI, 75.2%; $P = .028$). RUN VL (LSI, 82.0%) and VM (LSI, 66.8%) were lower in INV limb 6M postop ($P < .04$). INV limb VL ISOM-FC was impaired at 4M ($P = .019$) and 6M ($P = .024$) post-ACLR while ISOM-RAPID between-limb asymmetries were found for all muscles at all intervals ($P \leq .02$). INV limb VL ISOM-RAPID and LAND VM significantly increased between measurement intervals ($P \leq .01$).

CONCLUSIONS: Collegiate athletes demonstrated impaired rate and control of quadriceps activation at 4 to 6 months post ACLR, which were more pronounced in the VL and VM than the RF.

CLINICAL RELEVANCE: As large, uniarticular knee extensors, neuromuscular function of the vasti muscles may be more impaired than the RF following joint trauma. To address specific neuromuscular deficits post ACLR, rehabilitation strategies to target VL and VM (such as NMES) are recommended to restore quadriceps function for successful return to sport.

SPL18

DOES THE 11+ CHANGE COLLEGIATE WOMEN'S SOCCER PLAYERS' CUTTING BIOMECHANICS?

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PURPOSE/HYPOTHESIS: Sudden cutting maneuvers have been identified as a component of noncontact ACL injuries in women's soccer players. Increased knee valgus and decreased knee flexion have been recognized as biomechanical elements of noncontact ACL injuries. The 11+ is a warm-up program for soccer players that emphasizes biomechanical technique, and has been shown to reduce lower extremity injury rates, including ACL injuries. However, it is unknown if the 11+ alters a player's biomechanics. Therefore, the purpose of this study was to determine whether the 11+ changed knee and hip kinematics and kinetics in collegiate women soccer players.

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

MATERIALS/METHODS: Players completed pre and postseason motion analysis of a 90° cutting task. Kinematic and kinetic data were recorded simultaneously using an 8 camera motion system and 2 embedded force plates. During the season, 1 team completed their typical warm-up, and 2 teams performed the 11+. Peak knee and hip angles and external moments of the dominant limbs were analyzed with repeated-measures ANOVAs with planned least squares comparisons. Alpha was set a priori at $P < .05$.

RESULTS: There was an interaction ($P = .04$) for hip flexion angle. The control group had a significant decrease in hip flexion angle from pre to postseason ($P < .01$) but the intervention group did not ($P = .40$). There was no difference between groups at preseason ($P = .46$), but there was postseason (control mean, 42.2°; intervention mean, 50.5°; $P < .01$). There was an interaction ($P < .01$) for hip flexion moment. The control group had a significant decrease in moment from pre to postseason ($P < .01$), but not the intervention group ($P = .11$). There was no difference between groups at preseason ($P = .37$), but there was at postseason (control mean, 0.72 Nm; intervention mean, 1.2 Nm; $P < .01$). There was a main effect (ME) of time for hip adduction moment ($P < .01$) and hip internal rotation moment ($P = .02$). For hip internal rotation angle there were MEs of time ($P < .01$) and group ($P < .01$). There was an interaction for knee flexion angle ($P = .03$). The control group had a significant decrease in knee flexion angle from preseason to postseason ($P = .02$), but not the intervention group ($P = .8$). For knee abduction angle, there were ME for time ($P < .01$) and group ($P = .02$). There were no other significant interactions or ME.

CONCLUSIONS: The 11+ may prevent decreases in hip and knee flexion angles across a soccer season, which may be protective for ACL injury. However, no changes in biomechanical measures of valgus collapse were present in collegiate women's soccer players.

CLINICAL RELEVANCE: The 11+ may be effective in addressing sagittal plane biomechanical risk factors for ACL injury, but may not adequately address frontal and transverse plane biomechanics. However, more work is needed to determine whether timing of the intervention in the athlete's development or dosage may also affect potential for biomechanical change.

SPL19

EFFECT OF KNEE RANGE OF MOTION ON RETURN TO FULL QUADRICEPS STRENGTH AT 1 YEAR FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION WITH CONTRALATERAL PATELLAR TENDON GRAFT

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PURPOSE/HYPOTHESIS: Quadriceps strength deficits are common following anterior cruciate ligament (ACL) reconstruction. Many criterion-based rehabilitation programs suggest between-limb differences should be no more than 10% before return to sport, but many patients never achieve this goal. While some suggest the underlying mechanisms for persistent quad weakness are currently unclear, range of motion (ROM) is 1 factor often overlooked. Lack of full knee extension has been shown to play a role in functional deficits such as quad weakness, but there is limited data

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looking at the long-term implications of this. The hypothesis was that patients with normal ROM at 1 year postop would have greater mean quad strength and more patients would have quad strength to within 10% of the opposite limb to those with abnormal ROM.

NUMBER OF SUBJECTS: Nine hundred seventy-eight.

MATERIALS/METHODS: From 1988 to 2012, 978 patients underwent primary ACL reconstruction with contralateral (CL) PTG and completed 1-year postoperative testing. Patients excluded from the study included those who underwent bilateral ACL reconstruction, revision ACL reconstruction, or showed radiographic evidence of osteoarthritis (OA) at the time of surgery. Using the International Knee Documentation Committee (IKDC) scoring system, patients were categorized into 2 groups based on ROM measurements: normal and abnormal, with the normal group being patients who had knee extension within 2° and knee flexion within 5° of the noninvolved knee; abnormal group was defined as lack of normal extension and/or flexion. Quad strength was evaluated using Cybex isokinetic dynamometer testing at 180°/s and 60°/s.

RESULTS: Out of 978 patients, 87 had abnormal ROM and 891 had normal ROM. The percentage of patients who had symmetrical strength within 10% between knees was 60% in patients with normal ROM versus 47.2% with abnormal ROM (P = .033) with isokinetic testing at 60°/s. When looking at mean quad strength, the normal ROM group was 105.6% versus 101.4% in the abnormal ROM group (P = .04) at 60°/s. For quad strength at 180°/s, the mean was 100.9% in the normal ROM group compared with 97.3% in the abnormal ROM group (P = .021).

CONCLUSIONS: At 1 year postoperation, patients with normal ROM had statistically significantly greater quad strength and more patients had side-to-side strength within 10% than those with abnormal ROM.

CLINICAL RELEVANCE: It is suggested that patients who do not obtain normal ROM have decreased likelihood of obtaining full quad strength at 1 year postoperation compared to those that do obtain normal ROM after ACL reconstruction.

SPL20

THE INFLUENCE OF RUNNING SURFACE ON LOWER EXTREMITY STRESS IN RECREATIONAL RUNNERS

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PURPOSE/HYPOTHESIS: Running is a popular recreational activity nationally. Runners, however, are at an elevated risk for injury because of the repetitive nature and impact of the sport. Stress fractures account for a large percentage of injuries. Stress fractures of the lower extremities affect up to 20% of runners. Running mechanics have been studied in depth and peak positive tibial acceleration and ground reaction force have shown to be associated with stress fracture. Female individuals with a history of tibial stress fracture had significantly higher vertical loading rates and tibial shock compared to a cohort without history of tibial stress fracture. Research has primarily looked at forces on a single running surface. The purpose of this study is to examine impact of the lower extremity on 3 different running surfaces: treadmill, track, and concrete.

NUMBER OF SUBJECTS: Twenty.

MATERIALS/METHODS: Participants were outfitted with commercially available wearable athletic technology on the right distal medial tibia. Participants warmed up at a self-selected pace on the treadmill for a self-selected time period. Runners completed 3 consecutive, 1-mile runs at a self-selected pace on the treadmill (TM) (Landice, Inc, Randolph, NJ), road (RD), and track (TK). The surface order was randomized for each runner. Garmin GPS (Garmin International, Olathe, KS) watch monitored pace and distance on the track and road. Runners were not permitted to use headphones during testing. The following measurements were collected via Vert (Fort Lauderdale, FL) wearable sensor data: impact count (the average accelerations registered averaging one tenth per second), average Gs, and percent stress (percentage of high versus low stress movements within a session). Participants were able to view their personal data on each surface following completion of their testing session.

RESULTS: No difference was noted between impact counts between various conditions (TM versus RD, P = .22; TM versus TK, P = .77; TK versus RD, P = .50). There was 17% lower stress as measured by average Gs (TM versus RD, P = .02; TM versus TK, P = .05) and 43% less total percent stress (RD versus TM, P = .01; TM versus TK, P = .1) on the treadmill when compared to the road and track. There was no significant difference in G force (P = .09) or percent stress (P = .89) between road and track. Although paces differed from treadmill and road (9:45 versus 9:08 minutes per mile, P = .003), as well as treadmill and track (9:45 versus 8:53, P = .003), stride length did not differ between surfaces (TM versus RD, P = .16; TM versus TK, P = .07; TK versus RD, P = .33).

CONCLUSIONS: Lower extremity percent stress and average G forces, measured by the Vert wearable technology sensor, were lower for treadmill running versus road or track running.

CLINICAL RELEVANCE: These findings suggest that initiation and progression of an interval running program, on a treadmill, may be a viable option to decrease stressful forces, on the lower extremity, that are seen during road and running.

SPL21

BASEBALL PLAYERS WITH A DIAGNOSIS OF THORACIC OUTLET SYNDROME DEMONSTRATE DEFICITS IN SHOULDER RANGE OF MOTION WHEN COMPARED TO MATCHED HEALTHY CONTROLS

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PURPOSE/HYPOTHESIS: Thoracic outlet syndrome (TOS) is becoming more recognized as a diagnosis in the throwing athlete. Currently, there is limited information on the objective profile and the development of TOS in baseball players. The purpose of this study was to compare shoulder range of motion of baseball players diagnosed with TOS to a group of healthy, matched controls.

NUMBER OF SUBJECTS: Fifty-three adolescent baseball players who were diagnosed with TOS (mean ± SD age, 17.2 ± 2.3 years; height, 180.9 ± 10.1 cm; weight, 80.0 ± 13.3 kg) were compared to 53 healthy (age, 17.2 ± 2.4 years; height, 183.9 ± 9.0 cm; weight, 83.8 ± 11.5 kg) baseball players.

MATERIALS/METHODS: Participants in the TOS group were diagnosed by a fellowship-trained, board-certified orthopaedic surgeon and enrolled into the study upon their initial visit. The healthy group was enrolled and measured prior to either the beginning of the fall or spring baseball seasons. Participants were measured for shoulder internal (IR) and external rotation (ER) range of motion (ROM) and humeral retrotorsion (HRT). All measurements were taken bilaterally and the differences (throwing arm to nonthrowing arm) were used to calculate means for glenohumeral internal rotation deficit (GIRD), glenohumeral external rotation gain (GERG), total rotational motion difference (TRMDiff), and humeral retrotorsion difference (HRTDiff). The Kerlan-Jobe Orthopaedic Clinic (KJOC) Shoulder and Elbow Questionnaire was recorded for the TOS group at time of enrollment. Group comparisons were made between the TOS and Healthy baseball players using a MANOVA and descriptive comparisons were made with independent t tests (P<.05).

RESULTS: There were no significant differences between groups for age (P = 1.0), height (P = .17), weight (P = .13), or years of experience (P = .42). The TOS group was made up of 69.8% pitchers, 22.6% infielders, 3.7% outfielders, and 3.7% catchers. Healthy participants consisted of 69.8% pitchers, 22.6% infielders, 1.9% outfielders, and 5.6% catchers. TOS had significantly less throwing arm ER (TOS, 103.4° ± 10.4°; healthy, 109.6° ± 7.5°; P = .001) and GERG (TOS, 3.0° ± 9.2°; healthy, 8.8° ± 9.2°; P = .002) than healthy. No significant differences between groups were seen for GIRD (TOS, –14.1° ± 8.5°; healthy, –12.5° ± 10.0°; P = .366) or HRTDiff (TOS, –15.5° ± 10.3°; healthy, –16.9° ± 9.3°; P = .489). TRMDiff was

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significantly greater in TOS (–11.1° ± 11.1°, $P<.001$) than healthy (–3.7° ± 9.4°). The mean duration of symptoms for TOS was 7.1 ± 10.9 months and the average KJOC was 44.9 ± 13.2.

CONCLUSIONS: Adolescent baseball players diagnosed with TOS present with shoulder ROM deficits when compared to a matched, healthy cohort. A loss of throwing arm ER appears to be the main factor behind shoulder ROM changes in the TOS group.

CLINICAL RELEVANCE: These findings provide a clinical profile for adolescent baseball players diagnosed with TOS and may help to determine an appropriate course of treatment.

SPL22

HIP AND KNEE ENERGY ABSORPTION CONTRIBUTION CHANGES WITHIN LIMBS ACROSS THE CONTINUUM OF CARE IN PARTICIPANTS UNDERGOING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: The purpose of this study was to compare within limb EAC of the hip and knee during a double limb squat (DLS) in ACL-R participants at the time points of preoperative (Pre), 12 weeks postoperative (12 weeks), and time of return to sport (RTS).

NUMBER OF SUBJECTS: Thirty participants (21 female, 9 male) with a tear of the ACL (mean ± SD age, 16.1 ± 1.7 years; height, 169.2 ± 9.8 cm; mass, 65.3 ± 11.3 kg) were enrolled at preoperative ACL-R.

MATERIALS/METHODS: Repeated measures within-subject study design. Biomechanical data of the lower extremity were collected using an 8-camera Qualisys Motion Capture System and 2 AMTI force plates while participants performed 5 consecutive DLS with a controlled velocity (60 bpm). All measurements were collected bilaterally and within limb comparisons were made across time (Pre, 12 weeks, RTS) for both the involved and uninvolved limbs. The contribution of hip and knee energy absorption (Ht·W) was calculated during the descent phase of the squat. Multiple repeated-measures ANOVA were run to examine the differences within limbs in EAC of the hip and knee during the DLS at 3 time points. Post hoc comparisons were made using a Bonferroni correction to examine hip and knee EAC differences at the 3 time points for both the involved and uninvolved limbs. Alpha level was set at $P<.05$.

RESULTS: The involved limb of ACL-R participants demonstrated significant changes in hip EAC across time ($P<.001$). Likewise, hip EAC of the uninvolved limb changed significantly at Pre, 12 weeks, and RTS ($P = .013$). At the knee, EAC of the involved ($P = .001$) limb demonstrated significant changes across time while EAC of the uninvolved limb did not show significant changes ($P = .349$). Post hoc tests revealed that involved hip EAC at 12 weeks was significantly larger than both Pre (Pre, 0.40 ± 0.13; 12 weeks, 0.49 ± 0.12; $P<.001$) and RTS (12 weeks, 0.49 ± 0.12; RTS, 0.43 ± 0.12; $P = .015$). There were no significant involved hip EAC differences between Pre and RTS ($P = .488$). For uninvolved hip EAC, RTS was significantly greater than Pre (RTS, 0.38 ± 0.11; Pre, 0.33 ± 0.09; $P = .009$) while there were no differences between 12 weeks and Pre ($P = .370$) or 12 weeks and RTS ($P = .144$). At the knee, involved limb EAC was significantly lower at 12 weeks than Pre (Pre, 0.50 ± 0.14; 12 weeks, 0.42 ± 0.13; $P = .004$) and RTS (12 weeks, 0.42 ± 0.13; RTS, 0.49 ± 0.12; $P = .004$). No differences were noted between involved knee EAC at Pre and RTS ($P = 1.0$).

CONCLUSIONS: Participants with an ACL tear demonstrate different eccentric loading strategies during a DLS at the hip and knee and within limbs across the continuum of injury (Pre, 12 weeks, RTS). While hip and knee EAC of the uninvolved limb remain fairly consistent across time, the involved limb appears to utilize a greater hip than knee EAC strategy, especially at 12 weeks.

CLINICAL RELEVANCE: The finding of altered lower extremity loading should be considered when developing treatment strategies across the ACL continuum of care.

SPL23

FACTORS ASSOCIATED WITH INITIAL INTEREST AND TREATMENT SELECTION OF PATIENTS WITH HIP PAIN

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PURPOSE/HYPOTHESIS: Rates of arthroscopic hip surgery have risen significantly, but it is unclear whether surgical management yields superior outcomes to physical therapy (PT) alone. An understanding of potential factors related to initial treatment interest versus selected treatments may better inform treatment expectations to optimize patient outcomes. The purpose of this prospective study was to compare demographics and self-reported function between individuals with hip pain who (1) were or were not initially interested in surgery or PT, and (2) whether or not they had surgery within 3 months of evaluation.

NUMBER OF SUBJECTS: Sixty-two participants (41 female; mean ± SD age, 45.5 ± 14.4 years; BMI, 28.5 ± 6.7 kg/m^2).

MATERIALS/METHODS: After initial evaluation with their surgeon, enrolled participants reported initial treatment interests (surgery, PT, or other), previous participation in PT, and completed the Hip Outcome Score-Activities of Daily Living (HOS). Treatment within 3 months of initial evaluation (surgical group, SG; nonsurgical group, NSG) was collected from electronic health records. Independent t tests were used to compare age, BMI, and HOS scores between groups: (1) interest versus no interest in PT, (2) interest versus no interest in surgery, and (3) SG versus NSG ($P\leq.05$). Fisher's exact tests were used to assess differences in sex distribution, treatment interest, and previous PT treatment between SG and NSG groups ($P\leq.05$).

RESULTS: Sixty-two patients with nonarthritic hip disease (n = 38), osteoarthritis (n = 10), greater trochanteric pain syndrome (n = 4), or other diagnoses (n = 10) were included in this study. One third of participants were interested in surgery, 18 (29.0%) were interested in PT, 14 (22.6%) were interested in both, and 9 (14.5%) were interested in other treatment. Age, BMI, sex distribution and HOS were not different between those interested or not interested in surgery ($P\geq.14$) or physical therapy ($P\geq.16$). Nearly 90% of individuals with previous PT experience were not interested in additional PT (previous PT, 10.5%; $P<.01$). Interest in surgery was not associated with whether or not individuals previously had PT ($P = .10$). None of the participants with interest in PT (0/18) underwent surgery ($P<.01$); 66.6% (14/21) with interest in surgery underwent surgery ($P<.01$).

CONCLUSIONS: Treatment interest was not associated with demographics or self-reported function in this cohort. Previous PT was negatively associated with interest in additional PT, but not interest in surgery. Treatment interest (surgery or PT) was associated with whether or not patients underwent surgery.

CLINICAL RELEVANCE: Previous participation in PT may increase interest in undergoing surgery for hip pain. Presumably, if patients seek treatment in a hip preservation clinic following PT, the PT did not yield the desired outcomes, which may be attributed to factors including anatomical variations, neuromuscular deficits, or inadequate rehabilitation. These data indicate an opportunity to reassess and refine current physical therapy intervention strategies with this patient population.

SPL24

COMPARISON OF HIP RANGE OF MOTION AND STRENGTH IN INJURED VERSUS NONINJURED ADOLESCENT BASEBALL PITCHERS

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PURPOSE/HYPOTHESIS: Overhead pitching motion is a repetitive asymmetrical activity requiring a transfer of torque from the lower extremity (LE), through the trunk, and dissipated in the upper extremity (UE). Alterations in the LE kinetic chain during a pitch may place excessive stress on the UE, which may increase injury risk. This study aimed to determine: (1) if there is a difference in hip passive range of motion (PROM) and strength in adolescent pitchers' with and without a previous history of injury, (2) if there is limb asymmetry in PROM/strength and relation to injury, and (3) if a relationship exists between age and strength.

NUMBER OF SUBJECTS: One hundred.

MATERIALS/METHODS: One hundred healthy adolescent baseball pitchers between 9 and 17 years old (mean ± SD age, 13.46 ± 2.33 years) participated in this study. Subjects had a 1-time assessment of hip PROM and strength. Hip flexion (FLEX), Extension (EXT), Internal rotation (IR), External rotation (ER), and Abduction (ABD) strength and ROM were measured in various positions. Fifty-five of the 100 subjects (13.35 ± 2.28 years) completed an online survey indicating injury history over the prior 12 months: 13 injured (I) and 42 noninjured (NI). Subjects were placed into 1 of 3 age groups: preadolescent (9-11), adolescent (11-14), and late adolescent (15-17) as well as (I) or (NI) based on reported injury history. Subjects strength was normalized based on body weight.

RESULTS: No significant differences in hip strength or PROM were found between the I and NI groups or for hip strength between the stance and stride limbs. Pitchers had a greater degree of supine hip IR ($P = .028$) and total rotation (TROT) PROM ($P = .022$) in the stance limb, and increased supine ABD ($P = .023$) and seated IR ($P = .002$) in the stride limb. The NI group had significantly greater supine TROT limb asymmetry than the I group ($P = .045$). In the NI group, 40.47% had greater than 10° of limb TROT asymmetry, whereas this was found in only 15.38% of the I group. Normalized strength decreased over time with preadolescents having significantly greater strength in hip ER, IR, FLEX, and EXT, while the adolescents had significantly more ABD strength.

CONCLUSIONS: Adolescent baseball pitchers have increased supine stance limb IR and TROT, and stride limb ABD and seated IR reflecting the demands of the pitching motion. Injured pitchers presented with decreased limb asymmetry for TROT which may lead to compensations, predisposing injury. While adaptations in the throwing shoulder have been extensively researched, exploration into the possibility that asymmetrical total rotation across both hips may be a normal adaptation is needed. Hip strength adaptations were found between age groups. As subjects' body weight increased over time, a corresponding increase in strength was not found.

CLINICAL RELEVANCE: Understanding the ROM and strength demands of the pitching motion and the adaptations that occur is important when evaluating pitchers along with the compensations that can arise due to altered pitching mechanics. Long-term strength programs may be beneficial to maintain strength proportional to body weight.

SPL25

DIFFERENCES IN INTERNATIONAL KNEE DOCUMENTATION COMMITTEE SUBJECTIVE KNEE FORM SCORES ACROSS THE REHABILITATION CONTINUUM DO NOT EXIST BETWEEN THOSE ATHLETES WITH ISOLATED ANTERIOR CRUCIATE LIGAMENT INJURIES AND THOSE WITH CONCOMITANT MENISCAL PATHOLOGY

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PURPOSE/HYPOTHESIS: The purpose of this study was to assess the differences in the International Knee Documentation Committee Subjective Knee Form (IKDC) across the rehabilitation continuum between those athletes with isolated anterior cruciate ligament (ACL-I) injuries and those with combined ACL and meniscal pathology (ACL-M).

NUMBER OF SUBJECTS: A total of 65 participants (24 no meniscal damage, 41 meniscal damage) were enrolled in the study (mean ± SD age, 16.05 ± 1.4 years; height, 1.70 ± 0.1 m; mass, 69.2 ± 17.1 kg).

MATERIALS/METHODS: Participants were enrolled into the study following initial ACL injury and completed the IKDC questionnaire at time of enrollment and again at 8 and 12 weeks following surgery, and finally at time of release for return to sport testing (RTS). Participants were divided into 2 groups; those with a primary isolated ACL injury and those who sustained a primary ACL injury in addition to either a medial or lateral meniscal injury with subsequent repair or meniscectomy. A 1-way ANOVA was used to assess for baseline differences in age, height and weight, and a chi-square analysis was completed to assess for differences in sex between the 2 groups. A 2-way repeated-measures ANOVA was run to assess for differences between the groups at the 4 time points.

RESULTS: There was no significant difference between groups in regards to age ($P = .612$), height, ($P = .588$) weight ($P = .653$), or sex ($P = .208$). There was no significant effect of group, indicating that the IKDC scores between groups were similar at each time point ($F_{1,63} = 1.85$, $P = .178$). There was a significant effect of time ($F_{2.14,134.9} = 178.36$, $P<.001$). Bonferroni post hoc analysis revealed a significant difference in IKDC between preoperative to 8 weeks ($P = .009$), 8 weeks to 12 weeks ($P<.001$), and 12 weeks to time of RTS ($P<.001$). A follow-up analysis to examine the difference between ACL-I and those participants who underwent a meniscal repair versus a meniscectomy was completed. A 1-way ANOVA with a post hoc Bonferroni correction found those participants who had undergone a meniscal repair had a significantly lower IKDC score compared to those who had undergone a meniscectomy at the 8-week ($P = .026$) and 12-week ($P = .004$) time points. No differences between those who had an ACL-I and either meniscal procedure were found at any time point.

CONCLUSIONS: IKDC scores do not significantly differ between those participants who sustain a meniscal injury and undergo a meniscal procedure at any point during the ACL rehabilitation continuum. Differences in IKDC scores are present between participants who undergo an ACL reconstruction with meniscal repair and those who undergo an ACL reconstruction with meniscectomy at the 8- and 12-week time points.

CLINICAL RELEVANCE: Clinicians should consider the significantly lower IKDC scores at the 8- and 12-week time points in those participants who undergo meniscal repairs compared to meniscectomy during the ACL-R rehabilitation process.

SPL26

CHANGES IN MEDIAL ELBOW ELASTICITY AND JOINT-SPACE GAPPING DURING MAXIMAL GRIPPING

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PURPOSE/HYPOTHESIS: Prevention of elbow injury is one of the highest priorities for baseball players. It has been shown that more than 60 repetitive pitches increase medial elbow joint space gapping, but the effect on medial elbow joint ligamentous elasticity is not known. Our hypothesis was that gripping reduces medial elbow joint space gapping, increases flexor pronator muscle stiffness, but ulnar collateral ligament (UCL) elasticity is not changed. The purpose of this study was to investigate medial elbow joint space gapping and elasticity of the UCL and flexor pronator muscle during gripping, to gain further understanding of the stabilizing mechanisms of the medial elbow joint.

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NUMBER OF SUBJECTS: Twenty-nine.
MATERIALS/METHODS: The study included 29 elbows from 29 healthy college students (mean ± SD age, 20.9 ± 0.4 years; height, 166.8 ± 7.9 cm; weight, 59.0 ± 9.6 kg). Medial elbow joint space gapping was measured using B-mode ultrasound under gravity valgus stress. Elastography was used to determine the elasticity (strain ratio) of the UCL and forearm flexor pronator muscles. These measures were carried out at rest and during maximal gripping. Paired *t* tests were used to compare medial elbow joint space gapping and elasticity of the UCL and flexor pronator muscles between rest and gripping.
RESULTS: Medial elbow joint space gapping (millimeters) during gripping was significantly less than that at rest (rest, 3.84 ± 0.79; gripping, 3.10 ± 0.62; $P<.001$). The strain ratio for the UCL during gripping was significantly more than that at rest (rest, 3.94 ± 1.92; gripping, 17.64 ± 10.97; $P<.001$). The strain ratio for the flexor pronator muscle during gripping was significantly harder than that at rest (rest, 0.35 ± 1.92; gripping, 1.72 ± 0.99; $P<.001$).
CONCLUSIONS: Medial elbow joint space gapping during maximal gripping was reduced by 19% compared to that at rest. It is suggested that muscle activity associated with gripping helps protect the medial elbow joint during gravity valgus stress. Elastography revealed that the UCL is stiffer than the flexor pronator muscle. The elastography change rate (from rest to gripping) for the UCL was 4.48 and that for the flexor pronator muscle was 4.91. Therefore, the change in elasticity increases at the same rate, suggesting that both tissues contribute to a decrease in medial elbow joint space gapping to same degree.
CLINICAL RELEVANCE: In this study, subjects did not throw, performing gripping only. The results of this study were contrary to our hypothesis and provides basic knowledge regarding medial elbow joint-space gapping and elasticity of the UCL and flexor pronator muscle. From previous research, it is clear that medial elbow joint-space gapping increases with repetitive pitching. Future studies should consider preventative methods that reduce medial elbow joint-space gapping and consequent protects to elasticity of the UCL during repetitive pitching.

SPL27

EFFECTS OF BLOOD FLOW RESTRICTION TRAINING ON ROTATOR CUFF STRENGTH

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PURPOSE/HYPOTHESIS: Blood flow restriction (BFR) training is a technique that has been used for many years in strength training facilities in order to build muscle. However, only recently has it begun to be researched and utilized in the rehabilitation process. Evidence has shown that BFR can be used to decrease atrophy, increase hypertrophy and augment strength gains from exercise. Studies have mainly looked at utilization in the lower extremity and, more specifically, looked at adaptations distal to the occlusion site. The purpose of this study was to investigate the effects of BFR training proximal to the occlusion site in the upper extremity focusing on the rotator cuff.
NUMBER OF SUBJECTS: Ten.
MATERIALS/METHODS: Subjects were randomly assigned to either the 50% arterial occlusion group or the less than 25% arterial occlusion group. The occluded side was also randomized for the right or the left arm. For testing, the subjects lied prone on a table with the arm being tested in 90° of abduction and external rotation. Three maximum effort external rotation "break test" measurements were recorded for each arm using handheld dynamometry placed on the dorsum of the wrist. The exercise protocol of prone 90°/90° shoulder external rotations was performed 2 times per week for 6 weeks with at least 48 hours between sessions. The protocol was performed on the nonoccluded side followed by the occluded side, with the proximal edge of the cuff placed at the insertion of the deltoid.
RESULTS: Neither group had statistically significant strength gains. In the 50% occluded group, average maximum strength increased from 34.8 to 39.0 lb on the occluded side (12.1%, $P = .094$), and 36.37 to 38.95 lb on the nonoccluded side (7.1%, $P = .329$). In the 25% occluded group, average maximum strength increased from 41.15 to 46.95 lb on the occluded side (14.1%, $P = .117$), and 43.65 to 44.2 lb on the nonoccluded side (1.4%, $P = .846$).
CONCLUSIONS: The pre-to-post improvement for the occluded group is clearly higher than the nonoccluded group, although nonsignificant. However, the 25% occluded group appears to have improved at the same rate as the 50% occluded group, leading us to believe that very little BFR is required to improve strength on small muscle groups such as the rotator cuff. Additional studies with larger sample sizes are needed to corroborate these preliminary findings.
CLINICAL RELEVANCE: First, the results from this study suggest that pathologies involving the rotator cuff is another area where BFR may be utilized. According to these results, we may be able to augment the effects of exercise to enhance the development of strength in the rotator cuff. Second, the results indicated that there was a greater systemic effect in the 50% occluded group as the nonoccluded side showed greater strength gains than the nonoccluded side in the less than 25% group. Third, the findings in this study suggest that we may not need to occlude the upper extremity to the recommended 50% to see enhanced strength gains. Future research should explore the rate of occlusion that minimizes risk without sacrificing results.

SPL28

RELATIONSHIP BETWEEN KERLAN-JOBE ORTHOPAEDIC CLINIC SCORES AND ELBOW RANGE OF MOTION IN BASEBALL PLAYERS WITH AN ULNAR COLLATERAL LIGAMENT TEAR

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PURPOSE/HYPOTHESIS: The primary purpose of this study was to compare Kerlan-Jobe Orthopaedic Clinic Shoulder and Elbow Scores (KJOC) and elbow flexion and extension range of motion (ROM) measures at initial visit (time of injury) and time of release from physical therapy (PT). A secondary aim was to determine if there was a relationship between KJOC scores and elbow ROM in baseball players diagnosed with an ulnar collateral ligament (UCL) tear.
NUMBER OF SUBJECTS: Forty-eight patients (mean ± SD age, 17.54 ± 2.0 years; height, 186.3 ± 5.7 cm; weight, 88.2 ± 9.0 kg) diagnosed with a UCL tear.
MATERIALS/METHODS: Testing was conducted at the participants' initial visit and again at time of release from PT. This investigation was part of a larger ongoing study examining clinical outcomes of participants with a throwing-related UCL injury across the continuum of care. Participants completed a KJOC questionnaire and were measured for elbow ROM at both time points. Elbow ROM was measured in sitting with the elbow extended or flexed at 90° of shoulder flexion. Side-to-side differences were calculated for elbow flexion (FlexDiff) and extension (ExtDiff) and used for analysis. Paired *t* tests were calculated to compare mean changes over time for KJOC and elbow ROM. Pearson product moment correlations were run to compare the relationship between KJOC scores and elbow ROM ($P<.05$).
RESULTS: Seventy-nine percent of participants underwent UCL reconstruction. At time of release from PT, the average distance thrown during the interval throwing program was 105 ft. KJOC scores were significantly less ($P<.001$) at time of injury (40.10 ± 17.69) than at time of release (77.87 ± 13.42) from physical therapy. Elbow ROM ExtDiff was significantly improved at time of release from PT when compared to initial injury (initial, −3.4° ± 5.7°; release, −1.9° ± 3.8°; $P<.001$) while there were no significant differences in elbow FlexDiff between time points (initial, −2.1° ± 1.5°; release, −1.4° ± 2.7°; $P = .12$). There were no significant correlations between KJOC scores and elbow ExtDiff or FlexDiff at either time points

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(*P*>.05). A strong positive correlation between Initial FlexDiff and ExtDiff (r = 0.713, *P*<.001) was found. In addition, there were weak correlations for Initial FlexDiff and Release FlexDiff (r = 0.344, P = .001) and ExtDiff (r = 0.358, P = .001), Initial ExtDiff and Release FlexDiff (r = 0.403, *P*<.001), and moderate correlations for Initial ExtDiff and Release ExtDiff (r = 0.561, *P*<.001) and Release FlexDiff and ExtDiff (r = 0.518, *P*<.001).

CONCLUSIONS: Although elbow ROM improves over time, it is not related to patient-reported outcome scores (KJOC) in baseball players diagnosed with a UCL tear.

CLINICAL RELEVANCE: While KJOC scores may help to explain a patient's perception of their ability to participate following an injury to the UCL, it does not appear to be associated with objective data needed for clinical decision making.

SPL29

THE EFFECT OF MECHANISM OF INJURY ON GAIT MECHANICS, TIBIOFEMORAL LOADING, AND RESPONSE TO POSTOPERATIVE RETURN-TO-SPORT TRAINING IN MALE ATHLETES AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Tibiofemoral underloading during gait early after ACLR is associated with radiographic osteoarthritis (OA) 5 years after ACLR, hence improving gait mechanics is a potential strategy to reduce OA risk. Mechanism of injury (MOI) is related to functional performance and patient reported outcomes, but the influence of MOI on walking mechanics or response to RTS training is unknown. The purpose of this study was to investigate the effects of mechanism of ACL injury on gait mechanics, tibiofemoral loading, and response to RTS training after ACLR.

NUMBER OF SUBJECTS: Thirty-four (17 contact, 17 noncontact).

MATERIALS/METHODS: This is a secondary analysis of prospectively collected data from a clinical trial. MOI was self-reported. Male athletes after primary ACLR received 10 training sessions of strength, agility, plyometric, and secondary prevention exercises. Gait mechanics were captured pre (23 ± 8 weeks) and posttraining (30 ± 8 weeks). Gait kinematics, kinetics, and electromyography data were collected during overground walking at self-selected speeds maintained (±5%) within and across sessions. Tibiofemoral joint contact forces were calculated using a validated musculoskeletal model. Variables of interest were peak knee flexion angle (pKFA) and moment (pKFM), knee adduction moment, total tibiofemoral contact force (pTCF), and medial compartment contact force (pMCCF). A 2-by-2-by-2 (time-by-MOI-by-limb) ANOVA (α = .05) was used for each variable of interest.

RESULTS: A 2-way interaction of limb by MOI was observed for pMCCF (P = .016) and pKFM (P = .015). Regardless of time, the noncontact group underloaded their involved knee (pMCCF: involved [IN], 2.5 ± 0.4 body weight [BW]; uninvolved [UN], 3.0 ± 0.4 BW; interlimb difference, −0.4 BW), while the contact group had symmetrical loading (IN, 2.7 ± 0.6 BW; UN, 2.8 ± 0.5 BW; interlimb difference, −0.1 BW). Both groups had smaller pKFM in their involved limb (contact: IN, 0.40 ± 0.14 Nm/kg·m; UN, 0.47 ± 0.14 Nm/kg·m; noncontact: IN, 0.39 ± 0.11 Nm/kg·m; UN, 0.53 ± 0.11 Nm/kg·m) but the noncontact group displayed a greater interlimb difference (contact, −0.06 Nm/kg·m; noncontact, −0.14 Nm/kg·m). Main effects of limb were observed in pMCCF, pKFM, pKFA, and pTCF with smaller values in the involved versus uninvolved knee (*P*<.01).

CONCLUSIONS: Medial tibiofemoral joint underloading before and after RTS training in the noncontact (but not the contact) group suggests male athletes who sustain noncontact ACL injuries may be at higher risk of developing early onset OA. Further follow-up and radiographic evidence is needed.

CLINICAL RELEVANCE: The disparities in joint loading among MOI groups both before and after RTS training suggest that male athletes who sustain noncontact ACL injuries may benefit more from an intervention to address gait mechanics after ACLR. Our RTS training program did not improve gait symmetry in male athletes 6 to 7 months after ACLR regardless of MOI. Future studies should focus on interventions that are specific to each MOI to improve gait symmetry.

SPL30

SECOND INJURIES AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: HOP PERFORMANCE VERSUS NONMODIFIABLE FACTORS

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PURPOSE/HYPOTHESIS: Athletes who return to sport (RTS) after an ACLR are approximately 15 times more likely to have a second injury than matched controls. Approximately 30% of those under 20 years old at their first surgery go on to have a second ACL injury, most in the first year after return to cutting/pivoting/jumping sport. Criteria for (RTS) can decrease reinjury risk by up to 84%, and limb symmetry is a common component of many RTS criteria. However, an improved LSI after ACLR does not necessarily indicate return to preoperative function and may overestimate recovery of knee function. Since most athletes do not have pre operative scores, we propose to use the Highest Score Symmetry Index (HSSI) which uses the individuals best performance on the uninvolved limb at any time point. Using the best performance may improve RTS criteria and reduce the rate of reinjury. We hypothesize that athletes who fail more hops less than 90% HSSI will have a higher rate of second injury.

NUMBER OF SUBJECTS: Sixty-seven athletes from an ongoing longitudinal RCT after ACLR.

MATERIALS/METHODS: All subjects were enrolled in a secondary prevention and return to sport program: 10 sessions of progressive balance, plyometrics and strengthening. At the time the athlete passed all RTS criteria, HSSI was calculated for 4 single-legged hop tests (single, crossover, triple, and 6-meter timed hops). We used logistic regression to predict second injury status 2 years after ACLR on number of failed hops, sex, age, and meniscus involvement (odds ratio; 95% CI).

RESULTS: There were 10 second injuries (5 ipsilateral), 9 of which were in the women (4 ipsilateral), with 29% of women and 3% of men having a second injury. The overall model was statistically significant: P = .008, number of hops failed (0.701; 0.284, 1.730), age (0.921; 0.762, 1.114), sex (0.088; 0.009, 0.889), meniscus (2.931; 0.489, 17.583). When women were analyzed separately, overall model was statistically significant P = .033, with age (0.766; 0.517, 1.136), number of fails (0.841; 0.293, 2.419), and meniscus (6.583; 0.640, 67.725).

CONCLUSIONS: While age was not a statistically significant predictor of second injury, average age at primary ACL injury was 16.0 ± 1.6 for those with a second injury but 22.3 ± 7.8 for those who did not. Only 1 participant over 18 at primary injury had a second injury. Additionally, there were no second injuries in participants who failed 3 or 4 hops based on HSSI. This may indicate that, while RTS criteria may decrease second injuries by preventing unprepared athletes from returning, high performing athletes are at high risk for second injury because they are most able to return to cutting/pivoting/jumping sports. This may indicate that in athletes who perform very well, there are very important nonmodifiable risk factors for second injury. Sex, age at primary injury, and meniscal involvement are stronger predictors of second injury than performance on hopping tests.

CLINICAL RELEVANCE: The highest risk factors for second injury are either nonmodifiable or are also part of a successful outcome. Patient education and RTS decisions should weigh these factors carefully.

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SPL31

BIOPSYCHOSOCIAL FACTORS OF FEMALE RUNNERS WITH AND WITHOUT A HISTORY OF STRESS FRACTURES

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PURPOSE/HYPOTHESIS: To identify physiological and self-identified factors related to stress fractures in female runners using mixed quantitative/qualitative methodology.

NUMBER OF SUBJECTS: Twenty-one women with stress fracture histories, and 21 women without stress fracture histories, matched for age and running distance, aged 20 to 50 years.

MATERIALS/METHODS: Physiological data included nutritional, hormonal, and bone-related histology; and hip/spine bone mineral density (BMD) and body composition using dual-energy X-ray absorptiometry (DXA). Semi-structured qualitative interviews were conducted to gain insight into self-perceived contributing factors. For women without stress fracture histories, interviews gathered thoughts on factors important for running related bone health.

RESULTS: Data are complete for 21 participants with data collection to end by June 30, 2018. Thus results are preliminary. Compared to women without fractures, women with stress fracture histories had increased bone formation markers (10.1 ± 2.8 versus 8.5 ± 2.5 mcg/L) but similar bone resorption markers. Parathyroid hormones levels were increased (35.8 ± 13.3 versus 31.7 ± 6.6 pg/mL). Calcium, vitamin D, and albumin levels were similar between groups. Of note, several premenopausal women in each group had estradiol levels typical of postmenopausal women. Women with stress fracture histories had lower body mass indexes (21.9 ± 2.7 versus 23.6 ± 3.3), lower *z* scores for spine (−0.738 ± 0.831 versus −0.075 ± 1.311) and hip BMD (−0.246 ± 0.769 versus 0.113 ± 0.557), and lower age-matched fat content percentiles (17.3 ± 23.8 versus 25.6 ± 18.5). Ongoing iterative analysis of qualitative data revealed differences in awareness between groups. Within a primary emergent theme of awareness, participants who had not had a stress fracture demonstrated (1) knowledge and observation of effective nutrition strategies, (2) ongoing attention to wellness, and (3) use of strategies to avoid and minimize musculoskeletal injury that were not described by their counterparts who had sustained a stress fracture.

CONCLUSIONS: Preliminary results demonstrate trends for differences between groups across many factors. Women with stress fracture histories were leaner with decreased BMD and altered bone related biomarkers. Some of these differences have been shown to be important in risk for osteoporotic fractures in postmenopausal women. Yet, these tests are not routinely performed in active premenopausal women. Differences were seen in awareness of preventative strategies for women who sustained fractures. Thus prevention strategies should include medical screening/management and education on modifiable factors related to wellness.

CLINICAL RELEVANCE: Research has shown that twice as many women experience running related stress fractures compared to men, and these risks are multifactorial. The literature is lacking in regard to best practice for preventing and treating stress fractures. Also, few studies seek the opinion and experiences of women who sustain fractures. Identification of clusters of risk factors is needed to allow women to remain active through running while minimizing fracture risk.

SPL32

THE INFLUENCE OF ANTERIOR KNEE PAIN ON FUNCTION AND TIMING OF RETURN TO PLAY FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION WITH PATELLAR TENDON AUTOGRAFT

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PURPOSE/HYPOTHESIS: Postoperative anterior knee pain is a prevalent, debilitating, and poorly defined condition frequently associated with patellar tendon autograft (PTA) used during anterior cruciate ligament reconstruction (ACL-R). Unfortunately, there is little available evidence describing the impact that this condition has on function and time of return-to-play (RTP). Therefore, the purpose of this study was to determine whether functional differences exist for patients with AKP compared to matched controls following ACL-R with PTA.

NUMBER OF SUBJECTS: A matched case-control study of 60 athletes (AKP, n = 30; control, n = 30) following ACL-R with PTA from a single surgeon was conducted from 2014 to 2017. Athletes in the AKP group were medically diagnosed and treated postoperatively for AKP. Patient matching variables included age, sex, race, prior level of function (MARX score) and surgical profile. The mean age of our sample was 18.9 ± 4.6 with 66% being female and an average MARX score of 13.6 ± 3.2.

MATERIALS/METHODS: Knee function was assessed at 3 months, 6 months, and RTP using the IKDC subjective survey, Y Balance anterior reach test, and knee extension peak torque. Knee extension peak torque was assessed isometrically at 3 months, and isokinetically (60°/s, 180°/s, and 300°/s) at 6 months and RTP. Limb symmetry indices were calculated for Y Balance anterior reach (longest reach [cm]), and knee extensor peak torque. Time from surgery to RTP was recorded in months as the time to meet objective discharge criteria. Baseline demographics and the isometric peak torque were assed using an independent *t* test. Repeated measured ANOVA were used to compare subjective IKDC scores, isokinetic peak torque, and Y Balance anterior reach. Statistical significance was set at $\alpha = .05$.

RESULTS: The AKP group demonstrated a longer time from surgery to RTP when compared to the control group (9.5 ± 3.8 months versus 8.0 ± 2.2 months, $P<.001$). Isometric peak torque could not be assessed at 3 months as only 6 patients within the AKP group were able to complete the assessment secondary to symptoms. Subjective IKDC scores were similar at 3 months ($P = .569$), and lower at 6 months ($P = .023$), and RTP ($P = .015$) for the AKP group. No differences were observed for y-balance anterior reach and isokinetic peak torque between groups at 6 months and RTP ($P>.05$).

CONCLUSIONS: Based on our data, the development of AKP after ACL-R with PTA appears to delay the time from surgery to RTP, and significantly reduce subjective function at 6 months and RTP when matching for patient demographics. No differences existed between groups for the assessment of isokinetic peak torque and Y Balance anterior at 6 months and RTP, however, the AKP group was unable to participate in the isometric testing protocol at 3 months due to symptoms.

CLINICAL RELEVANCE: Considering the negative effects, clinicians should explore ways of mitigating the development of AKP after ACL-R with PTA. Additional efforts should be devoted to finding effective management strategies of AKP when encountered within the postoperative setting.

SPL33

RELATIONSHIPS BETWEEN ISOMETRIC AND FUNCTIONAL MEASUREMENTS OF RAPID QUADRICEPS ACTIVATION IN DIVISION I COLLEGIATE ATHLETES 7 MONTHS POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Resolution of neuromuscular asymmetries following anterior cruciate ligament reconstruction (ACLR) is imperative for successful return to sport and to maximize athletic performance. We have recently shown that athletes post-ACLR run and jump with reduced involved limb quadriceps rate of activation (RA). Isometric testing of the

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knee extensors may be a surrogate for quadriceps RA during functional tasks. Thus, the purpose of this study was to assess the relationships between the quadriceps RA across isometric and functional tasks in elite athletes preparing for return to sport post-ACLR.
NUMBER OF SUBJECTS: Eleven Division I athletes (mean ± SD age, 21.0 ± 1.3 years; BMI, 26.1 ± 4.2 kg/m^2; 6 female) 6.9 ± 2.7 months post ACLR.
MATERIALS/METHODS: Athletes completed maximal countermovement jumps (CMJ), treadmill running at fastest comfortable speed, and maximal, rapid voluntary isometric knee extension contractions at 90° of knee flexion. Surface electromyography (EMG) of the 3 superficial quadriceps muscles (QUAD) were recorded. RA was calculated by utilizing the root mean square (RMS) values of the EMG signal in 0- to 100-millisecond epochs from the initiation of the eccentric (ECCRA), concentric (CONCRA), and landing (LANDRA) phases of the CMJ. During running, rate of EMG rise (RUNRA) was averaged over 19.6 ± 2.1 strides by taking the slope from 20% to 80% of the activation peak. Isometric RA was calculated as the RMS of the EMG signal from 0 to 100 milliseconds (ISOM0-100) and 100 to 200 milliseconds (ISOM100-200) after contraction onset. Wilcoxon Signed-Ranks tests were utilized to evaluate limb asymmetries in QUAD RA. Spearman's Rank correlations were used to determine the associations between involved limb QUAD RA during running, jumping, and isometric tasks.
RESULTS: Task specific involved-uninvolved limb deficits in QUAD RA were 50.6% ISOM0-100, 47.4% ISOM100-200, 33.8% RUNRA, 41.1% ECCRA, and 21.8% CONCRA (all, $P<.05$). No asymmetry was observed for LANDRA. ECCRA was significantly correlated with ISOM100-200 (r = 0.664, P = .026) and CONCRA was significantly correlated with RUNRA (r = 0.627, P = .039). No other statistically significant correlations between involved-limb running, jumping, and isometric QUAD RA were observed.
CONCLUSIONS: QUAD RA asymmetries are apparent during isometric and functional tasks 7 months post ACLR in collegiate athletes, with isometric efforts representing the greatest limb-to-limb deficits. Running and jumping are unique motor skills requiring task specific coordination of multiple joints, muscles, and sensorimotor systems, which may contribute to the lack of significant correlations in QUAD RA across tasks.
CLINICAL RELEVANCE: QUAD RA deficits persist across multiple isolated and functional tasks, which may inhibit successful return to sport in elite level athletes. To mitigate asymmetries, QUAD RA should be trained both in isolation and during functional tasks as gains made in 1 task may not carry over to others. Effective task-specific strategies to improve QUAD RA need to be further defined.

SPL34

MODULATING QUADRICEPS CORTICAL EXCITABILITY USING PRINCIPLES OF OPERANT CONDITIONING AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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BACKGROUND AND PURPOSE: Persistent quadriceps weakness and activation failure are common in individuals with anterior cruciate ligament (ACL) reconstruction. A growing body of evidence indicates that this chronic quadriceps dysfunction could be partly mediated due to reduced corticospinal excitability. However, current rehabilitation approaches do not directly target corticospinal deficits, which may be critical for restoring optimal clinical outcomes after the surgery. The purpose of this case study was to test the feasibility of a novel transcranial magnetic stimulation (TMS)-based operant conditioning paradigm to improve corticospinal excitability and quadriceps function after ACL reconstruction.
CASE DESCRIPTION: A 24-year-old man with an ACL reconstruction (6 months post surgery) trained for 20 sessions (2 to 3 times per week for 8 weeks) to upregulate his TMS-induced motor evoked potential (MEP) torque of the quadriceps muscles using operant conditioning principles. Quadriceps MEPs were evoked when the participant performed a small background contraction (5% of maximum) of the knee extensor muscles. During each training session, 20 control MEPs were first measured where the participant received no feedback of their MEP size. The participant then performed 225 conditioning trials (3 blocks by 75 trials) where he was encouraged to increase the quadriceps MEP, and received immediate feedback on whether MEP size was above the criterion value established from the control trials (ie, whether the trial was a success). The participant was encouraged to maintain a success rate of 60% or greater throughout the training. Quadriceps strength, voluntary activation, motor cortical excitability, and patient-reported knee outcomes were evaluated before and after the intervention.
OUTCOMES: The participant was able to successfully up-condition the MEPs and gradually increase his cortical excitability of the quadriceps muscles over the 20 training sessions. Upon completion of training, the control and conditioned responses increased by about 400% and 500%, respectively. Examining the pre/post MEP recruitment curves indicated substantial increase in motor cortical excitability with training (84.7%). These changes were paralleled by improvements in knee extensor strength (12.9%) and voluntary quadriceps muscle activation (13.6%) of the reconstructed leg. Improvements in limb symmetry indices (strength, 77%-87%; voluntary activation, 86%-97.2%), and patient-reported knee outcomes (KOOS average, 72.4-98.6) were also observed after the training.
DISCUSSION: This study demonstrates, for the first time, that operant conditioning of motor evoked responses is a feasible approach to facilitate motor cortical excitability and improve quadriceps function after ACL reconstruction. Further testing with a larger cohort of ACL reconstructed individuals is necessary to verify the efficacy of operant conditioning of corticospinal pathways for ACL rehabilitation.

SPL35

LANDING MECHANICS AT RETURN TO SPORT DIFFER IN FUNCTIONALLY RECOVERED ATHLETES 2 YEARS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Previous work indicates altered landing strategies are common at the time of return-to-sport (RTS) in young athletes post anterior cruciate ligament reconstruction (ACLR). After ACLR, the Knee injury and Osteoarthritis Outcome Score (KOOS) is widely used to evaluate knee-related functional outcomes. National registry data has established KOOS cutoff scores indicating functional recovery (FR) at 2 years post ACLR. It is unknown if landing strategies post ACLR are associated with longitudinal KOOS FR status. This study tested the hypothesis that RTS landing mechanics would be altered in young athletes who do not achieve 2-year FR compared to those who do achieve 2-year FR.
NUMBER OF SUBJECTS: Fifty-nine athletes (78% female; mean ± SD age, 17.8 ± 2.9 years at RTS) after primary, unilateral ACLR.
MATERIALS/METHODS: At RTS, 3-D motion analysis data were collected during the landing phase of a single-leg (SL) drop task. Biomechanical variables

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included involved limb peak vertical ground reaction force (vGRF) (N/kg), peak total support moment (TSM) (Nm/kg), peak internal knee extension moment (KEM) (Nm/kg), peak knee flexion angle (KFA) (degrees) and knee flexion excursion (EXC) (degrees) from initial contact to peak flexion. Contributions (percent) of the hip, knee and ankle to the TSM were also evaluated. At 2 years post RTS, the same cohort completed the KOOS and FR groups (FR-yes/FR-no) were created based on the previously reported cutoffs for the KOOS-Sport and KOOS-Quality of Life (QOL) subscales (QOL greater than 81, Sport greater than 80), as these are reported to be the most important to patients. Independent samples *t* tests evaluated differences in RTS landing mechanics between the 2-year FR-yes and FR-no groups ($\alpha = .05$).

RESULTS: At 2 years post RTS, 20% of the cohort (n = 12) was classified as Sport FR-no and 34% (n = 20) was classified as QOL FR-no. For the Sport FR groups, the Sport FR-no group had lower TSM (5.3 versus 5.8, $P = .025$), KEM (1.7 versus 2.3, $P = .002$), KFA (46.4 versus 55.7, $P = .007$) and EXC (39.7 versus 46.3, $P = .043$) on the involved limb compared to the Sport FR-yes group. The contribution of the knee to the TSM was lower (30.8% versus 38.4%, $P = .005$) and the contribution of the ankle to the TSM was higher (35.2% versus 29.5%, $P = .009$) in the Sport FR-no group compared to the Sport FR-yes group. For the QOL FR groups, the QOL FR-no group had lower KEM (1.9 versus 2.3, $P = .050$), KFA (49.4 versus 56.4, $P = .024$) and EXC (40.1 versus 47.4, $P = .007$) on the involved limb compared to the QOL FR-yes group. There were no differences in vGRF ($P > .05$).

CONCLUSIONS: Young athletes after ACLR not functionally-recovered at 2 years post RTS demonstrated a knee loading-avoidance SL landing strategy at the time of RTS compared to those who were functionally recovered at 2 years post RTS.

CLINICAL RELEVANCE: These findings suggest the potential importance of optimizing movement patterns prior to RTS to promote better longitudinal knee-related function after ACLR. Further investigation of landing strategies and potential impact on long-term function and joint health is warranted.

SPL36

INCREASE IN JOINT LOADING DURING WALKING AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IS RELATED TO EARLY KNEE DEGENERATION

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PURPOSE/HYPOTHESIS: Gait mechanics are implicated in the pathogenesis of early osteoarthritis (OA) after ACL reconstruction (ACL-R). However previous studies have provided conflicting findings on association of knee loading with OA. The objective was to investigate the association of change in knee loading from before ACL-R to 6 months and 1 year after ACL-R with increase in MRI-assessed joint degeneration over 1 to 3 years after ACL-R. We hypothesized that increases in knee loading would be associated with early joint degeneration in individuals with ACL-R.

NUMBER OF SUBJECTS: ACL-R (n = 32), control (n = 14).

MATERIALS/METHODS: Participants with ACL-R (n = 32) underwent MRI before surgery, and 6 months (6M), 1 year (1Y), and 3 years after surgery (3Y); walking gait analyses were completed before, and 6M and 1Y after surgery. Uninjured control participants (n = 14) underwent gait analyses at the same time as 1Y for ACL-R group. ACL-R participants were categorized into early progression of degeneration (progressors) and nonprogressor groups based on worsening of tibiofemoral cartilage, meniscus, or bone marrow lesion (BML) MRI scores from 1Y to 3Y after ACL-R. Changes in knee loading (knee adduction moment impulse [KAM impulse], knee flexion moment impulse [KFM impulse] and vertical ground reaction force impulse [vGRF impulse]) were compared between the progressor and nonprogressor groups from before surgery to 6M and 1Y after surgery. Differences in knee loading were also compared between the progressor, nonprogressor, and control groups 1Y after surgery.

RESULTS: Of the 32 participants, 10 showed progression over 1Y to 3Y after ACL-R (cartilage, 9/32; meniscus, 2/32; BML, 8/32). Proportion of individuals with lesions after the injury and those with worsening lesions from before to 6M after surgery were not significantly different between progressor and nonprogressor groups. Greater proportion of individuals in progressor group had worsening lesions from 6M to 1Y after surgery. Change in gait mechanics from before surgery to 6M after surgery was not significantly different between the groups. From 6M to 1Y after surgery, the progressor group had a greater increase in KAM impulse ($P = .014$) and vGRF impulse ($P = .016$) compared to the nonprogressor group. The differences between the groups for KFM impulse were not significant. The differences in KAM impulse and KFM impulse were not significant between the 2 ACL-R groups and uninjured controls at 1Y after ACL-R. The progressor group walked with greater vGRF impulse compared to the control group at 1Y after ACL-R ($P = .029$).

CONCLUSIONS: Individuals with ACL-R who show an increase in knee loading during walking from 6M to 1Y after ACL-R develop early knee degeneration. The period form 6M to 1Y after ACL-R is usually when athletes return to play. Our findings clarify the role of gait mechanics in pathogenesis of PTOA following ACL-R.

CLINICAL RELEVANCE: Future research should investigate rehabilitation strategies that could mitigate the increase in knee loading from 6M to 1Y after ACL-R.

SPL37

PREDICTING ELBOW JOINT LOADING IN YOUTH BASEBALL PITCHERS USING SLOT-ANGLE KINEMATICS

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PURPOSE/HYPOTHESIS: Pitching related elbow injuries, which were once only seen in adults, are becoming more common in youth players. Upper body (ie, slot angle) kinematics during the delivery phase of the pitch are often purported to influence elbow joint loading. The purpose of this study was to use a time series approach and use various upper body kinematic variables to predict elbow joint loading, and assess the association between slot-angle kinematics and the potential for elbow injury risk. We hypothesized that slot angle kinematics would be correlated with elbow valgus joint moment.

NUMBER OF SUBJECTS: Twenty-four youth baseball pitchers (mean ± SD age, 11 ± 1 years; height, 1.55 ± 0.11 m; weight, 45.5 ± 11.9 kg).

MATERIALS/METHODS: Data collection occurred in a laboratory setting with a 14-camera motion capture system and a pitching mound instrumented with 2 force plates. Reflective markers were applied over bony landmarks and marker clusters were placed on segments of the upper body. A static trial was collected in order to calculate joint centers, and a dynamic calibration trial was used to calculate the functional joint center of the shoulder. Calibration markers were then removed, and only marker clusters remained attached as dynamic pitching trials were performed. Each participant was allowed to warm up before data collection. They then pitched 15 fastballs at a strike zone 46 ft away. Kinematic (250 Hz) and kinetic

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(1250 Hz) data were collected, and pitch velocities were monitored with a radar gun. The 5 fastest strikes were used for analysis. Joint kinematics and kinetics were calculated for the time period from maximum knee height to ball release. The discrete peak external net elbow valgus joint moment was extracted along with the kinematic time series data for elbow flexion/extension, shoulder elevation, shoulder plane, shoulder internal/external rotation, torso flexion/extension, torso tilt, and torso rotation. The discrete peak elbow valgus moment of each pitch was then predicted from the kinematic time-series data through a statistical parametric mapping (SPM) regression approach. Separate SPM regression models were built for each kinematic time series variable.

RESULTS: None of the SPM regression models were able to demonstrate a correlation between the kinematic time-series and the peak elbow external valgus moment.

CONCLUSIONS: Although other studies previously found that upper body kinematics are related to elbow joint loading, all of them have used only discrete kinematic data points. The current results, however, show that when the entire movement sequence of the pitch is considered upper body kinematics are not related to elbow joint loading in little league players.

CLINICAL RELEVANCE: The movement mechanics used by little league players to deliver fastball pitches do not seem to impact the overall load placed on the elbow. Therefore, assessing slot angle kinematics does not appear warranted when evaluating elbow injury risk in youth baseball players.

SPL38

SINGLE-LEG LONG HOP DISTANCE, STRENGTH, AND LANDING MECHANICS SYMMETRY FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN ADOLESCENT ATHLETES

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PURPOSE/HYPOTHESIS: To evaluate whether symmetry during isokinetic strength testing and hop distance of the single leg, long hop (SLLH) test, are associated with symmetry in sagittal plane kinematics and kinetics during return to sport (RTS) testing of adolescent athletes after anterior cruciate ligament reconstruction (ACLR).

NUMBER OF SUBJECTS: Thirty adolescent athletes (mean ± SD age, 15.5 ± 1.5 years; 10 female).

MATERIALS/METHODS: Motion analysis (VICON Motion Systems, Inc., Los Angeles, CA) and force plate (Advanced Mechanical Technology, Inc, Watertown, MA) data were collected during the RTS testing. The limb symmetry index (LSI = [ACLR limb/uninjured limb] × 100) was calculated for the hop distance, peak knee flexion angle, peak knee extensor moment, and peak knee power absorption during the loading phase for the maximum distance trial of the SLLH. Concentric quadriceps strength symmetry was derived from the peak torque data collected during maximum effort knee extension/flexion at 60°/s, 180°/s, and 300°/s on a HUMAC isokinetic dynamometer (CSMI USA, Stoughton, MA). Pearson product moment correlations were used to determine if (1) symmetrical hop distance was associated with symmetrical sagittal plane kinematics and kinetics and (2) to determine if symmetry in quadriceps torque was associated with symmetrical hop distance and symmetrical sagittal plane kinematics and kinetics.

RESULTS: Symmetry of hop distance (93.5% ± 6.9%) was positively associated with peak knee flexion angle symmetry (93.1% ± 15.5%, $r = 0.475$, $P = .008$). However, no other associations between the hop distance symmetry and peak knee extensor moment symmetry (92.0% ± 32.6%, $r = 0.272$, $P = .146$), peak knee power absorption symmetry (86.4% ± 42.6%, $r = 0.008$, $P = .967$), or quadriceps strength symmetry (60°/s: 93.5% ± 13.5%, $r = 0.011$, $P = .552$; 180°/s: 92.5% ± 8.7%, $r = -0.105$, $P = .581$ and 300°/s: 93.1% ± 12.2%, $r = 0.006$, $P = .975$) were identified. No additional associations between quadriceps strength symmetry and peak knee flexion angle symmetry (60°/s: $r = 0.274$, $P = .142$; 180°/s: $r = -0.002$, $P = .991$ and 300°/s: $r = 0.278$, $P = .137$), peak knee extensor moment symmetry (60°/s: $r = -0.273$, $P = .144$; 180 °/s: $r = -0.23$, $P = .142$ and 300°/s: $r = -0.080$, $P = .674$) and peak knee power absorption symmetry (60°/s: $r = 0.318$, $P = .087$; 180°/s: $r = 0.15$, $P = .429$ and 300°/s: $r = 0.088$, $P = .644$) were found.

CONCLUSIONS: Hop distance of the SLLH was only associated with peak knee flexion angle. Hop distance symmetry was not associated with symmetry of knee kinetic measures during the loading phase, suggesting assessing knee kinetics may aid in return to sport decision making.

CLINICAL RELEVANCE: Asymmetrical loading mechanics may put an athlete at risk for secondary ACL injury. Results of this study suggest factors other than symmetrical concentric strength and hop distance contribute to knee loading symmetry. Further research is needed to investigate factors such as eccentric interventions and tests to assess an athlete's ability to load the knee.

SPL39

CONCOMITANT INJURY AT THE TIME OF ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IMPACTS KNEE FUNCTION 2 YEARS AFTER RETURN TO SPORTS

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PURPOSE/HYPOTHESIS: Concomitant meniscal (MEN) or articular cartilage (AC) pathology at the time of anterior cruciate ligament (ACL) injury may negatively affect outcomes following ACL reconstruction (ACLR). It is unknown if these concomitant pathologies affect knee function in young, active patients. The purpose of this study was to test the hypothesis that concomitant pathology at the time of ACL injury in young, athletes would result in poorer patient-reported and performance-based function at the time of return to sport (RTS) and 2 years post RTS.

NUMBER OF SUBJECTS: Eighty-six athletes after primary, unilateral ACLR were evaluated at time of RTS (70% female; mean ± SD age, 17.0 ± 2.2 years). A subset of 30 athletes were evaluated at 2 years post-RTS (77% female; age, 19.3 ± 2.3 years).

MATERIALS/METHODS: Presence of concomitant MEN or AC pathology were identified via preoperative magnetic resonance images (MRI) or operative note. Subjects were grouped as: ACL only, ACL+MENorAC, or ACL+MEN+AC. At RTS and 2 year post-RTS, all subjects completed the Knee injury and Osteoarthritis Outcome Score (KOOS) and single-leg hop tests: single (SH), triple (TrH), crossover (CH) for distance and 6-m timed hop (TiH). Limb symmetry indices (LSI) were calculated. Group differences were evaluated with 1-way ANOVA (post hoc testing as appropriate) at RTS and independent-samples t tests at 2 years post RTS ($\alpha \leq .05$).

RESULTS: Of the entire cohort, 81% had at least 1 concomitant injury, with no demographic differences among ACL only (n = 21), ACL+MENorAC (n = 49) and ACL+MEN+AC (n = 16, $P > .05$). There were no differences among the groups on RTS KOOS subscales ($P = .056$-$.50$), SH LSI ($P = .58$), or TiH LSI ($P = .31$). TrH ($P = .037$) and CH LSI ($P = .049$) were different among groups, but post hoc tests were not significant ($P > .05$). Of the 2-year post-RTS cohort, 83% had at least 1 concomitant injury

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(ACL+MENorAC, n = 15; ACL+MEN+AC, n = 10). The ACL-only group (n = 5) was removed from analysis due to small sample size. There were no demographic differences between ACL+MENorAC and ACL+MEN+AC groups (P>.05). The ACL+MEN+AC group had lower 2-year KOOS subscales compared to the ACL+MENorAC for pain (93 versus 99, respectively; P = .02), symptoms (83 versus 95, P = .04), activities of daily living (ADL) (96 versus 100, P = .05), and quality of life (QOL) (75 versus 95, P = .02) Hop test LSIs were not different.

CONCLUSIONS: The presence of concomitant MEN or AC pathology did not affect function at RTS. Those with both MEN and AC pathology had lower KOOS pain, symptoms, ADL and QOL subscales compared to those with only MEN or AC pathology at 2 years post RTS.

CLINICAL RELEVANCE: The presence of MEN and AC pathology at the time of ACL injury may be predictive of poorer function at 2 years post RTS, given that pain, symptoms, and QOL exceeded clinically meaningful differences. This may indicate signs of early degeneration in those with concomitant MEN and AC pathology, suggesting longer postoperative surveillance may be appropriate. Future work will assess imaging markers of early joint degeneration and movement mechanics in these patients.

SPL40

CHANGES IN HIP MUSCLE STRENGTH OVER THE COURSE OF RECOVERY FROM AN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: IMPLICATIONS FOR RUNNING MECHANICS

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PURPOSE/HYPOTHESIS: Hip muscle strength is an important risk factor of a second injury after anterior cruciate ligament reconstruction (ACLR). Little is known about hip muscle improvements over the course of physical therapy. Furthermore, whether improvements in hip muscle strength is related to running mechanics following an ACLR is not well defined. Thus, the purpose of this study was to assess if hip strength (isometric abduction, external rotation, extension, and a single-leg bridge test) improved between 3 and 6 months after ACLR. We also sought to determine if hip strength was associated with hip internal rotation kinematics during running 6 months after ACLR.

NUMBER OF SUBJECTS: Twenty-five subjects (13 male; mean ± SD age, 18.0 ± 3.1 years; 24 patellar tendon graft).

MATERIALS/METHODS: Three trials of hip abduction (AB), external rotation (ER), and extension (EXT) strength were recorded using previously published techniques using stabilization straps. The single-leg bridge (SLBridge) was performed hook-lying with shoulders flexed to 90°. Subjects were cued to lift their hips and extend 1 leg, keeping their pelvis level. Time was stopped when the subject could no longer hold the test position. At 6 months, subjects repeated the muscle strength assessment as well as completed an instrumented running gait analysis. Peak hip internal rotation angles were calculated and averaged across 5 trials. The average muscle strength at 3 and 6 months was assessed with a paired t test. The relationship of hip muscle strength at 6 months to running mechanics was evaluated with a Pearson product-moment correlation coefficient.

RESULTS: There were significant improvements in hip AB (3 months, 6 months) (13.76 ± 4.13 N/m and 16.04 ± 4.44 N/m, P<.01), EXT (9.33 ± 4.87 N/m and 10.79 ± 3.64 N/m, P = .02), and ER (5.44 ± 2.92 N/m and 6.92 ± 3.10 N/m, P<.01) strength. No improvements were found in SLBridge time between the 3 and 6 months (43.42 ± 36.81 seconds and 39.62 ± 20.00 seconds, P = .53). At 6 months, only hip ER strength remained significantly impaired (ACLR, 6.92 ± 3.10 N/m; uninvolved, 7.74 ± 3.10 N/m; P = .01). Significant correlations were found between hip internal rotation angle and Hip ER (r = −0.43, P = .034) and EXT (r = −0.46, P = .020). No significant relationships were found for the remaining variables.

CONCLUSIONS: While hip strength improved from 3 to 6 months, there continued to be significant differences in ER strength between limbs. Hip ER is important for hop test performance and has been linked to ACL retear risk. Although SLBridge times did not improve between the 2 time points, there were no side to side differences at 6 months. Both Hip ER and EXT were associated with greater hip internal rotation while running. Poor hip transverse plane control has also been linked to ACL retear risk.

CLINICAL RELEVANCE: The findings of this study indicate that clinicians should place greater emphasis on improving hip ER and EXT strength prior to returning athletes to running and returning to sport.

SPL41

HIP AND TRUNK EXCURSION DURING SINGLE-LEG HOP LANDING PREDICTS SECOND ANTERIOR CRUCIATE LIGAMENT INJURY RISK

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PURPOSE/HYPOTHESIS: The incidence of second ACL injury after anterior cruciate ligament reconstruction (ACLR) is greater than 30% in young athletes. Single-leg (SL) hop testing is widely used as part of return-to-sport (RTS) testing following ACLR. Objective assessment of SL hop distance is used to measure performance, however the association between altered movement patterns during the SL hop and second ACL injury risk is unknown. The purpose of this study was to quantify altered joint movement patterns during SL hop landing and determine their association with future ACL injury risk. The tested hypothesis was that altered kinematics at the knee, hip, and trunk during the landing phase of the SL hop would be associated with subsequent ACL injury risk.

NUMBER OF SUBJECTS: Eighty young (mean ± SD age, 16.9 ± 3.2 years) individuals (53 female, 27 male) who underwent ACLR, completed rehabilitation, and were cleared to RTS (time from ACLR to RTS, 7.2 ± 2.1 months) were included.

MATERIALS/METHODS: At the time of RTS, each participant performed a SL hop for distance test. Three-dimensional motion analysis was used to assess trunk, hip, knee, and ankle angles and excursion during the landing phase of the SL hop. Participants were then followed for 24 months for the occurrence of a second ACL injury. One-way ANOVA and logistic regression were used to identify group differences and predictors, respectively, of second ACL injury.

RESULTS: Fifteen participants (11 female) sustained a second ACL injury within 24 months of release to RTS. No difference in age, height, or weight were observed between second injury participants and those who did not suffer a second injury (P>.05). During the SL hop test, there were no group differences in distance hopped (159.4 ± 21.0 cm versus 157.4 ± 24.7 cm, P = .775), but participants who sustained a second ACL injury demonstrated increased sagittal plane hip excursion (27.2° ± 11.8° versus 17.1° ± 7.6°, P<.001) and increased frontal plane trunk excursion (17.0° ± 5.7° versus 12.5° ± 4.6°, P = .002) during landing. No between group differences in sagittal or frontal plane knee kinematics were observed during landing (P>.05). Univariate logistic regression identified that every 10° increase in hip flexion excursion during landing was associated with 3 times the odds of second ACL injury (OR = 3.03; 95% CI: 2.36, 3.70), and every 10° increase in lateral trunk excursion during landing was associated with 6 times the odds of second ACL injury (OR = 6.05; 95% CI: 4.78, 7.32).

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CONCLUSIONS: Participants who sustained second ACL injury within 24 months of RTS demonstrated increased sagittal plane hip excursion and frontal plane trunk excursion during the landing phase of a SL hop for distance despite similar functional performance.
CLINICAL RELEVANCE: In a population of young athletes after ACLR, trunk and hip landing kinematics, rather than distance hopped, may better identify athletes at risk for future ACL injury. Rehabilitation should focus on evaluating and improving landing kinematics, in addition to functional performance on SL hop measures, as a potential method to reduce second injury risk and improve outcomes in this population.

SPL42

SHOULDER AND ELBOW INJURIES IN NCAA BASEBALL: AN EPIDEMIOLOGICAL STUDY OF 2004-2014

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PURPOSE/HYPOTHESIS: Shoulder and elbow injuries have a dramatic impact on participation at all levels of baseball. Recent epidemiological studies at high school and professional levels have targeted shoulder injuries (SI) and elbow injuries (EI). We are aware of no research that analyzed SI and EI among college baseball student-athletes (SAs). Therefore, the purpose is to describe the SI and EI injury rates and characteristics among college baseball SAs.
NUMBER OF SUBJECTS: Four hundred sixty-four SI, 281 EI.
MATERIALS/METHODS: This is a descriptive analysis of the NCAA Injury Surveillance System (ISS). Participating colleges were volunteers from division I, II, and III. Data were collected on SAs who reported a SI or EI and missed at least 1 day. Injury rates (IRs) and rate ratios (RR) compare the incidence within the levels of: division, event type, and time of season. Descriptive analysis compared the frequency of occurrence within the levels of: mechanism, event segment, recurrence, injury type, academic year, player position, and injury outcome.
RESULTS: During the 2004-2014 academic years, the SI IR was 4.02 per 10 000 athlete-exposures (AEs) with a national estimate of 11,575 SI. DI S-As were more likely to sustain a SI than those playing in DII or DIII. SI were 81% more likely to occur during competition, and the majority occurred during innings 4 to 6 and innings 7 to 9. Pitchers had the highest distribution of SI (46%) followed by fielders (26.5%), and the majority (80%) were new injuries. 52% resulted in a loss of playing time for 2 weeks or less while 9.7% ended the SAs season. 7% of all SI resulted in surgery. Freshmen were the majority (41%) followed by juniors (29%). During the same time period, the EI IR was 2.44 per 10 000 AEs, and the national estimate was 7375 EI. DI players were more likely to sustain an EI than those who play DII, but there was no difference with DIII. EI were more than twice as likely to occur during competitions compared to practice. Specifically, 37% occurred during innings 4 to 6, and 32% were reported during precompetition warmup. Pitchers accounted for 62%, and fielders made up 15%. Seventy-six percent were new injuries, and 56% occurred to the pitcher. Forty percent resulted in a loss of playing time for 2 weeks or less while 21% ended the SAs season, and 17.5% of all EI resulted in surgery. Freshmen (33%) and juniors (34%) made up equal proportions of the EI cohort.
CONCLUSIONS: Common Injury trends for SI and EI were identified such as higher IR among DI players and during competitions, specifically innings 4 to 6. Additionally, most of the cohort were freshmen and juniors. In contrast SI resulted in total morbidity with higher IR, but EI resulted in increased occurrence of surgery and greater time loss.
CLINICAL RELEVANCE: This study establishes characteristics of SI and EI among college baseball SAs. While not analytical, this research may be used with clinical and scientific information to develop preventive and rehabilitation programs. In addition to improving care, such clinical reasoning may encourage further descriptive and analytical research for the prevention and treatment of SI and EI.

SPL43

ANKLE JOINT LOADS DURING ROUTINE TRAINING ACTIVITIES

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PURPOSE/HYPOTHESIS: Ankle trauma associated with fracture and ligament damage is the most common cause of ankle osteoarthritis (OA). Treatment options for posttraumatic ankle OA are limited, emphasizing the need for well-defined rehab progressions and load management criteria. Understanding joint loads during routine training activities encountered by athletes is key to designing optimal rehab programs following ankle injury. The purpose of this study was to quantify ankle joint contact forces (AJCF) incorporating both internal and external forces across a continuum of common training activities.
NUMBER OF SUBJECTS: Twenty males and 20 females (mean ± SD age, 21.3 ± 2.0 years; height, 176.1 ± 9.8 cm; weight, 74.6 ± 13.3 kg).
MATERIALS/METHODS: Three-dimensional kinematics and kinetics were collected during 6 randomized conditions: walk (1.5 m/s), run (3.5 m/s), sprint (5.5 m/s), cut (3.5 m/s), double-leg jump, and single-leg jump. Jump height was standardized to 75% of maximum. Take-off and landing for jump tasks were analyzed separately. Motion capture data and subsequent joint moments from 5 trials were input to a musculoskeletal model to estimate AJCF during ground contact. Peak resultant AJCF and AJCF impulse were compared across conditions using multivariate repeated measures ANOVA ($\alpha = .05$) and partial eta-square effect sizes.
RESULTS: Both peak AJCF and AJCF impulse differed across conditions ($P<.01$, $\eta^2 = 0.77$-0.79). Peak AJCF increased when transitioning from walking to DL and SL activities ($P<.01$, $\eta^2 = 0.79$). Within tasks with that loaded both limbs simultaneously, DL landing (6.4 ± 1.3 BW) displayed higher peak AJCF than walking (5.5 ± 0.5 BW, $P = .01$) and DL jumping (5.7 ± 1.0 BW, $P = .03$). Within SL tasks, greater peak AJCF was experienced during cutting (9.9 ± 1.7 BW) and sprinting (10.6 ± 1.3 BW) compared to SL jump (8.9 ± 1.1 BW, $P \leq .01$) and land (8.9 ± 1.4 BW, $P = .01$). Running peak AJCF (9.4 ± 1.4 BW) did not differ from SL jump, SL land, or cut ($P<.01$) but was less than sprinting ($P<.01$). Compared to all other conditions, sprinting displayed the lowest impulse (1.1 ± 0.1 BW·s, $P \leq .02$) and SL land displayed the highest (2.9 ± 0.7 BW·s, $P \leq .01$). Running had the second lowest impulse (1.2 ± 0.2 BW·s) while DL jump/land, cutting, and walking represented transitional activities (1.3-1.59 BW·s).
CONCLUSIONS: Across routine training tasks, peak AJCF increased as expected when transitioning from DL to SL activities suggesting DL and SL plyometric activities should be incorporated prior to return to running following ankle injury. However, OA in the lower extremity has been associated with cumulative joint loads. AJCF impulse representing total load per contact was greatest in SL jump/land and lowest in running and sprinting. After ankle injury, exercise prescription that incrementally increases both peak and cumulative loads may provide the greatest likelihood for optimal long term joint health.
CLINICAL RELEVANCE: Following ankle injury, it is important to develop tolerance to peak loads associated with training activities through graded load progression and to be mindful of cumulative load for OA prevention. Data from this study can be used to guide exercise progression and activity prescription.

SPL44

PARTIAL CONTROLLED EARLY POSTOPERATIVE WEIGHT BEARING VERSUS NON–WEIGHT BEARING AFTER RECONSTRUCTION OF THE FIBULAR (LATERAL) COLLATERAL LIGAMENT: A RANDOMIZED CONTROLLED TRIAL AND EQUIVALENCE ANALYSIS

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PURPOSE/HYPOTHESIS: (1) To determine if early partial controlled weight bearing after an FCL reconstruction resulted in an objective difference in laxity on varus stress radiographs at 6 months postoperatively when compared to patients that were non–weight bearing. (2) To determine if there was a difference in pain, edema, range of motion and subjective patient reported outcomes between these 2 groups at 3 different time points.
NUMBER OF SUBJECTS: Thirty-nine.
MATERIALS/METHODS: Patients were prospectively enrolled from January 2014 to April 2017. Patients that underwent isolated FCL reconstruction or combined ACL and FCL reconstruction were included in this study. Patients were randomly assigned to either a control group, which was non–weight bearing for 6 weeks, or a treatment group with partial controlled weight bearing at 40% of body weight with crutches for 6 weeks. Patient related data including knee pain, edema, and range of motion were collected in all patients at postoperative day 1, 6 weeks and 6 months. Subjective outcome were collected preoperatively and at 6 months postoperatively. The primary objective end point was varus stability evaluated by bilateral varus stress radiographs obtained preoperatively and at 6 months postoperatively.
RESULTS: Thirty-nine patients were enrolled in the study, with 6 month follow-up obtained in 36 patients (92%). There was a significant improvement between the preoperative side-to-side difference (SSD) (2.4 ± 1.0) and postoperative SSD (0.2 ± 1.0) for lateral compartment laxity on varus stress radiographs in all patients (P<.001). Clinical and statistical equivalence was found between groups in terms of SSD on varus stress radiographs (P<.001). The SSD in knee edema was significantly lower in the partial early weight bearing group (β = −0.6 cm, P = .001) but there were no significant differences in knee pain, flexion or extension. All patients demonstrated significant improvements in subjective outcome scores between the preoperative and 6 months postoperative conditions (P<.001 for every score measured).
CONCLUSIONS: Clinical and statistical equivalence was found at 6 months postoperatively between the early partial weight bearing and non–weight bearing groups in patients undergoing an isolated FCL reconstruction or an ACL/FCL combined reconstruction. There were no significant differences observed between the 2 groups regarding knee stability, pain, swelling, range of motion, or subjective outcomes. Based on these findings we recommend early partial weight bearing following isolated FCL reconstruction or combined ACL and FCL reconstructions.
CLINICAL RELEVANCE: This study demonstrates that an early partial weight bearing protocol after an isolated FCL reconstruction or when combined with an ACL reconstruction is safe and effective with no objective or subjective differences in outcomes at 6 months compared to non–weight bearing for the first 6 weeks.

SPL45

THE RELATIONSHIP BETWEEN HIP STRENGTH AND POSTURAL STABILITY IN COLLEGIATE ATHLETES WHO PARTICIPATE IN LOWER EXTREMITY–DOMINANT SPORTS

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PURPOSE/HYPOTHESIS: Lower extremity (LE) injuries are common among student-athletes, causing significant missed playing time. Studies have shown that core strength, including the hip musculature, has been implicated as a risk factor for injury and is a target of rehabilitation. Studies have also shown a relationship between poor postural stability and risk for LE injury. The relationship between hip strength and postural stability measures, especially dynamic postural stability, are not well known. This study's purpose is to examine the relationship between hip strength and both static and dynamic postural stability.
NUMBER OF SUBJECTS: A total of 162 Division I student-athletes (soccer, basketball, and football) from 2 universities volunteered for the study. Subjects consisted of 111 males and 51 females.
MATERIALS/METHODS: Isometric hip internal/external rotation and hip abduction/adduction strength was measured using a handheld dynamometer. Static and dynamic postural stability were measured with a force plate. Static postural stability was measured during a single-leg, balance task under eyes open (EO) and eyes closed (EC) conditions. Dynamic postural stability was measured during a single-leg landing which required the subject to jump forward over a hurdle and land on the force plate. A single composite balance score based on the ground reaction forces was calculated and averaged across 3 trials for each of the postural stability tasks. Pairwise correlations (Pearson) were performed between the hip strength variables and the postural stability scores for all subjects and separately for males and females. Significance was set at P<.05 a priori.
RESULTS: There were no significant correlations between hip strength and dynamic postural stability for any of the pairwise correlations. There were statistically significant correlations between static postural stability and each of the hip strength variables for all subjects and male subjects (correlation coefficients ranged from −0.1923 to −0.3445). There were only 2 significant correlations between hip strength and EC static postural stability (hip internal/external rotation) and 1 for hip strength and EO postural stability (hip internal rotation) for female subjects.
CONCLUSIONS: There was no relationship between isometric hip strength and dynamic postural stability; whereas, there was a relationship between the strength measures and static postural stability, thus refuting our hypotheses. These significant, but low correlations were observed in more of the comparisons within the male cohort potentially demonstrating a sex difference.
CLINICAL RELEVANCE: The relationship between core strength and postural stability is likely more complicated than the relationship assessed in the current study. Future research on this relationship and the implications on injury prevention should include other measures of muscle performance (isokinetic strength and/or electromyography) and integrate other assessment of neuromuscular control including proprioception.

SPL46

REDUCED FEMORAL BONE MINERAL DENSITY IN COLLEGIATE ATHLETES FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION SURGERY

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PURPOSE/HYPOTHESIS: Immediately following anterior cruciate ligament reconstruction (ACLR) surgery, loading of the surgical limb is substantially reduced to allow for graft healing. Loading is progressively increased over time with return to sports participation typically taking 6 to 12 months. This period of reduced loading, muscle strength, and sports participation reduces bone integrity of the surgical limb. The purpose of this study was to characterize whether significant changes in bone mineral density (BMD) occurred at 4 specific regions of the femur and tibia following ACLR surgery. We hypothesized that reduced limb loading following ACLR would result in observable BMD deficits in the surgical limb compared to the nonsurgical limb.
NUMBER OF SUBJECTS: Fifteen NCAA Division I collegiate athletes (9 female, 6 male; mean ± SD age, 20.1 ± 1.3 years) who underwent unilateral ACLR surgery (bone-patellar tendon-bone, n = 13) were evaluated.

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MATERIALS/METHODS: BMD measurements were acquired via full-body dual-energy X-ray absorptiometry (DXA) scans prior to surgery, and at 6 and 12 months following surgery. Using 2-cm-high regions of interest (ROIs), we sampled BMD at 15% and 25% of the femur length, measured from the intercondylar notch, and at 25% and 50% of tibia length, measured from the proximal tibia plateau. Two-way repeated-measures ANOVA was conducted to evaluate the effects of time and limb on BMD followed by post hoc paired *t* tests when appropriate.
RESULTS: Prior to ACLR, no between limb differences in BMD were present at any of the ROIs. Significant interaction effects were observed between time and limb for the 15% ($P<.001$) and 25% ($P<.01$) femur ROIs. The femur 15% ROI BMD in the surgical limb decreased by 6% from presurgery to 6 months (1.231 ± 0.144 g/cm^2 to 1.155 ± 0.124 g/cm^2, $P<.0001$) and 9% from presurgery to 12 months (1.119 ± 0.118 g/cm^2, $P<.0001$), while the nonsurgical limb did not significantly change (approximately 3%, $P = .06$) over time. The surgical limb had 5% ($P = .017$) lower femur BMD at 15% ROI compared to the nonsurgical limb at 12 months. The femur 25% ROI BMD decreased (3%, $P = .007$) from preoperative to 12 months in the surgical limb only; however, no between limb differences were observed. No differences in BMD occurred over time or between limbs at either tibial ROI.
CONCLUSIONS: ACLR leads to a significant BMD decline at 2 distal femur ROIs. Examination of BMD beyond 1 year post ACLR is needed to determine if BMD values return toward presurgical values.
CLINICAL RELEVANCE: These findings may have implications for bone health, injury risk, and recovery timeline in athletes who undergo ACLR surgery and return to sport. It is possible that this bone loss leads to increased fracture risk later in life. The mechanism(s) leading to lower distal femur BMD and thinner cortices are unknown, but likely multifactorial. Reduced quadriceps strength, activity reduction and gait changes postoperatively could contribute to bone loss; however these do not explain why the reduction in BMD was specific to the femur.

SPL47

THE RELATIONSHIP BETWEEN PHYSICAL PERFORMANCE MEASURES AND SKILL LEVEL IN COMPETITIVE TENNIS PLAYERS: A PILOT STUDY

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PURPOSE/HYPOTHESIS: The sport of tennis requires sport specific technical skills in order to become a competitive player. It is not well understood as to what clinical performance measures are represented by players as they become more advanced. Identification of these specific performance variables may allow improvement in screening and program design to enhance a player's on-court performance. The purpose of this pilot study was to investigate what variables of upper extremity (UE) and lower extremity (LE) range of motion (ROM), strength, motor control, and power correlate to skill level in competitive tennis players.
NUMBER OF SUBJECTS: Forty-two male (mean ± SD age, 23.9 ± 5.82 years) National Tennis Rating Program tennis players rated 4.5 to 6.0.
MATERIALS/METHODS: Subjects underwent a series of ROM, strength, motor control, and power testing. Shoulder external rotation (ER) and internal rotation (IR) at 90° of abduction, trunk rotation, prone hip ER and IR, and ankle dorsiflexion were measured using standard goniometric measures. Strength was assessed using a handheld dynamometer for rotator cuff, scapular, and hip musculature. Motor control was evaluated through LE and UE Y Balance testing. Power assessments were made using the broad jump and single-leg (SL) hop test for LE and the seated unilateral shot put test for UE. Data were normalized to the dominant arm. Pearson correlation assessed associations between these performance variables and player skill level ($P<.01$).
RESULTS: ROM and strength variables did not demonstrate any significant correlations to player skill level ($P>.01$). Significant correlations to player skill level were found for the nondominant UE Y Balance ($r = 0.500$, $P<.01$), dominant UE Y Balance ($r = 0.388$, $P = .006$), contralateral SL hop ($r = 0.485$, $P = .001$), and ipsilateral SL hop ($r = 0.461$, $P = .001$).
CONCLUSIONS: The results indicate that improved athletic performance in UE motor control and SL power tests are represented in more advanced tennis players. Based on these findings, improved tennis performance may be due to one's ability to generate LE power and then control the force transfer through the kinetic chain to the racket and tennis ball.
CLINICAL RELEVANCE: UE motor control through Y Balance testing and LE power through SL hop testing should be routinely screened and monitored as part of a player's clinical assessment. These performance variables may be an important area of focus during exercise programming or treatment design to improve overall tennis performance.

SPL48

CONFIDENCE IS ASSOCIATED WITH ABILITY TO MEET RETURN-TO-SPORT CRITERIA AND SECOND ANTERIOR CRUCIATE LIGAMENT INJURY RISK AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Over 30% of young patients sustain a second ACL injury after ACL reconstruction (ACLR)and return to sport (RTS). Evidence suggests current RTS criteria focused on functional impairments may be insufficient to identify patients at risk for future injury. The purpose of this analysis was to identify the relationship among knee-related confidence, ability to meet current RTS criteria and future ACL injury risk. The tested hypothesis was 2-fold: (1) participants who self-reported high knee-related confidence at the time of RTS after ACLR would have a greater likelihood of meeting all RTS criteria and; (2) these participants would also present with a higher likelihood of second ACL injury after RTS.
NUMBER OF SUBJECTS: One hundred sixty athletes (115 female; mean ± SD age, 17.1 ± 2.2 years; range, 13-25 years) after ACLR who were medically cleared to RTS.
MATERIALS/METHODS: Within 4 weeks of RTS clearance (8.3 ± 2.4 months after ACLR), the Knee injury and Osteoarthritis Outcome Score (KOOS) scale and 6 standard RTS assessments, including International Knee Documentation Committee Subjective Knee Form (IKDC), isometric quadriceps femoris strength limb symmetry index (LSI [percent]), and LSI of 4 single-leg hop tests were completed. Success in meeting RTS criteria was defined as an IKDC score of 90 or greater and all LSI scores of 90% or greater. Two confidence groups were created based on response to the KOOS Quality of Life subscale Question 3 (QOL3): "Confident" (QOL3 of 0, n = 62) and "Lacking" confidence (QOL3 of 1 or greater, n = 98). Subjects were tracked for 24 months after RTS to identify the incidence of a second ACL injury. Chi-square analysis was used to evaluate the association between knee confidence, success in meeting 6 RTS criteria, and incidence of second ACL injury during the tracking period.
RESULTS: At the time of medical release to RTS, 44/160 (27.5%) met all 6 RTS criteria and 33/160 (20.6%) suffered a second ACL injury within 2 years after RTS. No differences in age and time to RTS were seen between the groups ($P>.05$). A higher proportion of confident patients at the time of RTS successfully met all 6 RTS criteria (45.2%), compared to those lacking knee-related confidence (16.3%) ($P = .001$). Confident patients were 4 times more likely to meet all 6 RTS criteria (OR = 4.22; 95% CI: 2.03, 8.78). A higher percentage of confident patients suffered a second ACL injury (30.6%) compared to those lacking confidence (14.3%), as confident patients were nearly 3 times more likely to suffer a second ACL injury (OR = 2.65; 95% CI: 1.21, 5.80).

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CONCLUSIONS: Young athletes after ACLR, who report high knee-related confidence at the time of RTS, are more likely to demonstrate more optimal physical function as indicated by meeting all RTS criteria; however they are also more likely to sustain a second ACL injury within the 2 years after RTS.
CLINICAL RELEVANCE: Current RTS measures may be insufficient to accurately identify patient risk for second ACL injury after ACLR and RTS. Future work must consider how the inclusion of psychosocial measures, such as knee-related confidence into RTS criteria may help improve outcome for this patient population.

SPL49

ACTIVITIES THAT EVOKE FEAR AND FEAR INTENSITY BEFORE AND AFTER AN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION RETURN-TO-SPORT TRAINING PROGRAM

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PURPOSE/HYPOTHESIS: Fear of reinjury is one of the main reasons why patients with anterior cruciate ligament (ACL) reconstruction do not return to sport, and some patients also demonstrate elevated kinesiophobia. The purpose of this study was to examine fear related to specific activities before and after an ACL reconstruction return to sport training program. We hypothesized that jumping and cutting would be activities that commonly evoke fear in patients with ACL reconstruction, and that fear intensity would decrease following the return to sport training program.
NUMBER OF SUBJECTS: Subjects were 26 patients with primary ACL reconstruction (15 female, 11 male; mean ± SD age, 17.6 ± 4.8 years; 20 bone-patellar tendon-bone, 6 hamstring autografts).
MATERIALS/METHODS: After completing traditional physical therapy, patients voluntarily enrolled in a 5-week (10-session) return-to-sport training program consisting of jumping, agility and strengthening exercises. Testing was conducted pretraining and posttraining. Patients listed the top 3 activities that evoked fear and quantified the fear intensity on a scale from 0 (no fear) to 10 (greatest fear imaginable). Patients similarly rated fear intensity for other activities including: (1) reinjuring their knee during activity, (2) knee giving way during activity, and (3) experiencing knee pain during activity. The primary fear-evoking activity was categorized as "Cutting," "Jumping," "Contact," and "Other." The prevalence of each category was computed, and McNemar's test examined changes in categorization from pretraining to posttraining. Paired *t* tests analyzed the pretraining to posttraining change in fear intensity for all activities.
RESULTS: The order of prevalence for categorization of the primary fear-evoking activity pretraining and posttraining was cutting (pre, 42.3%; post, 46.2%), contact (pre and post, 23.1%), other (pre, 19.2%; post, 15.4%) and jumping (pre and post, 15.4%). In 9/26 patients (34.6%) the primary fear-evoking activity changed category from pretraining to posttraining (P = .004). Fear intensity significantly decreased from pretraining to posttraining for the primary fear-evoking activity (6.8 ± 2.2 to 4.5 ± 2.8 points), fear of reinjuring the knee during activity (4.8 ± 2.7 to 2.5 ± 2.2 points), fear of knee giving way during activity (4.3 ± 2.6 to 1.5 ± 1.7 points), and fear of pain during activity (3.8 ± 2.8 to 1.9 ± 2.0 points; all, P<.001).
CONCLUSIONS: Cutting was the primary fear-evoking activity for almost half the sample, but variability was demonstrated across patients. Many patients identified a new primary fear-evoking activity after training. Fear intensity improved for a variety of activities after the return-to-sport training program.
CLINICAL RELEVANCE: A return-to-sport training program can lower activity-related fear in patients with ACL reconstruction. However, it may be necessary to identify individual activity-related fear to optimize training and return to sport.

SPL50

CONCUSSION SYMPTOMATOLOGY IN ELITE EQUESTRIAN SPORTS: A GROWING EPIDEMIC

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PURPOSE/HYPOTHESIS: In the alone the horse industry has become a 50 billion dollar economic boon with an estimated 2.4 million horses involved with showing and racing combined. Nearly 30 million Americans compete in equine sporting events but not without risk for potentially severe neurologic injury. Data from the years 2002 to 2013 retrieved from the National Trauma Data Bank concluded that equestrian athletics at 45.2% represents the largest contributor of sports-related traumatic brain injuries. In athletes a concussion can be detrimental as it may result in immediate termination of competition, end a competitive season, or cut short a lucrative career in professional sports. The purpose of this study was to explore the prevalence and sequelae of concussion related injuries in elite equestrian sports.
NUMBER OF SUBJECTS: Eighty-seven subjects.
MATERIALS/METHODS: This study utilized a retrospective analysis of data collected from 87 equestrian athletes during horse shows in Colorado and California in 2016, and additional competitions in Florida and Kentucky in 2018. The average age of subjects was 34.4 years (range, 18-58 years). Subjects completed a concussion screening tool as part of routine medical care provided by a physical therapist who offers rehabilitation services to elite equestrian athletes around the country. Questions from the tool explored the incidence of concussions and residual symptoms related to injury in the equestrian discipline of show jumping where in this study subjects jumped an average height of 1.4 m.
RESULTS: Data analysis revealed that 77 out of 87 subjects (88.5%) reported at least 1 concussion (n = 16) with 2 individuals reporting a total of 10. In aggregate 224 concussion related injuries were reported with an average of 2.54 incidences per subject. Medical attention was sought in 37% of the subjects. When asked about return to sport, 87% did so within 1 to 3 days from time of injury. Concussion symptoms included: headaches (81%), neck pain (60%), nausea (35%), balance (34%), cognitive difficulties (22%), blurred vision (0.06%), and fogginess (0.5%). Residual symptoms of concussion existed in 60% of subjects for weeks following injury, including headaches and neck pain.
CONCLUSIONS: Results from this study support prior research concluding that concussions are a significant and frequently unreported health risk in equestrian sports. Subjects not only failed to report head trauma a high percentage of the time, they subsequently returned to sport between 24 to 72 hours following injury despite unresolved symptoms of headaches, neck pain, and in some cases memory loss. These symptoms may pose a safety concern for athletes competing on horses often weighing in excess of 1200 lb.
CLINICAL RELEVANCE: Further studies are needed to determine the long-term effects of failing to detect, appropriately treat, and medically manage symptoms of mild to moderate concussions in elite equestrian athletes. In addition, results from this study indicate a need for medical professionals to adequately recognize potential risks for neurologic consequences associated with equestrian sports.

SPL51

BASELINE PENN SCORE IDENTIFIES PATIENTS NOT LIKELY TO RESPOND TO PHYSICAL THERAPY TREATMENT IN PATIENTS WITH SHOULDER INSTABILITY

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PURPOSE/HYPOTHESIS: There is wide variation in the initial treatment of shoulder instability ranging from early surgical intervention and conservative care. One reason for this may be the lack of evidence to guide nonoperative rehabilitation programs. The objective of this study is to investigate the association between active (exercise-based) physical therapy interventions and discharge functional status after conservative management for patients with shoulder instability.
NUMBER OF SUBJECTS: Patients (n = 54; mean ± SD age, 21 ± 9 years; 28 female) referred for physical therapy.
MATERIALS/METHODS: Patients referred with a diagnosis of shoulder instability by a fellowship trained board certified orthopaedic surgeon data were queried from the ATI Patient Outcomes Registry for the Penn Shoulder Score (PSS), patient demographics, and injury circumstances at initial evaluation. Additionally, billed CPT codes, therapy duration, visits, and discharge PSS were obtained. After an episode of physical therapy for shoulder instability, a discharge PSS of 90 or greater identified a patient as "high functioning" (n = 28), while a discharge PSS less than 90 identified a patient as "low functioning" (n = 26). Baseline factors (demographics, prior history, and initial function) were compared using chi square analysis and a 1-way ANOVA to examine differences between groups. An ROC curve was then used to evaluate the ability to predict posttreatment high function based on the initial PSS. Treatment parameters including total visits, units per visit (UPV), active UPV, manual UPV, and change in PSS were compared between functional groups using separate univariate ANCOVAs controlling for baseline PSS (α<.05).
RESULTS: There were no differences in baseline factors between the high and low functioning groups (P>.05) except for PSS at initial evaluation (68 ± 21 versus 49 ± 17, P = .001). The ROC curve revealed a cut score of approximately 50 was able to discriminate between the functional groups at discharge (AUC = 0.73, P = .005). Initial analysis demonstrated significant differences between high and low groups for manual UPV (0.3 ± 0.3 versus 0.6 ± 0.5, P = .03), active UPV (3.0 ± 0.6 versus 2.7 ± 0.5, P = .05), and change in PSS (27.8 ± 18.6 versus 8.5 ± 11.7, P = .001), respectively. However, when initial PSS was controlled for, the manual (P = .3) and active UPV (P = .1) were not different between the high and low functioning groups. The groups remained significantly different for change in PSS over the course of treatment regardless of admit PSS (P = .001).
CONCLUSIONS: Over half of the patients referred for conservative treatment of shoulder instability displayed normal shoulder function at discharge. There were no clear treatment patterns associated with these outcomes.
CLINICAL RELEVANCE: Our results suggest young, active patients may initially respond to physical therapy and function at a relatively high level. Further study warranted to better understand the predictors of success.

SPL52

LOAD MAGNITUDE AND VOLUME DIFFER IN MALE ATHLETES WITH AND WITHOUT PATELLAR TENDINOPATHY

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PURPOSE/HYPOTHESIS: Patellar tendinopathy (PT) is prevalent in athletes who participate in sports with repetitive jumping maneuvers. Mismanagement of the volume of load acting on the tendon is believed to be a key factor contributing to PT development. Therefore, it may be important to consider the combination of load magnitude, frequency and duration to better manage and prevent symptomatic PT. The purpose was to investigate differences in load magnitude and volume between male athletes with and without PT.
NUMBER OF SUBJECTS: Forty-one male athletes (Tegner of 5 or greater) classified into 3 groups based on tendon pain and ultrasound evaluation of the proximal tendon: symptomatic with patellar tendon abnormality (PTA) (SYM-PTA) (n = 13; mean ± SD age, 19.62 ± 1.61 years; height, 1.82 ± 0.05 m; weight, 83.46 ± 5.12 kg), asymptomatic with PTA (ASYM-PTA) (n = 14; age, 21 ± 1.96 years; height, 1.84 ± 0.07 m; weight, 81.63 ± 13.03 kg), and healthy control (CON) (n = 14; age, 19.64 ± 1.60 years; height, 1.84 ± 0.09 m; weight, 79.91 ± 12.95 kg).
MATERIALS/METHODS: Participants wore an ActiGraph GT9X Link accelerometer for a 7-day monitoring period and physical activity (PA) measures of average steps/day, moderate-vigorous physical activity (MVPA)/day (minutes), and stepsMVPA/day were extracted. Three-dimensional kinematics and kinetics were collected using a 10-camera motion capture system and 2 floor-embedded force plates. Participants completed 5 double-limb jump-landing trials from a 30-cm box positioned at 50% of participant height away from the force plates; the middle 3 trials were averaged for analysis. Peak patellar tendon force (FPT) and impulse (FPTI), internal knee extension moment impulse (KEMI), knee power (KP) and negative knee work (KW) were calculated for the involved/dominant limb (load magnitude variables). Cumulative load volume (denoted by "c") variables were estimated by multiplying stepsMVPA/day by each load magnitude variable of interest, respectively. Differences between groups were compared using 1-way ANOVAs and Tukey post hoc tests (α≤.05). Cohen's d effect sizes evaluated magnitude of group differences.
RESULTS: Participants with SYM-PTA demonstrated lower biomechanical load magnitude and load volume than CON for all variables (P<.05), but no differences in PA. The magnitude of the effect for load volume difference between SYM-PTA compared to CON was considered to be strong and significant for cFPT (d = 0.98), cFPTI (d = 1.09), cKEMI (d = 1.09), cKP (d = 1.04), and cKW (d = 1.14). There were no significant differences in load magnitude or load volume between the SYM-PTA and ASYM-PTA or ASYM-PTA and CON (P>.05).
CONCLUSIONS: SYM-PTA athletes displayed significantly lower load volume compared to CON athletes, driven by lesser biomechanical knee load magnitude during landing, not load frequency (stepsMVPA/day). ASYM-PTA athletes did not differ from either of the other 2 cohorts.
CLINICAL RELEVANCE: Chronic underloading may lead to reduced tissue capacity and limit the adaptive potential of tendon when exposed to high loading in sport. Our findings highlight the importance of a comprehensive approach to load monitoring in individuals with PT, including biomechanical movement profiles and load volume.

SPL53

THE ACUTE EFFECTS OF THROWING WEIGHTED BASEBALLS ON SHOULDER RANGE OF MOTION

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PURPOSE/HYPOTHESIS: Baseball pitching injuries are increasing at an alarming rate. While weighted ball throwing programs have been shown to be effective at increasing pitching velocity, previous research has identified a 24% injury rate and a 3.3° increase in shoulder external rotation range of motion (ROM) after performing a 6-week program using balls weighing between 2 and 32 oz. However, this previous research did not investigate separately the effect of the underload and overload balls. The purpose of this study was to examine the acute effects of throwing different weighted baseballs on ROM. By analyzing these differences, it may be possible to determine the specific weight range that may lead to the greatest increase in ROM.
NUMBER OF SUBJECTS: Seventeen male high school baseball pitchers.
MATERIALS/METHODS: Each participant was tested on 3 different days, 1 week apart, with 3 different conditions in random order: (1) underload throwing, using regulation 5-oz baseballs and 4- and 2-oz balls; (2) over-

load throwing, using 5-, 6-, and 9-oz balls, and (3) heavy overload throwing, using 5-, 16-, and 32-oz balls. Testing began each session by measuring shoulder ROM (external rotation and internal rotation) using standard goniometric measurements. Subjects then threw 3 throws with each weighted ball from 3 different positions—kneeling, rocker, and run and gun—for a total of 27 throws each test session. ROM measurements were repeated at the end of each test session. The effect of each throwing condition on ROM was compared from pretraining to posttraining using a paired *t* test ($P = .05$).

RESULTS: The mean age, height, and mass for all subjects were 17.1 years, 180.9 cm, and 79.2 kg, and respectively. There was no significant difference in external rotation after throwing with underload weights. The overload condition showed a statistically significant increase of 3.3° in external rotation ($P = .05$). The heavy overload condition showed a statistically significant increase in external rotation of 8.4° ($P<.001$). There were no differences in internal rotation for any group.

CONCLUSIONS: A significant increase in shoulder external rotation was observed immediately after throwing overload balls. This effect increased as the weight of the ball increased.

CLINICAL RELEVANCE: Based on the results of this study, it appears that these changes in shoulder external rotation may be due mostly to the use of overload balls, especially 16- and 32-oz balls. It is currently unclear if this rapid increase in ROM may be dangerous in the long term. Previous research has shown that 78% of pitching injuries occur in athletes with greater relative amounts of dominant arm ROM. The current study results may be used to develop more scientifically validated weighted ball programs. The use of heavier balls should be used with caution and ROM should be monitored during implementation of these programs.

SPL54

CLINICAL MEASURES DIFFER AT RETURN-TO-SPORT CLEARANCE IN FUNCTIONALLY RECOVERED ATHLETES 2 YEARS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: After ACL reconstruction (ACLR), clinical measures are used to help determine when athletes are ready for return-to-sport (RTS). However, the impact of these measures on function over time is less extensively studied. National registry data has established functional recovery (FR) 2 years after ACLR using the Knee Injury and Osteoarthritis Outcome Score (KOOS), but it is unknown how RTS clinical measures impact 2-year FR. The purpose of this analysis was to test the hypothesis that scores on clinical measures would be lower in athletes at the time of RTS clearance after ACLR who do not achieve 2-year FR compared to those who do achieve 2-year FR.

NUMBER OF SUBJECTS: Sixty-two young athletes (77% female; mean ± SD age at RTS, 17.6 ± 2.9 years) after primary, unilateral ACLR.

MATERIALS/METHODS: The following data were collected at RTS clearance (7.7 ± 2.0 months after ACLR): International Knee Documentation Committee Subjective Knee Form (IKDC), isokinetic (180°/s) quadriceps femoris (QF) and hamstring (HS) strength limb symmetry indices (LSI [percent]), and LSI of 4 single-leg hop tests (single-hop [SH], triple-hop [TH], crossover-hop [CH], and 6-meter timed hop [TiH]). At 2 years post RTS clearance, all participants completed the KOOS, and FR groups (FR-yes and FR-no) were created based on the previously reported cutoffs for each subscale (Pain greater than 90, Symptoms greater than 84, ADL greater than 91, Sport greater than 80, Quality-of-Life [QOL] greater than 81). The KOOS-Symptoms, -Sport and -QOL subscales were the focus of the analysis, as these are reported to be the most important to the patient. Independent samples *t* tests (Mann-Whitney *U* tests for nonnormally distributed data) evaluated differences in RTS outcomes between the 2-year FR-yes and FR-no groups ($\alpha = .05$).

RESULTS: At 2 years, 35 subjects were in the All FR-yes group and the IKDC at RTS was higher (91) compared to the All FR-no group (81) ($P = .001$). At RTS, the 2-year Symptoms FR-yes group (n = 47) had higher scores compared to the Symptoms FR-no group (n = 15) for IKDC (89 versus 78) ($P = .008$), SH LSI (94 versus 90) ($P = .035$), and TrH LSI (96 versus 92) ($P = .037$). At RTS, the 2-year Sports FR-yes group (n = 50) had higher scores compared to the Sports FR-no group (n = 12) for IKDC (90 versus 73) ($P<.001$), TrH LSI (96 versus 92) ($P = .047$), with a trend for SH LSI (94 versus 90) ($P = .073$). At RTS, the 2-year QOL FR-yes group (n = 42) had higher scores compared to the QOL FR-no group (n = 20) for IKDC (89 versus 80) ($P = .007$), SH LSI (94 versus 91) ($P = .042$), TrH LSI (96 versus 93) ($P = .035$), and TiH LSI (97 versus 94) ($P = .038$).

CONCLUSIONS: ACLR patients that are functionally recovered at 2 years after RTS clearance according to the KOOS-Symptoms, -Sport, and -QOL subscales demonstrate higher RTS scores on the IKDC, SH LSI, and TrH LSI.

CLINICAL RELEVANCE: Ensuring that patients after ACLR meet cutoffs on the IKDC, SH LSI, and TrH LSI at the time of RTS clearance may be associated with maintaining higher function 2 years later. Future work is needed to determine if any RTS testing variables or cutoff values can be used to predict long-term FR.

SPL55

RELATIONSHIP BETWEEN MAXIMUM HIP ISOMETRIC STRENGTH, PEAK GLUTEAL MUSCLE FORCE VALUES, AND HIP KINEMATICS DURING RUNNING

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PURPOSE/HYPOTHESIS: Decreased hip adduction and external rotation strength has been proposed to affect the eccentric control of femoral adduction and internal rotation during running. It has been suggested that excessive hip adduction and internal rotation can increase joint forces and tissue tension, which can lead to lower extremity overuse injuries. Clinically, hip strength is commonly assessed with isometric testing. Several studies have examined the relationship between isometric hip strength and hip adduction and internal rotation motion during running which have yielded mixed results. However, it is unknown how isometric hip strength relates to the maximal force produced by the gluteal muscles during running. Further, no studies have investigated the relationship between the estimated muscle forces produced during dynamic tasks and the observed hip kinematics in running. Therefore, our purpose was to determine if there were any relationships between isometric hip strength and peak gluteal muscle forces and hip kinematics in running. We hypothesized that there will be no relationship between these measures during running.

NUMBER OF SUBJECTS: Sixteen.

MATERIALS/METHODS: Sixteen NCAA Division III freshman collegiate cross-country runners aged 18 to 20 years (12 female) were tested. Isometric strength values for the hip abductors and external rotators were measured using a hand held dynamometer. Subjects ran down a 20-m runway at a self-selected average training pace while their gait was analyzed using a 3-D motion capture system and force plate. Muscle forces were calculated from static optimization using a musculoskeletal model. Pearson correlation coefficients were performed to assess the association between isometric hip abduction and external rotation strength, peak gluteus maximus, medius, and minimus muscle forces, and peak hip internal rotation and adduction ROM during running. Each leg was treated independently.

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RESULTS: No significant relationships were observed ($P>0.05$) between any of the measures of isometric strength and gluteal muscle forces ($r = -0.007$ to 0.187) or between isometric strength and hip kinematics ($r = -0.165$ to 0.219). Significant relationships were observed between gluteus minimus ($r = -0.662$, $P<.001$) and medius ($r = -0.726$, $P<.001$) muscle force and peak hip adduction angle.
CONCLUSIONS: No relationships were observed between isometric hip external rotation or abduction strength and gluteal muscle forces during running. Therefore, maximal isometric hip strength may not be related to gluteal muscle forces and hip kinematics. However, gluteus medius and minimus muscle forces may relate to hip kinematics which have been associated with running injury.
CLINICAL RELEVANCE: Isometric hip strength may not be a reliable indicator of the muscle forces that are produced during dynamic tasks, such as running. Hip kinematics however were related to muscle forces in healthy runners.

SPL56

PROSPECTIVE ASSESSMENT OF RETURN TO ACTIVITY FOLLOWING ATHLETIC ANKLE INJURY

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PURPOSE/HYPOTHESIS: To obtain baseline values of perceived and objective preinjured physical function and to determine if and when athletes return to those baseline levels following ankle injury. We hypothesized that athletes returning to sport following an injury would not have a significantly lower level of physical function compared to their preseason baseline levels.
NUMBER OF SUBJECTS: Seven hundred forty-six collegiate athletes currently participating in sport and medically cleared by a team physician for full participation participated in this study.
MATERIALS/METHODS: Potential subjects were approached during preseason physical examinations. Demographics including name, age, sex, race, height, weight, sport, years playing sport, and history of injury to the ankle were collected. Subjects completed the Foot and Ankle Disability Index (FADI) and the FADI Sport (FADISP) (perceived function) and the single-leg hop for distance (SLH) and anterior reach portion of the star excursion balance test (SEBT) (objective function). If an ankle injury occurred in season, the athlete completed the FADI and FADISP to determine if any change occurred from baseline testing to time of injury. When discharge occurred, the research team was contacted in order to distribute the FADI and FADISP and employ the physical performance tests performed during baseline testing. Each subject was contacted at 1, 3, and 6 months following return to activity to complete the FADI and FADISP. The subjects completed the performance tasks at each time point until the values were within the established minimal detectable change from baseline testing for both SEBT and SLH. Nonparametric sign rank and rank sum tests were used to assess differences within time points and between previous and no previous injury.
RESULTS: Forty-two subjects (mean ± SD age, 19 ± 1 years; height, 178 ± 10 cm; weight, 78 ± 14 kg) sustained an ankle injury during the study period, missing 31 ± 44 days (range, 1-200 days). FADI and FADISP scores were significantly reduced at initial injury (44% and 72%) and discharge (3% and 9%) compared to baseline ($P<.001$). There was no statistical difference in the performance of either physical task at any time point compared to baseline. Twenty-seven of the 42 subjects reported a previous ankle injury. No differences existed between subjects with and without previous injury at any time point for any measure.
CONCLUSIONS: Perceived and objective physical function is near normal for ankle injuries at discharge. Objective function appears to return to baseline at time of discharge while subjectively, subjects may have small deficits in perceived physical function when return to activity is permitted. Previous ankle injury did not influence perceived or demonstrable physical function.
CLINICAL RELEVANCE: The study revealed that patient perception of symptoms and pain aligned with a blinded clinician making the decision to return an injured athlete to sport following rehabilitation. Employing a prospective approach to establishing baseline physical function values for each individual athlete may help bolster the concept of identifying a return to preinjured levels of activity.

SPL57

ARE LOWER EXTREMITY MUSCULOSKELETAL INJURIES ASSOCIATED WITH CONCUSSIONS IN HIGH SCHOOL ATHLETES?

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PURPOSE/HYPOTHESIS: Previous research indicates that concussion increases the risk of lower extremity injuries (LE) after return to sport. However, no study has examined the risk of precedent and subsequent concussion (Conc) and their relationship with a lower extremity injury. Therefore our purpose was to determine if the risk of combined injuries (LE injury-Conc) is elevated in high school athletes based on athlete sport and sex.
NUMBER OF SUBJECTS: Thirty-three thousand three hundred eighty-seven high school athletes were monitored, and 5480 LE injuries and 955 concussions were reported.
MATERIALS/METHODS: Injured athletes were identified by their school athletic trainer (AT) who confirmed a time-loss injury during a team-sponsored practice or game. ATs documented the date, mechanism, and sport of injury. Injured athletes were referred to a board-certified physician for diagnoses and follow-up care. Each athlete completed prescribed treatment and returned-to-sport criteria before returning to play. Cumulative injury proportions were calculated with 95% confidence intervals. Chi-square analyses and risk ratios were used to compare frequency of concussion after RTS following a LE injury. Comparisons were made overall by sex then by matched sports and sex ($\alpha = .05$).
RESULTS: A cumulative incidence of LE injury was 16.4/100 (95% CI: 16.0, 16.8) athletes with a female-to-male rate ratio of 1.1 (95% CI: 1.07, 1.2). The cumulative incidence of concussion was 2.9/100 (95% CI: 2.7, 3.0) athletes with a female-to-male rate ratio of 1.0 (95% CI: 0.92, 1.2). Three hundred twelve athletes sustained a concussion after a LE injury with similar frequency for male (n = 198) versus female athletes (n = 114, $P = .31$). When comparing combined injuries by sex comparable sports, female soccer athletes were more likely to demonstrate higher risks for combined injuries (LE injury-Conc) at approximately 1.4 times greater risk when compared to male athletes within 1 year of recovery ($P = .004$; RR = 1.4; 95% CI: 1.2, 1.7) . High school basketball players were at similar risk of sustaining a concussion after a LE injury ($P = .68$) regardless of sex. Female lacrosse players were at greater risk of sustaining a concussion following a LE injury ($P = .05$; RR = 1.5; 95% CI: 1.1, 2.1) as their male counterparts.
CONCLUSIONS: In general when comparing all high school sports including football there appears a small but significant increased risk for male athletes to suffer a LE injury after concussion. When considering sex comparable sports females seem to be at higher risk for sustaining combined injuries but specifically when considering soccer and lacrosse.
CLINICAL RELEVANCE: This study demonstrates that the ability to return to sport after injury may not indicate resolution of all impairments that raise the risk of subsequent LE injuries or concussions especially in high school athletes. Specific attention should be given to the injury risk for female athletes returning to lacrosse and soccer. Additional studies are warranted.

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SPL58

SECOND ANTERIOR CRUCIATE LIGAMENT INJURY RATES AND CHARACTERISTICS AFTER COMPLETION OF A SECONDARY PREVENTION PROGRAM

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PURPOSE/HYPOTHESIS: Twenty-five percent to 30% of young athletes experience a second ACL injury after return to sport (RTS), and these injuries usually occur early, after few athletic exposures. Other factors besides timing of RTS may also contribute to increased risk of second injury, including sex, age, and graft type. These potential risk factors have not been studied in conjunction with completing a secondary prevention program. Our purpose was to analyze group differences between athletes who did and did not sustain a second ACL injury after completing the ACL-SPORTS protocol and to provide descriptive statistics of the second injuries.

NUMBER OF SUBJECTS: Seventy-nine level 1-2 athletes (40 male) after ACLR.

MATERIALS/METHODS: Enrollment occurred after primary ACLR and rehab upon achieving postop milestones: 12 weeks or greater postoperation, 80% or greater isometric quadriceps strength index (QI), minimal effusion and full ROM. Subjects completed the secondary prevention ACL-SPORTS protocol, including 10 sessions of strengthening, agilities, and plyometrics. All subjects passed stringent RTS criteria prior to returning to level 1-2 activity. Subjects were followed for 2 years after ACLR to assess for occurrence of second ACL injury. Second injury characteristics were recorded, including side, mechanism, and time from primary ACLR to second injury. We used independent *t* tests and chi-square tests of proportions to compare group differences in age, sex, graft type, and time to RTS clearance ($\alpha = .05$).

RESULTS: There were 10 second ACL injuries (5 ipsilateral/5 contralateral, 2 contact/8 noncontact). Second injuries occurred between 8 to 24 months after ACLR (mean, 15 months). The proportion of athletes with second injury differed ($P = .012$) in regards to graft type, with a prevalence of 24% (9/37) in those with hamstring grafts, but only 6% (1/18) in allograft and 0% (0/24) in BPTB. Women were also more likely ($P = .006$) to sustain a second injury, with rates of 23% of women (9/39) versus 3% of men (1/40). Those who had second injuries were on average 5 years younger (17 versus 22 years) and met RTS criteria 1 month earlier (31.5 versus 35.8 weeks).

CONCLUSIONS: In our cohort, younger female athletes with a hamstring autograft were most likely to sustain a second injury, despite completing a secondary prevention program and meeting RTS criteria. Athletes who had second injuries passed RTS criteria 1 month earlier than those that did not. Grindem et al. found that for every 1 month delay in RTS up to 9 months, the rate of knee reinjury was reduced by 51%, suggesting timing of RTS may also be a meaningful risk factor. However, men, older athletes, and young women with BPTB grafts, were less likely to reinjure after completing this program.

CLINICAL RELEVANCE: Our findings suggest that risk factors for second injury following a rehabilitation protocol that included a secondary prevention program include: younger age, female sex, hamstring graft and timing of RTS. Patient education regarding graft selection and the importance of delaying RTS even if RTS criteria are met should be prioritized, particularly in young female athletes returning to level 1-2 sports.

SPL59

CHANGES IN CLINICAL MEASURES AND TISSUE ADAPTATIONS IN COLLEGIATE SWIMMERS ACROSS A COMPETITIVE SEASON

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PURPOSE/HYPOTHESIS: Competitive swimmers incur shoulder pain and pathology. In addition to training volume, certain physical characteristics such as impairments in shoulder endurance or mobility, and tissue adaptations such as posterior capsule thickness (PCT) may be risk factors for injury. No longitudinal studies have collectively examined training volume, shoulder ROM, shoulder endurance and PCT concurrently with pain and swimming related disability throughout the season. Therefore, the purposes of our study were (1) to assess pain, and disability, IR, ER, and horizontal adduction (HADD) ROM and endurance longitudinally over a competitive collegiate season and (2) determine the relationship between training volume and clinical and tissue adaptations.

NUMBER OF SUBJECTS: Thirty Division III swimmers.

MATERIALS/METHODS: A repeated-measures design was used to assess participants at 3 time points: beginning (T1), middle (T2), and end of season (T3). Dependent variables included pain and disability using the Penn Shoulder Score and Disabilities of the Arm, Shoulder and Hand sports module, IR, ER, and HADD ROM using a digital inclinometer, the posterior shoulder endurance test (PSET), and PCT using ultrasound. Reliability of measures were previously established. ANOVAs with repeated measures on time were used to assess longitudinal changes. Follow-up *t* tests were performed to compare the 3 timepoints. Pearson correlation coefficients were performed to assess the relationship between training volume and clinical and PCT adaptations.

RESULTS: Seventeen males and 13 females aged 19.6 ± 1.1 years participated. There was a significant reduction in left and right IR and HADD ROM at all timepoints except HADD T2 to T3 ($P \leq .035$). PSET increased significantly on right ($P = .025$) and left ($P = .036$) at all timepoints. There was no change in pain but a significant reduction in disability from T1 to T3 ($P = .0001$). There was a significant positive correlation between swimming yardage at T1 and T2 and PCT at T3 ($P = .034$ and $P = .028$).

CONCLUSIONS: The results of the current study found a loss of IR and HADD on both shoulders throughout the season. A positive correlation between training yardage and PCT was also found and may explain the ROM loss that was observed. In previous studies, PCT has been related to reduced IR ROM and stiffness. Interestingly, the swimmers reported less disability which may indicate the loss of motion was a positive adaptation. Consistent with this, studies using 3-D videography during freestyle suggest that increased IR during the pull phase and late initiation of ER during recovery phase place swimmers at risk for impingement. Considering reduced swimming disability from T1 to T3, our finding of improved PSET is consistent with prior research identifying greater endurance in those with less pain and disability.

CLINICAL RELEVANCE: Significant reductions in IR and HADD ROM across a swimming season may be positive adaptations due to a reduction in disability. However, further studies are needed to determine if these changes represent risk factors or favorable adaptations in competitive swimmers.

SPL60

JUMP LOAD AND INJURY STATUS IN COLLEGIATE WOMEN'S VOLLEYBALL: A LONGITUDINAL STUDY

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PURPOSE/HYPOTHESIS: External load measures may be used as reference values for clinicians when making return-to-play decisions or when

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monitoring athletes after return to play. Although load measurements have become common in field-based sports, little has been reported in court and jumping-based sports. The purpose of this descriptive study was to quantify normative values of jump load and injury status over the course of a volleyball season and describe jump load upon return to play after injury. We hypothesized that jump load would be significantly lower during the week following return to play than the week before injury.
NUMBER OF SUBJECTS: Sixteen Division I collegiate female volleyball players participated in the study.
MATERIALS/METHODS: Subjects were instrumented with an accelerometer to record jump count frequency (JC) during all 58 practices and 32 matches over a 17-week season. The acute-chronic workload ratio (ACWR) was calculated as a rolling average by dividing subjects' previous week's JC by their JC over the previous 4 weeks. Injury status was monitored using a weekly, modified Oslo Sports Trauma Research Centre Overuse Injury Questionnaire that detailed the severity of any pain and the effect of that pain on participation and performance. Injuries were defined as a condition that resulted in time lost from any practice or game. Means of 20 multiple imputation repetitions using fully conditional specification replaced missing JC data. Descriptive statistics were computed and paired *t* tests compared subjects' JC in the week before injury and the week after returning to play ($\alpha = .05$).
RESULTS: In general, weekly JC decreased throughout the season, with team averages ranging from 602 ± 311 jumps in week 1 to 268 ± 150 jumps in week 8, and healthy individual ranges between 61 and 1387 jumps in any given week. The average weekly ACWR ranged from 0.31 to 1.22 throughout the season. There were 8 injuries reported across 5 subjects. Questionnaire scores averaged 13.0 ± 14.1/100 (range, 0-77) in uninjured cases, and 58.6 ± 21.1 (range, 28-83) in injured cases. Two subjects missed more than 1 consecutive day due to injury, with these cases registering the 5 highest individual ACWR in the weeks following return to play. There were no significant differences in JC between the week before and after injury (mean difference, 17.9 ± 128; $P = .73$).
CONCLUSIONS: Jump load is highly variable over the course of a women's volleyball season. With high ACWR levels and no apparent reduction in load in the week following injury, volleyball players may be returned to full participation in their sport without respect for the required load.
CLINICAL RELEVANCE: Jump load is an interesting, yet understudied analytic that, when monitored, can help manage athletes' workloads. Clinicians may need to monitor discrete JC values and ACWR in healthy athletes to establish normative levels of load. Using these baseline values, clinicians can make informed decisions when rehabilitating athletes and returning them to play, as an athlete may not have the requisite fitness to accommodate high increases in workload after injury.

SPL61

SHORT-TERM EFFECTS OF 4-WEEK REAL-TIME GAIT RETRAINING ON TRUNK KINEMATICS AND PATELLOFEMORAL JOINT STRESS IN RUNNERS

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PURPOSE/HYPOTHESIS: Patellofemoral pain is the most common overuse injury among runners and is thought to be the result of elevated patellofemoral joint (PFJ) stress. One previous study showed that an around 7° increase in trunk flexion during running led to an immediate significant reduction in PFJ stress. However, it remains unclear short-term effects of such gait modification. This study aimed to examine short-term effects of gait retraining with real-time visual feedback on trunk flexion angle and PFJ stress in runners. We hypothesized that there would be a significant increase in trunk flexion angle and reduction in PFJ stress following retraining.
NUMBER OF SUBJECTS: This is an ongoing study. Ten asymptomatic recreational runners have completed the study (5 male, 5 female; mean ± SD age, 23.8 ± 3.5 years).
MATERIALS/METHODS: All subjects received gait retraining, which was designed to increase trunk flexion by 10°, once a week for 4 weeks. Real-time visual feedback of trunk angle was provided while subjects ran on a treadmill. Feedback frequency was gradually reduced to facilitate acquisition and internalization. Three-dimensional running analyses were performed prior to gait retraining (baseline), at weeks 2, 3, and 4 before training (retention), and at 1-month follow-up (retention). Automaticity of movement was assessed under dual-task condition at 1-month follow-up. Trunk and lower extremity kinematics (200 Hz, Qualisys) and ground reaction force (1000 Hz, Bertec) were recorded during treadmill running at a constant speed. PFJ stress was computed using a previously described model that incorporates subject specific parameters (ie, knee flexion angle and knee extensor moment) and data from the literature (ie, knee moment arms and joint contact area). One-way repeated-measures ANOVAs, with post hoc Bonferroni tests, were used to assess changes in mean trunk flexion angle and peak PFJ stress during stance phase of running overtime. Paired *t* tests were used to compare differences between single- and dual-task conditions.
RESULTS: Subjects successfully increased trunk flexion angle by 7.2°, 6.9°, and 8.0° at weeks 2, 3, and 4, respectively, and demonstrated 9.4 increase at 1-month follow-up, compared to baseline ($P<.001$). Significant reductions of PFJ stress were observed at all time points ($P<.001$). Peak PFJ stress decreased by 5%, 9%, and 10% at weeks 2, 3, and 4, respectively, and reached 16% reduction at 1-month follow-up. There were no significant differences in trunk angles (15.9° versus 16.9°) or PFJ stress (12.1 versus 12.0 MPa) between single- and dual-task conditions.
CONCLUSIONS: Gait retraining with real-time visual feedback was effective in modifying trunk flexion angle and reducing PFJ stress during running in the short term. Runners demonstrated automaticity of the learned motor skill at 1 month. Further studies are warranted to examine how the gait retraining effects pain and function in runners with patellofemoral pain.
CLINICAL RELEVANCE: Gait retraining focused on forward trunk lean posture can be used as an alternative strategy to reduce PFJ stress during running.

SPL62

SELF-REPORTED FUNCTION IMPROVES UP TO 2 YEARS AFTER RETURN TO SPORT FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: While studies have identified that long-term functional outcomes are suboptimal for many individuals following ACL reconstruction (ACLR), there is limited published information on functional changes over time in young, active individuals after ACLR. The purpose of this study was to investigate changes in self-reported knee function from the time of return to sport clearance (RTS) to 5 years post RTS. The tested hypothesis was knee function would improve through 2 years post RTS and decline at 5 years post RTS.
NUMBER OF SUBJECTS: Twenty-three young, active participants (17 female, 6 male) after primary, unilateral ACLR from a prospective, longitudinal study of ACLR outcomes were evaluated at RTS clearance and at 1, 2, and 5 years post RTS (mean ± SD age at 5-year follow-up, 21.62 ± 1.90 years).
MATERIALS/METHODS: At each testing session, all participants completed the Knee injury and Osteoarthritis Outcome Score (KOOS) (5 subscales: Pain, Symptoms, Activities of Daily Living [ADL], Sport and Recreation [Sport], and Quality of Life [QOL]). Repeated-measures ANOVA evaluated change in each KOOS subscale over time. Post hoc tests were conducted, as appropriate ($P<.05$ for all analyses).
RESULTS: KOOS Symptoms ($P = .029$), Sport ($P = .014$), and QOL ($P<.001$) subscales demonstrated significant differences between time points, while

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the Pain (P = .064) and ADL (P = .081) subscales did not. Post hoc tests revealed that the Symptoms subscale improved between RTS (mean ± SD, 84.91 ± 13.82) and 2 years (92.61 ± 9.16, P = .002), but did not differ between any other time interval (1 year, 89.56 ± 9.80; 5 years, 89.52 ± 13.81; all, P>.05). The Sport subscale demonstrated significant improvement from RTS (84.14 ± 15.20) to 1 year (90.87 ± 10.73, P = .017), RTS to 2 years (93.48 ± 10.38, P = .001), and RTS to 5 years (92.61 ± 13.47, P = .007), but did not show differences at any intervals between 1, 2, and 5 years (all, P>.05). The QOL subscale demonstrated significant improvements from RTS (70.52 ± 16.30) to 1 year (82.52 ± 15.27, P = .006), RTS to 2 years (88.70 ± 12.33, P<.001), RTS to 5 years (88.13 ± 15.03, P<.001), and 1 year to 2 years (P = .034). The QOL subscale did not differ between 1 year and 5 years (P = .100) or from 2 years and 5 years (P = .809).

CONCLUSIONS: KOOS Symptoms, Sport, and QOL subscales all improved over time from RTS. In these 3 subscales, improvements were noted from RTS to 1 and 2 years, but do not demonstrate improvement from 1 year to 5 years post RTS. On average, subscale scores decline from 2 years to 5 years, but this was not statistically significant.

CLINICAL RELEVANCE: The KOOS Symptoms, Sport, and QOL subscales have been identified as being most important to patients after ACLR. This analysis suggests that functional outcomes improve from RTS through 2 years post RTS, but may not change or begin to decline thereafter. Evaluation of the association between KOOS changes and other measures of functional performance would be informative. Further studies should track functional changes over time to inform interventions that may mitigate risk of functional decline.

SPL63

CHILDREN DEMONSTRATE ASYMMETRIC MOVEMENT PATTERNS DURING SINGLE-LEG HOP 9 MONTHS AFTER PEDIATRIC ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: While the number of anterior cruciate ligament reconstructions (ACLR) is increasing in the skeletally immature patient population, there is little published evidence to guide rehabilitation and return to sport (RTS) decision-making after pediatric ACLR (pACLR). A recent consensus statement from the International Olympic Committee (IOC) advocates that applying RTS criteria developed for the skeletally mature to the skeletally immature population after ACLR may not be appropriate and suggests that normalizing movement mechanics between limbs may be more appropriate. The purpose of this study was to examine biomechanical patterns during a single-leg hop (SLH) task in children after pACLR, a typical measure of functional performance in this patient population. It was hypothesized that between-limb asymmetries would be observed.

NUMBER OF SUBJECTS: Eight subjects were evaluated after primary, unilateral, physeal-sparing pACLR (8 male; ITB-band autograft: mean ± SD age, 11.9 ± 1.94 years; mean time from surgery, 9.64 ± 3.47 months) as part of a longitudinal study.

MATERIALS/METHODS: Biomechanical variables of interest were evaluated during the takeoff phase of a SLH for distance task utilizing a 12-camera 3-D motion-analysis system with 4 embedded force plates. Each subject performed 3 trials on each limb. Variables of interest included: SLH distance; peak knee flexion angle (PKFA); peak internal knee extension moment (PIKEM); peak internal knee abduction moment (PIKABM); peak vertical ground reaction force (vGRF); and peak anterior ground reaction force (aGRF). All kinetic variables were normalized by body mass (kilograms). Differences in variables of interest between limbs were compared with paired-samples t tests (P<.05).

RESULTS: There were no between-limb differences in SLH distance (involved [INV], 1.16 ± 0.34 m; uninvolved [UNINV], 1.18 ± 0.29 m; P = .292); PKFA (INV, 52.70° ± 7.41°; UNINV, 53.08° ± 6.15°; P = .790), or in vGRF (INV, 17.13 ± 1.86 Nm/kg; UNINV, 17.11 ± 2.12 Nm/kg; P = .914). The involved limb demonstrated significantly less PIKEM (0.82 ± 0.52 Nm/kg) than the uninvolved limb (1.12 ± 0.41 Nm/kg, P = .007). The involved limb demonstrated significantly less aGRF (3.94 ± 1.26 Nm/kg) than the uninvolved limb (4.23 ± 0.26 Nm/kg, P = .009).

CONCLUSIONS: Children in the later phases of rehabilitation after pACLR demonstrate asymmetric lower extremity biomechanics during the takeoff phase of a SL hop task. Future work is needed to further evaluate the presence of other movement asymmetries during landing and other tasks, as well as the potential impact of observed asymmetries on sports participation and risk of second ACL injury.

CLINICAL RELEVANCE: Biomechanical asymmetries were observed between limbs despite no significant difference in hop distance, supporting the IOC's stance that movement quality, rather than performance-based symmetry, on SL hop tests may be a key factor in determining RTS readiness after pACLR. Consideration for incorporating a quality of movement measure in RTS decision making for this patient population may be beneficial.

SPL64

CHARACTERIZATION OF CERVICAL SPINE IMPAIRMENTS IN CHILDREN AND ADOLESCENTS POST CONCUSSION

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PURPOSE/HYPOTHESIS: Patients with concussion may exhibit with cervical spine impairments. However, the nature and extent of cervical postconcussion impairments is unknown. Accurate characterization of cervical postconcussion impairments is needed to develop targeted physical therapy interventions. Therefore, the purpose of this study was to characterize the type, frequency and severity of cervical impairments in children and adolescents referred for physical therapy after concussion.

NUMBER OF SUBJECTS: A retrospective chart review was conducted for 73 consecutive children and adolescents between the ages of 8 to 18 years who received physical therapy following a concussion. Data were excluded if a patient was diagnosed with concomitant neurological injuries or had a history of neurological disorders such as epilepsy.

MATERIALS/METHODS: Cervical physical therapy assessment data collected during the initial evaluation was extracted. The extracted data were classified into 6 broad impairment categories. These categories included posture and generalized movement quality, myofascial tension to palpation, joint mobility, muscle strength and endurance, proprioceptive testing, and special tests for ligamentous stability and upper extremity radicular symptoms. The frequency and intensity of cervical impairments within and across the 6 categories were reported.

RESULTS: Ninety-two percent of patients demonstrated impairments in at least 3 out of 6 categories whereas 56% demonstrated impairments in at least 4 out 6 categories. Out of 6 impairment categories, posture (99%) and myofascial impairment (98%) demonstrated highest impairment frequency followed by joint mobility (86%) and muscle strength (62%). Joint proprioception was the least evaluated impairment category.

CONCLUSIONS: High prevalence of cervical spine impairments was observed with muscle length, joint mobility and muscle strength being most commonly impaired. The categories of impairments examined in this cohort were consistent with the recommendations of the most recent clinical practice guidelines for neck pain. This study provides preliminary data

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to support the development a targeted physical therapy approach to address documented cervical impairments in children and adolescents following concussion.

CLINICAL RELEVANCE: Despite the increased recognition of the possibility of cervical spine impairments after concussion, the extent and characterization of cervical spine involvement is yet to be established, especially in children and adolescents. This study will provide valuable insights into the extent and nature of cervical spine impairments after concussion.

SPL65

PHYSICAL ACTIVITY ENGAGEMENT AND PERCEIVED EFFECTS IN THE FIRST 28 DAYS AFTER CONCUSSION

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PURPOSE/HYPOTHESIS: Concussions are prevalent with potentially lasting effects for young, otherwise healthy adolescents. Physical therapists are often involved in providing therapeutic interventions for patients with concussions to facilitate recovery. Emerging evidence indicates re-engagement in physical activities (PA) is important for recovery processes but poorly understood. The aim of this study was to enhance understanding of patients' experiences with re-engagement in PA over the first 28 days after concussion.

NUMBER OF SUBJECTS: Twenty-seven youth (22 athletes) aged 13 to 17 years with concussion (13 male, 14 female).

MATERIALS/METHODS: The current study was part of a larger, mixed-methods project that included daily online surveys tracking symptoms and self-reported PA experiences, activity tracking from wearable technology, and summative semi-structured interviews. Case-by-case analysis of PA experiences from survey responses and interviews were used to characterize PA patterns, compare recovery trajectories and perceptions, and identify PA-related themes.

RESULTS: Survey completion rates ranged from 60% to 90% (mean, 82%). Participants reported little engagement in PA over the month in general, with only 1 participant reporting PA 3 or more days in the first week, 14 (51%) in the second week, 11 (40%) in the third week, and 12 (44%) in the fourth week. In the fourth week, 6 participants (22%) continued to report limiting PA due to injury-related factors. Common reasons for not engaging in PA after the first 2 weeks included sport out of season, school responsibilities, parent limitations, and poor communication with health care providers regarding restrictions. Of the 16 participants who engaged in PA in the first week, 7 (44%) reported PA as more difficult than prior to injury and 6 (38%) reported a mild increase in symptoms with PA. In the fourth week, of the 21 who reported engaging in PA, 6 (29%) perceived the PA as more difficult and 3 (14%) reported mild symptoms with PA. Recovery rates varied overall, with 4 participants reporting slow or no resolution of symptoms, and 4 reporting a regression or erratic recovery pattern.

CONCLUSIONS: The results of the study provide insight into real-world PA re-engagement behaviors and patient perceptions of their PA experiences. Lack of PA was linked primarily to physician restrictions or symptoms early after injury and shifted to noninjury factors later. Some participants continued to report PA as more difficult and symptom-inducing even in the later weeks. Re-engagement in PA after concussion is complex and influenced by factors directly and indirectly related to the injury, as well as factors not related to injury.

CLINICAL RELEVANCE: Physical therapists and other clinicians can use the results from this study to increase their awareness and understanding of the patient experience in the first 4 weeks after injury. A deeper understanding and appreciation of patient experiences can aid clinicians' ability to help patients with concussion navigate the complex PA re-engagement processes.

SPL66

PARALYMPIC TRACK-AND-FIELD CLASSIFICATION AS A PARTICIPATION BARRIER: A PHENOMENOLOGICAL STUDY OF EVENTS LEADING TO THE RIO PARALYMPIC GAMES

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PURPOSE/HYPOTHESIS: Classification is the process by which Paralympic athletes are put into groups based on their functional impairments to ensure fair competitions. The purpose of this study was to examine the US Track and Field team classification issues during the 2016 season, their effects on team members, including the perspective of some classifiers.

NUMBER OF SUBJECTS: US Paralympic Track and Field hopefuls for the Rio Paralympics (athletes = 83), staff (n = 21), family (n = 4), and classifiers (n = 3).

MATERIALS/METHODS: Subjects were observed and select participants, identified through purposeful snowball sampling, were interviewed. Observation notes taken and semi-structured interviews recorded for transcription. Relevant social media posts and media coverage analyzed utilizing Morgan's practice community to theoretically frame this phenomenological study. Study rigor was established through triangulation, member checking, peer debriefing, and maintenance of a clear audit trail.

RESULTS: Classification is seen by some as a barrier to new athlete recruitment and the continued participation in elite level adaptive sport. Classification and event management issues involving ambulatory sprinters and wheelchair racers produced common themes related to psychosocial and potential ethical issues of the classification process, as well as identifying potential opportunities for system improvement. A lack of transparency and inconsistency by Paralympic officials and classifiers led to a significant mistrust of the classification system by athletes. Potential opportunities for improvement include increased athlete involvement in policy decisions, transparent communication between athletes, coaches, classifiers, and Paralympic officials of the factors involved in policy decisions, and examination of the influence of specific impairments and performance enhancing technology in specific events.

CONCLUSIONS: Though intended to ensure fair competition, our results indicate that the current classification process is embroiled in controversies that detract from the validity of the classification system. Addressing concerns of fair play are essential to all sports. In particular, the appearance of illegitimacy within the adaptive sport community threatens the Paralympic movement.

CLINICAL RELEVANCE: Medical classifiers are often physical therapists. The medical classifiers interviewed for this study noted the importance of the classifier in ensuring fair competition for all participants, including the importance of not disadvantaging the entire field for the benefit of 1 in questionable cases. This mindset is consistent with the APTA's Code of Ethics and core values. Physical therapists can also serve the Paralympic movement by producing research to help improve the classification system and process.

SPL67

PEAK VERTICAL GROUND REACTION FORCE AND CENTER-OF-MASS VERTICAL EXCURSION ARE PROSPECTIVELY ASSOCIATED WITH INJURY IN ELITE CROSS-COUNTRY RUNNERS

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PURPOSE/HYPOTHESIS: Minimal consensus exists regarding specific biomechanical causes that contribute to lower extremity (LE) running-related injuries. Ground reaction forces (GRF) and joint kinematics are often regarded as important; however, few prospective studies have been conducted, especially involving elite distance runners. The purpose was to identify differences in preseason healthy running mechanics between athletes who did and did not sustain a LE musculoskeletal injury during the subsequent season.

NUMBER OF SUBJECTS: Sixty-three (35 female) NCAA Division I cross-country runners participated. Participating athletes were healthy at the start of the cross-country season, defined as the ability to fully participate in regularly scheduled mileage and not currently seeking medical attention for a LE injury.

MATERIALS/METHODS: Prior to the start of the season, whole body kinematics and GRFs were recorded while running at preferred speed. LE musculoskeletal injuries that required medical attention were monitored throughout the season by the teams' athletic trainers and reported on a weekly basis. Running mechanics commonly postulated to be associated with running-related injuries were compared between those that did and did not sustain an injury using a 2-way ANCOVA, with injury status and sex included as independent variables and speed as a covariate. Biomechanical variables of interest included step rate, stride length, foot inclination and knee flexion angle at initial contact (IC), center of mass (COM) vertical excursion, base of gait (BOG) at midstance, vertical impact peak magnitude and loading rate, peak vertical GRF (VGRF), and braking impulse.

RESULTS: No interaction terms were present in any models; only main effects for injury status are reported. Compared to noninjured athletes, injured athletes displayed greater peak VGRF (26.3 ± 2.5 N/kg versus 24.9 ± 2.4 N/kg, $P = .033$) and COM vertical excursion (9.6 ± 1.3 cm versus 8.8 ± 0.8 cm, $P = .041$), with a correlation between peak VGRF and COM vertical excursion of $r = 0.706$ ($P<.001$). No significant main effect for injury status was observed for step rate, stride length, foot inclination angle and knee flexion angle at IC, BOG at midstance, vertical impact peak magnitude, loading rate, or braking impulse.

CONCLUSIONS: Greater peak VGRF and COM vertical excursion are prospectively associated with LE musculoskeletal injuries in male and female collegiate runners. Other common biomechanical variables such as vertical impact peak and loading rate were not different between those that did and did not sustain an injury during the season.

CLINICAL RELEVANCE: Preseason screening of peak VGRF and COM vertical excursion may be useful to identify distance runners at increased risk of injury. The strong correlation between peak VGRF and COM vertical excursion suggests either variable may be monitored. Retraining strategies targeting either of these biomechanical variables may be useful to reduce injury risk. These findings need to be confirmed when training volume and prior injury are considered.

SPL68

LYSIS OF ADHESIONS FOR LOSS OF MOTION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A MATCHED-CONTROL ANALYSIS

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PURPOSE/HYPOTHESIS: Arthroscopic lysis of adhesions (LOA) is commonly used to treat refractory loss of motion following anterior cruciate ligament (ACL) reconstruction, however, little is known regarding the impact that these conditions and additional surgical procedures have on patient recovery. Therefore, the purpose of this study was to compare objective and subjective knee function between patients who require an arthroscopic LOA and a matched control following an ACL reconstruction. We hypothesized that patients who require a LOA will require more time to achieve objective discharge criteria, demonstrate poorer overall knee function values at return-to-play (RTP), and exhibit lower subjective knee function at 2 years.

NUMBER OF SUBJECTS: One hundred thirty-one patients were identified using ICD-9/10 diagnosis, and CPT procedural codes for study eligibility, of whom 29 (LOA group) met the sample criteria. The control group (n = 29) was matched by age, sex and surgical profile. The overall mean ± SD sample age was 24.5 ± 7.2 years with 30 (52%) males and a BMI of 25.5 ± 5.0 km/m^2.

MATERIALS/METHODS: A matched case-control study was conducted from 2014 to 2017 using a single surgeon patient sample. At RTP, we examined the differences in knee ROM, Y Balance anterior reach, single-leg, hop, subjective knee function (IKDC, 0-87), and time to RTP between groups. In addition, at 2 years patients were surveyed using the single assessment numeric evaluation (SANE) score to assess subjective knee function (0%-100%). Limb symmetry indices were calculated for between group comparisons using an independent samples t test. Statistical significance was set at $\alpha = .05$.

RESULTS: At the time of RTP, the LOA group demonstrated lower mean IKDC scores (77.2 ± 14.5 versus 84.8 ± 15.4, $P = .046$) scores, lower single-leg-hop symmetry (93.1% ± 7.4% versus 98.4% ± 3.2%, $P = .050$), and no differences in timing to meet functional discharge criteria (8.7 ± 2.5 months versus 9.0 ± 2.3 months, $P = .743$) when compared to the control group. The mean limb symmetry indices for each functional assessment tool exceeded the 90% threshold for both groups. No other functional comparisons were different between groups at RTP ($P>.050$). Subjective knee function at 2 years was not statistically different between the LOA and control groups, respectively (85.8% ± 14.9% versus 88.0% ± 10.8%, $P = .743$).

CONCLUSIONS: The results of this study do not support our original hypotheses. Specifically, LOA for arthrofibrosis after ACL reconstruction appears to be effective for allowing similar timing for RTP, with decreased IKDC subjective scores, and single-leg hop symmetry, however the LOA group still exceeded the 90% symmetry threshold for all functional testing. At 2 years, patients receiving LOA report similar knee function when compared to matched controls.

CLINICAL RELEVANCE: This study supports the use of LOA as an effective treatment for refractory cases of arthrofibrosis after ACL reconstruction. We recommend that patients receiving LOA after ACL reconstruction be held to similar functional discharge criteria, and RTP timelines.

SPL69

ASYMMETRIES IN QUADRICEPS STRENGTH AND GROUND REACTION FORCE DURING COUNTERMOVEMENT JUMPS ARE RELATED AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Asymmetries in quadriceps strength and lower extremity take-off and jump landing biomechanics post anterior cruciate ligament reconstruction (ACLR) are well documented in the literature; however, it is unclear if the 2 are associated and if this relationship is affected by the time since surgery. The purpose of this investigation was to evaluate the relationship between quadriceps strength limb symmetry index (LSI) and countermovement jump (CMJ) force LSI.

NUMBER OF SUBJECTS: Two hundred forty-one individuals (mean ± SD age, 23.6 ± 10.3 years; 125 female) that underwent unilateral ACLR prior to testing (7.0 ± 3.0 months).

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MATERIALS/METHODS: All measures were obtained as part of routine clinical care within a single institution, and stored within an electronic database. Records were extracted for all individuals that performed both quadriceps strength testing and CMJ testing at a single clinic visit. Quadriceps peak torque was obtained over 5 trials during isokinetic testing (60°/s) and was recorded for each limb. Ground reaction forces during CMJ were recorded from each limb across 3 trials. Average vertical force during the eccentric phase and concentric phase, as well as peak and average landing forces were calculated for each CMJ. Limb symmetry indices (LSI = [involved/uninvolved] × 100%) were calculated for each variable with Pearson correlations performed between quadriceps peak torque LSI and the LSI of each CMJ variable. Possible confounders (sex, age, mechanism of injury (contact versus noncontact), and time postsurgery) were explored using simple linear regression.

RESULTS: Quadriceps peak torque LSI was linearly associated with CMJ concentric force LSI (r = 0.46, P<.001). Quadriceps peak torque LSI had significant but weaker linear correlations with CMJ LSI eccentric force (r = 0.17, P = .008), average landing force (r = 0.24, P<.001), and peak landing force (r = 0.19, P = .003). The relationship between quadriceps peak torque LSI and each of the CMJ LSI variables was not affected by any of the potential confounders.

CONCLUSIONS: Quadriceps strength asymmetry was associated with asymmetry in CMJ forces; however, the correlations were only moderate at best. The relationship was strongest during take-off, with approximately 20% of the variance in CMJ concentric force asymmetry being explained by quadriceps strength asymmetry. These results indicate that each test may provide unique information relative to strength and movement asymmetries.

CLINICAL RELEVANCE: CMJ asymmetry cannot be directly attributed to quadriceps strength, and each of these components must be assessed individually. Quadriceps strength is only one of many possible factors that can contribute to CMJ asymmetry, supporting the need for interventions such as movement retraining as part of the rehabilitation process for individuals following ACLR. Concentric isokinetic strength testing was weakly correlated with force asymmetries during the eccentric movement phases of the CMJ, suggesting other contraction modes of strength testing should be considered.

SPL70

REHABILITATION DURATION IS A PRIMARY PREDICTOR FOR RETURN TO PREINJURY LEVEL OF SPORTS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Return to preinjury level of sports (PLS) is one of the successful outcomes after anterior cruciate ligament reconstruction (ACLR) surgery. Factors that predict return to PLS are not well determined. The purpose of this study was to determine the predictors for return to preinjury level of sports after ACLR.

NUMBER OF SUBJECTS: Eighty-eight.

MATERIALS/METHODS: Participants who are 1 to 5 years post ACLR completed a survey asking about their preinjury and postsurgery sport participation levels, knee injury profile, rehabilitation periods, and time to return to sport-related activities such as running. Participants were also asked to answer the question of whether they returned to the same preinjury level of frequency, duration, and intensity of sports. Patients' characteristics (age, sex, BMI, time from injury to surgery), injury variables (concomitant knee injuries, mechanism of injury), duration of rehabilitation, and return to specific sport-related activity variables were explored. Univariate and multivariate logistic regression were used to determine the predictors of returning to PLS.

RESULTS: Eighty-eight patients (mean ± SD age, 27.1 ± 6.6 years; 2 female) completed the survey with an average of 2.1 ± 1.2 years after ACLR, of which 10 returned to their PLS. The median time from injury to surgery was 6.6 months. Univariate predictors for return to PLS were baseline activity level (odds ratio [OR] = 5.46, P = .039), time from injury to surgery (OR = 9.19, P = .043), rehabilitation duration (OR = 5.25, P = .019), and the ability to run 4 months or less after surgery (OR = 11.06, P = .026). Patients who played competitive sports before injury were more likely to return to their PLS compared to those who played recreational sports. Patients who had their surgery occurred 6 months or less after injury, those who were able to run 4 months or less after surgery, and patients who spent more time in rehabilitation (greater than 4 months) were more likely to return to their PLS. All Patients who returned to their PLS were able to cut and pivot before 8 months (100%) compared to those who did not return (0%). No other variables were found to be predictors for return to PLS including age, BMI, mechanism of injury, and concomitant knee injury. The multivariate analysis revealed that return to preinjury level of sports is only predicted by rehabilitation duration (OR = 6.85, P = .042).

CONCLUSIONS: Several factors including baseline activity level, time from injury to surgery, and individual's ability to run, cut and pivot earlier after ACLR are predictors of returning to PLS. However, the multivariate analysis showed that longer period of rehabilitation after ACLR is the only predictor of returning to preinjury level of sports. This suggests that adequate time of rehabilitation after ACLR is a key factor for the return to PLS.

CLINICAL RELEVANCE: Time from injury to surgery, the ability to perform specific sport-related activities, and rehabilitation duration can be considered during the decision making of clearing patients to return to preinjury level of sports after ACLR.

SPL71

CONTRIBUTIONS FROM LOWER EXTREMITY JOINTS TO ABSOLUTE WORK IN INDIVIDUALS AFTER ACHILLES TENDON RUPTURE: APPLYING THE CLEW APPROACH

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PURPOSE/HYPOTHESIS: Changes in peak power during running and jumping reported in individuals after Achilles tendon rupture provide information at an instant in time. A constituent lower extremity work (CLEW) approach presents work (power over an interval of time) done by the joints and foot relative to the absolute work graphically in a pie chart. This approach has clinical utility in summarizing the altered movement strategy which may occur with injury. This study applies the CLEW approach to compare individuals with and without Achilles tendon rupture during a hopping task.

NUMBER OF SUBJECTS: Eleven individuals 1 to 3 years post Achilles tendon repair, 10 healthy controls.

MATERIALS/METHODS: Kinematic and kinetic data were collected using an 8-camera motion capture set-up and force plate. Participants did twenty-five repetitive hops, of which 10 hops from the middle of the trial were used for analysis. Six-degree-of-freedom powers were calculated at 4 constituents (distal foot, ankle, knee, hip) of the stance limb, and constituent work was reported as a percentage of absolute limb work. Differences between healthy controls, uninjured side, and injured side were assessed with 1-way ANOVA. Tendon elongation measured via ultrasound and Achilles tendon Total Rupture Score (ATRS) were collected in individuals with rupture for descriptive purposes.

RESULTS: Individuals with rupture had 1.8 ± 0.7 cm of tendon elongation and an ATRS score of 89 ± 14/100. There were no differences in jump height (P = .64) or absolute limb work (P = .37). In take off, the knee did increasingly more positive work from controls to uninjured side to injured side (mean ± SD control, 10% ± 3%; uninjured, 12% ± 3%; injured, 14%

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± 1%; P = .001) with significant pairwise comparisons between controls and the injured side (P = .001) and between uninjured and injured sides (P = .03). The ankle did progressively less work across groups (control, 35% ± 4%; uninjured, 33% ± 4%; injured, 28% ± 4%; P = .001), with significant pairwise comparisons between controls and the injured side (P = .001) and between uninjured and injured sides (P = .04). There were no differences in relative work at the hip or distal foot (P>.05). In landing, the knee did increasingly more eccentric work across groups (control, 7% ± 3%; uninjured, 7% ± 2%; injured, 10% ± 2%; P = .03). There were no differences in relative work done by the hip (P = .26), ankle (P = .07), or distal foot (P = .14).

CONCLUSIONS: In well-recovered individuals post Achilles tendon rupture, the knee appears to compensate for ankle dysfunction. These compensations did not seem to affect the relative contributions of the hip or distal foot. The CLEW approach was able to detect differences between groups.

CLINICAL RELEVANCE: Along with standard care, physical therapy may want to address knee health in individuals after Achilles tendon rupture. Additionally, the CLEW approach may be a clinically useful way to graphically assess changes in task strategy with injury.

SPL72

HIP ABDUCTION STRENGTH RELATIONSHIP TO SINGLE-LEG STEP-DOWN TASK IN PROFESSIONAL BASEBALL PLAYERS

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PURPOSE/HYPOTHESIS: The lower extremity (LE) and lumbopelvic region play a crucial role in transmitting energy and forces through the kinetic chain during throwing and pitching. Adequate strength and motion is necessary to optimize performance and mitigate injury. Prior studies indicate pitchers with deficits in lumbopelvic control had decreased pitching performance and increased risk of injury. Identification of specific muscle impairments associated with lumbopelvic and LE control can enable the development of targeted interventions. The single-leg step-down (SLSD) is a dynamic task that requires lumbopelvic and LE dynamic performance. The purpose of this study was to determine if hip abductor strength relates to SLSD performance. We hypothesize that greater hip abductor strength will be related to better performance as evidenced by less movement variations in the lumbopelvic and LE during the SLSD task.

NUMBER OF SUBJECTS: One hundred thirty professional baseball players (mean ± SD age, 22 ± 2.1 years); 61 position players, 69 pitchers.

MATERIALS/METHODS: Players attended 1 test session. Hip abductor strength was measured in a side lying position with a handheld dynamometer. The force (kilograms) measured during 2 maximal isometric contraction trials on each leg and expressed as a percentage of body weight; the average used for data analysis. The SLSD was performed as a step-down from an 8-inch box, tapping their nonstance heel on the floor and return to the box; twice on each leg. Performance of the SLSD was recorded with cameras in the frontal and sagittal planes. Dartfish video software was used to measure ankle dorsiflexion, knee flexion, hip flexion, trunk forward flexion, trunk lateral lean, knee valgus, and pelvic drop. The lead leg was defined as contralateral to the throwing arm and the trail leg was ipsilateral.

RESULTS: For position players, hip strength was not related to the joint angles during the SLSD task for the lead and trail legs. For pitchers lead leg, decreased hip abductor strength was associated with greater knee valgus (r = −0.24, P = .05). For pitchers trail leg, decreased hip strength was associated with greater pelvic drop (r = −0.28, P = .02).

CONCLUSIONS: This study indicates that hip abductor weakness in pitchers relates to movement deviations in the LE and lumbopelvic region during the SLSD task. The SLSD is a dynamic functional task requiring control of the trunk and LE, and may be a meaningful clinical test to identify lumbopelvic control deficits related to hip abductor weakness. Further research is needed to investigate other muscle impairments related to poor LE and lumbopelvic control and injury risk.

CLINICAL RELEVANCE: Hip abductor strength is of particular importance for baseball pitchers in order to minimize lumbopelvic movement deviations related to poor pitching performance and missed days of play due to injury. Hip abductor strength weakness may impact pitchers secondary to the demand of high force transfer from the LE to trunk during pitching.

SPL73

LIMB SYMMETRY AND SUFFICIENCY AMONG ADOLESCENTS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Return to sport (RTS) decision-making following anterior cruciate ligament reconstruction (ACLR) frequently involves strength and performance limb symmetry calculations without measures of absolute performance, or limb sufficiency. The purpose of this study was to test the hypothesis that the proportion of young athletes demonstrating both limb symmetry (SYMM) and sufficiency (SUFF) at time of RTS after ACLR would increase over the subsequent 2 years.

NUMBER OF SUBJECTS: One hundred four participants (mean ± SD age, 16.9 ± 3.4 years; 72 female) following ACLR (ACLR group) completed testing within 4 weeks of medical clearance to RTS, 12 months post RTS, and 24 months post RTS. Forty-six uninjured control participants (CTRL group: mean ± SD age, 17.0 ± 2.3 years; 31 female) completed a one-time testing session in order to determine strength and hop SUFF cutoff scores.

MATERIALS/METHODS: At each testing session, all participants completed isometric quadriceps strength testing and a battery of 4 single limb hop tests (single hop, triple hop, crossover hop, timed hop). SYMM for all performance tests was defined as 100% ± 10% limb symmetry ([involved limb/uninvolved limb] × 100%) and SUFF for all tests was defined by cutoff scores of less than 1 standard deviation below mean scores of CTRL group for each measure. Chi-square tests determined changes in the proportion of the ACLR group meeting SYMM and SUFF for all strength and battery of hop tests during the 2 years following RTS.

RESULTS: The proportion of athletes who met both SYMM and SUFF increased from RTS (41% and 17% for strength and hop testing, respectively) to 12 months post RTS (59%, P<.01 and 39%, P<.01, respectively), and from 12 months post RTS to 24 months post RTS for strength only (46%, P = .03; hop testing, 42%; P = .61). The proportion of athletes who achieved strength or hop testing SYMM only increased from RTS (44% and 56%, respectively) to 12 months post RTS (63%, P = .004 and 70%, P<.01, respectively), and from 12 months post RTS to 24 months post RTS (50%, P = .04 and 81%, P<.01, respectively). The proportion of athletes who achieved strength and hop SUFF only increased from RTS (76% and 30%, respectively) to 12 months post RTS (91%, P<.01 and 53%, P<.01, respectively), but not from 12 months post RTS to 24 months post RTS (89%, P = .74 and 51%, P = .89, respectively).

CONCLUSIONS: In accordance with our hypothesis, the proportion of young athletes after ACLR who are able to achieve SYMM and SUFF for strength and hop measures increased during the first 24 months following RTS.

CLINICAL RELEVANCE: Clinicians should consider the use of strength and performance SUFF measures in addition to SYMM measures over time

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in order to enhance RTS decision making. Further research is warranted to determine the relationship between SYMM and SUFF at time of RTS and outcomes such as second injury risk and movement mechanics.

SPL74

ACHIEVING RETURN-TO-SPORT CRITERIA DOES NOT INFLUENCE INCIDENCE OF SECOND ANTERIOR CRUCIATE LIGAMENT INJURY AMONG YOUNG ATHLETES

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PURPOSE/HYPOTHESIS: The majority of young athletes after anterior cruciate ligament reconstruction (ACLR) return to prior level of sport despite being unable to meet recommended return to sport (RTS) criteria. This population also suffers from the highest incidence of second ACL injury. The purpose of this study was to investigate the effect of both time between ACLR and RTS and the achievement of RTS criteria on incidence of second ACL injury. The tested hypotheses were that (1) time would not influence the proportion of young athletes who are able to meet RTS criteria, and (2) the incidence of second ACL injury among young athletes who met RTS criteria would be not differ based on the time from surgery to RTS.

NUMBER OF SUBJECTS: One hundred fifty-four participants (mean ± SD age, 17.1 ± 2.2 years) who underwent ACLR, completed rehabilitation, and were medically cleared to RTS.

MATERIALS/METHODS: All subjects were enrolled at time of RTS and classified into groups based on time between ACLR and RTS: early RTS group (less than 6 months postoperative [PO], n = 16), an average RTS group (6-9 months PO) (n = 86), and a late RTS group (9 months or greater PO, n = 52). At time of enrollment, the International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC), quadriceps and hamstring strength limb symmetry index (LSI), and single-leg hop test LSI was assessed for each participant. Recommended RTS cutoffs of IKDC score of 90 or greater and strength and hop test LSIs of 90% or greater were used. Subjects were tracked for 24 months for incidence of a second ACL injury to either the involved or contralateral limb. One-way ANOVA identified group differences in demographics. Chi-square analyses were used to determine the proportion of athletes within each group that met all RTS criteria, and among those who met criteria, to determine the proportion that suffered a second ACL injury.

RESULTS: No differences in age (P = .97), height (P = .49), or weight (P = .59) existed among the groups. At time of RTS, no differences in the proportion of athletes who met all RTS criteria were found between early RTS, average RTS, and late RTS groups (12.5% [2/16], 31.4% [27/86], and 12.5% [13/52], respectively; P = .23). With respect to second ACL injury, there was no difference among groups in the proportion of athletes who met all RTS criteria and suffered a second injury (early RTS group, 0% [0/2]; average RTS group, 33% [9/27]; late RTS group, 23% [3/13]; P = .39).

CONCLUSIONS: In accordance with our hypothesis, length of time between ACLR and RTS had no influence on the achievement of RTS criteria among young athletes after ACLR. Time between ACLR and RTS had no influence on the incidence of second ACL injury in athletes who met all RTS criteria.

CLINICAL RELEVANCE: In the months between primary ACLR and RTS, factors aside from time and achievement of RTS criteria, such as movement patterns and biopsychosocial factors, warrant further investigation on their potential influence on second ACL injury risk. Particularly among young athletes, further research is necessary to determine the optimization of postoperative management to address the high incidence of second ACL injury.

The American Academy of Sports Physical Therapy poster presentation abstracts (SPO1-SPO132) can be found on the JOSPT website, www.jospt.org.

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SPO1

THE USE OF PATIENT-REPORTED OUTCOME MEASURES IN THE PEDIATRIC SPORTS POPULATION

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PURPOSE/HYPOTHESIS: Patient reported outcome measures (PROs) allow physical therapists (PTs) to assess functional limitations, track progress and evaluate outcomes. Although professional organizations have issued recommendations for PRO use, these recommendations are primarily based on adult patients and it is currently unknown which measures are being used within the pediatric population. The purposes of this study are to summarize the current use of PROs among pediatric sports PTs and determine how PRO information is used within clinical care.

NUMBER OF SUBJECTS: Seventy-three PTs.

MATERIALS/METHODS: An online survey, developed in REDCap, was administered via email to members of the Sports Section Youth Athlete Special Interest Group and the Pediatric Research in Sports Medicine Society, over the course of 8 weeks. The survey consisted of 24 possible questions, taking 3 to 5 minutes to complete. Descriptive statistics and frequency tallies were utilized to analyze the data.

RESULTS: There was a wide range of clinical experience with 31% reporting 0 to 5 years (31%), 23% years, 16% 11 to 15 years, and 30% greater than 16 years. The majority (54%) reported working in a hospital based outpatient setting or private practice (24%). Ninety percent (n = 66) reported using PROs with 100% (n = 66) issuing them at the initial visit, 94% (n = 62) at discharge, and 91% (n = 60) monthly. Information obtained from PROs was used to demonstrate effectiveness of treatment (80%, n = 53/66), inform treatment decisions (77%, n = 51/66), satisfy insurance requirements (59%, n = 39/66), goal writing (60%, n = 40/66), and research (36%, n = 24/66). Inadequate time (42%, n = 28/66), difficultly remembering to administer (38%, n = 25/66) and uncertainty which PRO to use (21%, n = 14/66) were frequently reported reasons for not using PROs. The NDI (76%, n = 50/66), Oswestry (76%, n = 50/66), and QuickDASH (68%, n = 45/66) were most frequently used for neck, back and shoulder disorders, respectively. The Lower Extremity Functional Scale (LEFS) was utilized by 74% (n = 49/66) for hip or knee dysfunction, and 26% (n = 16/66) for ankle. Although the LEFS was most common, knee disorders demonstrated more variability in responses with 34/66 (52%) using the IKDC, 23/66 (35%) using the Pedi-IKDC and 13/66 (20%) using the KOOS.

CONCLUSIONS: The majority of pediatric sports PTs are using PROs to establish efficacy of treatment, inform clinical decision making and set goals. Inadequate time and indecision with regards to which scale to use, were identified as barriers to use. Knee disorders demonstrated the largest variability in scale use. The majority of region specific scales utilized have not been evaluated within the pediatric population.

CLINICAL RELEVANCE: Within today's value-based health care system, there is an increased emphasis on using PROs to demonstrate efficacy and functional improvement. Although many PTs are using PROs, variability in scale choice makes comparative outcomes research difficult. In addition, many of the PROs used are not validated within the pediatric population, which emphasizes the need for psychometric testing and/or scale development specifically for pediatric sports population.

SPO2

IS KINESIO TAPING EFFECTIVE IN REHABILITATION OF ATHLETES WITH ANKLE INJURY? A SYSTEMATIC REVIEW

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PURPOSE/HYPOTHESIS: There are many proposed benefits of Kinesio Tape (KT) suggesting that it could enhance ankle rehabilitation, however, its effectiveness is still unclear. Previous research showed conflicting results about KT effectiveness, and most studies lacked high quality. Therefore, there is a need to conduct a systematic review that investigated the effect of KT on athletes with ankle injuries. The purpose of this systematic review is to determine whether using KT improves the clinical outcomes in athletes with ankle injuries.

NUMBER OF SUBJECTS: Not applicable.

MATERIALS/METHODS: Electronic databases (MEDLINE, CINAHL, and Embase) were searched up to April 26, 2018 using a list of key words

related to ankle and Kinesio Tape. Eligible studies were included if they were randomized control trials, examined the effect of KT on ankle sprain rehabilitation in athletes with ankle sprain or ankle instability, and written in English. The Physiotherapy Evidence Database (PEDro) scale was used to assess the quality of the included studies. Two independent reviewers performed data extraction and synthesis with tabulation for each study including purpose, participants' characteristics, intervention, comparison, outcome measures, and findings/conclusion. Disagreements were resolved by a third reviewer. The protocol was registered in the PROSPERO database with the registration number CRD42017078644.

RESULTS: Only 4 studies met the eligibility criteria and were included in this systematic review. The quality of the studies ranged between low (3/10) to good (8/10) quality. Three of the included studies found that KT group showed no significant differences in balance, functional performance or swelling when compared to control. Only 1 study found that KT was effective for balance using Balance Error Scoring System when compared to baseline and control.

CONCLUSIONS: There is lack of high-quality RCTs investigating the effect of KT in athletes with ankle injuries. Based on the currently available RCTs, it appears that KT does not improve functional performance or swelling in athletes with ankle injuries. However, KT appears to improve balance in the immediate or 48-hour term. Due to the small number of high quality RCTs, further rigorous research is required.

CLINICAL RELEVANCE: Clinicians can use KT in athletes with ankle injuries to improve balance. However, using KT to improve functional performance or reduce swelling remains optional as it is not supported by current evidence.

SP03

IDENTIFYING DIFFERENCES AMONG PATIENTS WITH ACHILLES TENDINOPATHY WHO PRESENT WITH AND WITHOUT KINESIOPHOBIA

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PURPOSE/HYPOTHESIS: Kinesiophobia has been reported to negatively affect outcome in patients with musculoskeletal pain. A recent study reported that 38% of patients with Achilles tendinopathy have a high degree of kinesiophobia. The purpose of this study was to evaluate if there are differences in age, body mass index (BMI), symptom severity and duration, quality of life, and function in patients with Achilles tendinopathy (AT) patients who present with and without kinesiophobia.

NUMBER OF SUBJECTS: One hundred five patients (48 female; mean ± SD age, 52 ± 16.07 years) with a verified diagnosis of Achilles tendinopathy.

MATERIALS/METHODS: Based on the Tampa Scale of Kinesiophobia (TSK), patients were subgrouped into having kinesiophobia if TSK greater than 37 (n = 61, 29 female) and without kinesiophobia if 37 or less (n = 44, 19 female). Symptom severity, injury location (midportion and insertional), pain catastrophizing, quality of life, and physical activity level were assessed using Victorian Institute of Sport Assessment-Achilles (VISA-A), Pain Catastrophizing Scale (PCS), Foot and Ankle Outcome Score-Quality of Life (FAOS-QOL), and Physical Activity Scale (PAS) questionnaires. Total work and limb symmetrical index (LSI = [injured/uninjured] × 100) of heel-rise test were used to evaluate calf muscle function. The comparisons between the groups were analyzed using independent *t* test or Mann-Whitney *U* test, and Fisher exact test.

RESULTS: Fifty-eight percent (61/105) of patients with Achilles tendinopathy were considered to have kinesiophobia. No significant differences in injury location, was observed between groups ($P = .578$). Patients with kinesiophobia were significantly ($P<.05$) older (median, 58 years; range, 18-79 years versus 53 years; range, 20-79 years), had higher BMI (29.48 ± 7.45 kg/m^2 versus 24.79 ± 5.92 kg/m^2), longer duration of symptoms (28.9 ± 56.9 versus 13.79 ± 19.99), higher PCS score (10.4 ± 7.5 versus 6.5 ± 5.1). In addition patients with kinesiophobia reported a significantly ($P<.05$) greater degree of symptoms (VISA-A, 45.4 ± 20.5 versus 64.47 ± 18.8; FAOS-QOL, 43.75 [0-87.5] versus 56.3 [31.3-87.5]) and lower calf muscle function (LSI, 79% versus 87%).

CONCLUSIONS: The kinesiophobia group demonstrated greater duration of symptoms, higher degree of symptom severity, poorer quality of life and lower physical activity level than group without kinesiophobia.

CLINICAL RELEVANCE: Kinesiophobia may be a factor that affects outcomes in patients with Achilles tendinopathy, and might need to be addressed during treatment.

SP04

THE EFFECT OF LOAD CARRIAGE AND RECOVERY ON SHOULDER NEUROMUSCULAR FUNCTION

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PURPOSE/HYPOTHESIS: Heavy backpack walking stresses the shoulder complex which may lead to neuromuscular impairments arising from nerve compression of the brachial plexus. This study examined the effect of a 2-hour 20.5-kg load carriage task on shoulder strength, endurance, and nerve amplitude as well as the needed recovery time. We hypothesized: that all studied shoulder neuromuscular functions would deteriorate after 2 hours of loaded walking and recover to baseline values within 30 minutes after the task.

NUMBER OF SUBJECTS: Thirteen.

MATERIALS/METHODS: Thirteen healthy participants, 3 females and 10 males (mean ± SD age, 27 ± 5.3 years; weight, 82.5 ± 11.8 kg; height, 180 ± 5.6 cm). Subjects were excluded who had recent shoulder injuries, as were those with previous medical and neurological problems. Data were collected from the right shoulder at baseline, immediately post walking task and at subsequent intervals over the next 30 minutes during recovery. The load carriage task was administered in clinical lab settings, in which subjects walked for 2 hours on a treadmill with no inclination carrying a 20.5-kg backpack at a velocity of (5.5-7 km/h). Outcome measures were (1) Axillary nerve amplitudes recorded from Erb's point stimulation every 5 minutes during the 30-minute recovery. Maximal isometric strength and endurance were measured simultaneous during a maximal 30-second effort with shoulder abducted at 90° and arm externally rotated. Procedure was repeated every 10 minutes during recovery. (2) Strength, measured as average torque (Nm) generated between 2 and 5 seconds. (3) Endurance, measured as angular impulse (Nm·s) generated over the entire 30-second effort. All dependent measures demonstrated good reliability during pilot testing. Data were analyzed with Friedman's nonparametric repeated measures with 8 and 5 time points for nerve amplitudes and strength assessments respectively. Subsequent Wilcoxon signed-rank test was used if differences were found, to determine when baseline values were recovered. Due to multiple comparison adjusted *P* values for 7 comparisons ($P \leq .007$) and 4 comparisons ($P \leq .0125$) are considered significant.

RESULTS: Nerve amplitude was reduced immediately post load carriage task to 6.7 (IQR, 5.2-7.8 mV) compared to baseline (7.5; IQR, 7.15-9.6 mV; $P = .001$) but recovered to baseline value at the 15-minute time point. Strength was reduced immediately post load carriage task to 45 (IQR, 34.7-49.9 Nm) compared to baseline (52.5; IQR, 45.5-64 Nm; $P = .002$) but recovered at the 30-minute time point. Endurance was reduced immediately posttask to 1262 (IQR, 1014-1411 Nm) compared to baseline (1428; IQR, 1224-1802 Nm; $P = .011$) but did not recover in the next 30 minutes.

CONCLUSIONS: Walking with a heavy backpack reduced shoulder strength, endurance and motor nerve amplitude immediately post walking and requires a minimum of 15 minutes for shoulder neuromuscular function to start recovery.

CLINICAL RELEVANCE: Reduction in muscle function may increase the risk of shoulder injury and lead to deteriorating performance during overhead tasks following load carriage if adequate recovery is not allowed.

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SP05

MONITORING GAIT SMOOTHNESS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING ACCELEROMETRY: A PROSPECTIVE LONGITUDINAL STUDY

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PURPOSE/HYPOTHESIS: Persistent gait deficits following anterior cruciate ligament reconstruction (ACLR) are associated with the development of knee osteoarthritis. However, standard biomechanical gait analysis systems are expensive and time consuming. Therefore, developing an inexpensive, easily administered objective gait assessment tool may help clinicians to better monitor gait abnormality on a regular basis. Measurement of lower trunk accelerations during gait have been shown to provide useful information about gait smoothness, which helped to differentiate normal from abnormal gait patterns. This study aimed to monitor and compare changes in gait smoothness over time between individuals with ACLR and uninjured healthy subjects using a single accelerometer on the lower trunk.

NUMBER OF SUBJECTS: Fifteen ACLR participants (mean ± SD age, 26.23 ± 7.83 years) and 15 healthy controls (age, 27.20 ± 4.89 years).

MATERIALS/METHODS: Evaluation of participants took place in clinical settings at 2, 4, and 6 months postsurgery. A wireless tri-axial accelerometer was attached to subjects' lumbar spine (L4-L3). Participants were instructed to walk, walk fast (at 2, 4, and 6 months), and run (at 4 and 6 months) at self-selected speeds along a 12-m straight walkway. Gait smoothness was quantified using jerk (ie, the time derivative of acceleration) normalized by step distance and step duration. The lower is the normalized jerk (NJ) value, the higher is the gait smoothness. Paired *t* tests were used to compare 2 to 4 months postsurgery NJ in ACLR participants and independent *t* tests were used to assess differences in NJ between groups. At 6 months, the data of only 4 subjects were collected and processed. The results are reported below but they were not included in the current statistical analysis.

RESULTS: When compared to 4 months visit and controls, ACLR participants at 2 months visit showed significant higher NJ values in the vertical, mediolateral, and anteroposterior directions during walking ($P<.01$ for all directions) and walking fast ($P<.01$ for all directions). At 4 months visit, ACLR individuals still had significant higher NJ for all directions during walking ($P<.01$), walking fast ($P<.01$), and running ($P<.001$) compared to controls. At 6 months visit, the 4 ACLR individuals showed improvement in gait smoothness over time for all gait tasks, but they still had higher NJ values when compared to controls.

CONCLUSIONS: Gait smoothness of ACLR individuals improved across time, but did not reach the normal smoothness level of healthy controls 4 months postsurgery. There is a tendency for ACLR individuals not to reach the normal gait smoothness level even at 6 months after surgery, especially during running. Future studies should examine gait smoothness in a longer period and its association with functional measures.

CLINICAL RELEVANCE: Movement smoothness measured by a single accelerometer is an inexpensive and practical approach to detect and monitor gait deficits in individuals post ACLR in clinical settings during rehabilitation.

SP06

UTILIZING THE CLASSIFICATION AND REGRESSION TREE ANALYSIS TO DETERMINE THE RELATIONSHIP BETWEEN THE LANDING ERROR SCORING SYSTEM, FUNCTIONAL TESTS, AND CLINICAL MEASURES IN THE PROFESSIONAL BASKETBALL PLAYER

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PURPOSE/HYPOTHESIS: Background: lower extremity injuries occur at a relatively high rate in professional basketball. Evidence suggests that the Landing Error Scoring System (LESS) may be predictive of injury. The investigation of interactions among nonlinear factors may help further the understanding of the interdependence of various measures and poor performance on the LESS in professional basketball players. Purpose: to investigate predictors of poor performance on the LESS. We hypothesize that high LESS scores will be predicted by select clinical measures and components of common functional tests.

NUMBER OF SUBJECTS: Forty-seven professional basketball players.

MATERIALS/METHODS: Measurements were completed as part of preseason mobility screening prior to the 2015-16 and 2016-17 NBA seasons. Classification and Regression Tree analysis (CART) were used to investigate nonlinear interactions among predictors and their influence on players who scored greater than 7 on the LESS test.

RESULTS: Of the 47 total number of players included in this study, 11 players scored 7 or greater on the LESS test and 36 scored between lower than 7. Pruning resulted in 3 splits ($R^2 = 0.430$) demonstrating that LESS score was predicted by asymmetry in the YBT anterior reach (greater than 4 cm), 90°/90° hamstring score greater than 45.11°, and 90°/90° hamstring score less than 30.03°. The predictive model, after pruning, classified 5 of the 11 players with high LESS scores and 17 of the 36 players with moderate to low LESS scores. The area under the ROC curve was 0.8687 which suggests that classification of players using this model was not random.

CONCLUSIONS: Performance on the LESS has been linked with injury. CART analysis captured nonlinear and complex interactions between clinical and functional measures suggesting that lower extremity biomechanical factors may be associated with performance on the LESS.

CLINICAL RELEVANCE: The LESS test has been shown to be predictive of injury. Identifying which functional tests and specific clinical measures may be linked with poor performance on this test may aide clinicians in determining the appropriate interventions that may be associated with improved scores and minimize risk of injury.

SP07

THE ASSOCIATION BETWEEN ARCH TYPE AND PERFORMANCE ON THE Y BALANCE TEST IN PROFESSIONAL BASKETBALL PLAYERS

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PURPOSE/HYPOTHESIS: Background lower extremity injury is common in professional basketball. The Y Balance Test (YBT) is a widely used screening tool for injury predisposition. Arch mechanics are often cited as a related factor for balance and injury and the Arch Height Index Measurement System (AHIMS) is a reliable and valid system for classifying arch type. Purpose: to investigate the association between arch type and YBT performance in professional basketball players. We hypothesize that performance on the YBT is associated with a cavus and/or planus arch type.

NUMBER OF SUBJECTS: Sixty professional basketball players (120 arches).

MATERIALS/METHODS: YBT and AHI Measurements were completed as part of preseason mobility screening prior to the 2015-16 and 2016-17 NBA

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seasons. AHI measures were calculated and descriptive statistics were run to determine arch type based 1.0 SD above (cavus) and below (planus) the mean. YBT composite scores were documented and individuals who scored greater than 4 cm between sides for the anterior (ANT), posteromedial (PM), and posterolateral (PL) directions were identified. Frequency tables were compiled to determine the association between foot type and YBT performance.

RESULTS: The mean ± SD AHI was 0.3041 ± 0.0319. Of the 120 arches, 18 (15%) were planus, 84 (70%) were normal, and 18 (15%) were cavus, relatively speaking. On the YBT, asymmetry (greater than 4 cm difference between left and right) was found in the ANT (48), PM (68), and PL (72). It was noted that 72% of the planus arches performed poorly on the YBT PM and 83% of the planus arches presented with a YBT composite score less than 94.

CONCLUSIONS: These findings suggest that foot type may influence performance on the YBT in specific directions and in composite score.

CLINICAL RELEVANCE: Balance is influenced by many factors. Understanding the arch type in athletes may help inform clinicians on how best to intervene with individuals who present with poor balance performance.

SP08

CHANGES IN UPPER EXTREMITY MUSCULOSKELETAL CHARACTERISTICS ASSOCIATED WITH 1 COMPETITIVE SEASON OF COLLEGIATE SWIMMING

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PURPOSE/HYPOTHESIS: Upper extremity (UE) injuries are common in swimmers throughout the course of a competitive collegiate season. The measurement of UE musculoskeletal characteristics preseason and postseason may help identify these effects on an athlete's risk for injury. Therefore, the purpose of this study was to determine if a season of competition affects UE posture, range of motion, flexibility, and strength.

NUMBER OF SUBJECTS: Twenty-four NCAA Division I collegiate swimmers participated (mean ± SD age, 19.3 ± 0.9 years; height, 179.2 ± 8.8 cm; weight, 75.8 ± 7.5 kg).

MATERIALS/METHODS: All testing occurred within 4 weeks before and after a 24-week competitive collegiate swim season. Forward head posture (FHP) and forward shoulder posture (FSP) were assessed bilaterally with a lateral photograph and ImageJ software. Glenohumeral internal/external rotation, posterior shoulder tightness (PST), and pectoralis minor length (PML) were assessed bilaterally. Isometric strength of the upper/middle/lower trapezius (UTS/MTS/LTS), rhomboids, internal rotation (IRS) external rotation (ERS), pectoralis major, serratus anterior, and supraspinatus (SSS) were assessed bilaterally with a handheld dynamometer. A paired samples *t* test or Wilcoxon Signed-Rank test was used after the data were assessed for normality. Significance was set at $P<.05$.

RESULTS: Nondominant (NDom) FSP (difference, 6.7; $P<.001$) improved. Bilateral PST improved (Dom difference, 4.1; $P = .003$ and NDom difference, 4.3; $P = .001$). PML decreased bilaterally (Dom difference, 6.8; $P = .001$ and NDom difference, 7.7; $P<.001$). Dom and NDom LTS decreased (Dom difference, 1.7; $P = .003$ and NDom difference, 2.1; $P = .001$). NDom IRS decreased (difference, 2.3; $P = .007$). Dom and NDom ERS decreased (Dom difference, 1.7; $P = .038$ and NDom difference, 1.5; $P = .020$). Dom and NDom SSS decreased (Dom difference, 0.9; $P = .037$ and NDom difference, 1.4; $P = .002$).

CONCLUSIONS: After completion of a competitive collegiate swimming season, UE strength decreased while posture, range of motion, and flexibility improved. Athletes experience a gradual increase in intensity and volume of training during the training. Typically, the last 3 to 5 weeks of the season, training will decrease in volume and increase intensity to maximize performance going into the Championship Season. Furthermore, the high volume of competition in the final portion of the season could contribute to increased range of motion and flexibility. The changes in PST could also contribute to the observed changes in posture in which less FSP was observed.

CLINICAL RELEVANCE: Changes in posture and decreased rotator cuff isometric strength are known risk factors for injury in swimmers; these musculoskeletal characteristics are seen to be affected by a competitive season of swimming. Changes in FHP and FSP may lead to changes in biomechanics and a higher risk of injury towards the end of the competitive collegiate swimming season. In order to address these risk factors, injury prevention programs should be implemented that target increasing and maintaining rotator cuff strength while incorporating posterior shoulder flexibility and postural correction exercises.

SP09

WHAT EFFECT DOES SPATIOTEMPORAL PARAMETER MANIPULATION HAVE ON RUNNING ECONOMY?

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PURPOSE/HYPOTHESIS: Manipulation of spatiotemporal parameters has been proposed to positively influence repetitive kinematic and kinetic behaviors known to associate with running injury yet may have a negative effect on running economy (RE). The purpose of this of this review is to examine the effect that spatiotemporal parameter manipulation has on RE.

NUMBER OF SUBJECTS: Five articles were selected for this literature review.

MATERIALS/METHODS: PubMed and Ovid-MEDLINE databases were searched using the search terms: "Stride Rate" AND "Running Economy," "Step Rate" OR "Cadence" OR "Stride Frequency" and "Running Economy," "Step Rate" and "VO2," ((Running) AND (Efficiency OR Economy)) AND ((Step OR Stride) AND (Frequency OR Rate)), (Self-optimization) AND (running), (Stride* OR Cadence OR Step L* OR Step R*) AND (Oxygen Up* OR Oxygen Con* OR VO2* OR Running Eco* OR Running Eff*). Studies investigating the effect of stride length (SL) and stride frequency (SF) manipulation on RE were included if subjects ran 15 miles or more per week and were 18 to 50 years of age. Studies were excluded if subjects had a history of musculoskeletal injury in the past 3 months, history of lower extremity surgery within the past 6 months, or if published prior to 2005. Twelve articles were initially extracted, from which 7 were excluded due to failing to directly compare SF or SL manipulation to RE.

RESULTS: The following 5 articles met the inclusion criteria: Connick et al (2014), de Ruiter et al (2014), Hunter et al (2017), Hunter et al (2007), and Lieberman et al (2015). The included studies manipulated subjects' SF by increasing or decreasing their SF relative to their preferred stride frequency (PSF) in order to evaluate the impact of manipulation on RE. The studies collectively found that PSF and preferred stride length (PSL) are the most economical, suggesting that runners tend to naturally self-optimize with a high level of accuracy. Additionally, multiple studies found a curvilinear relationship between SF and RE, with an SF of approximately 85 strides per minute being optimal.

CONCLUSIONS: While clinicians often use spatiotemporal manipulation as a method of treating injured runners, current evidence suggests that any manipulation may lead to a decrease in RE. Given that multiple studies demonstrated runners' self-selected SF's being at or close to optimal SF, changes to these self-selected frequencies should be recognized for their potential to cause detrimental changes to a runner's RE.

CLINICAL RELEVANCE: Current trends in research suggest that spatiotemporal parameter manipulation can decrease the lower body forces associated with running, which may be protective against lower extremity injury. However, because spatiotemporal parameter manipulation can negatively impact

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VO2max and consequently RE, clinicians should take caution when considering the use of spatiotemporal parameter manipulation as an intervention.

SP010

A COMPLICATED CASE OF COMPARTMENT SYNDROME AND INTERPROFESSIONAL COLLABORATION

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BACKGROUND AND PURPOSE: Compartment syndrome (CS) is defined as pathological elevation of pressure in a muscular compartment. Lower extremity (LE) acute CS is typically caused by trauma (fracture or crush injury) and is a medical emergency requiring immediate surgery. Upper extremity (UE) chronic CS manifests as elevated pressures with exercise which typically return to normal with cessation of exercise. The less common UE CS is typically associated with overuse of forearm musculature during repetitive gripping activities such as rowing, manual labor, weightlifting, and motorcycling. There are several case studies on CS, but fewer on LE acute and UE chronic CS. To date there are no published cases of an individual with both LE acute and UE chronic CS. The purpose of this report is to present a client with a unique presentation of both chronic UE CS (developed over 2 years with chronic pain) and acute LE CS (nontraumatic in nature). The sequelae of uncommon diagnoses associated with this complex case of compartment syndromes will be described, highlighting the evolution of diagnoses, treatment adaptation, and the interprofessional collaboration involved. This case study provides an excellent example of an orthopaedic-based physical therapy treatment approach as it evolves toward the integration of neurologic intervention.

CASE DESCRIPTION: An 18-year-old male lacrosse face-off player initially presented in September 2017 with left LE acute CS and right UE chronic CS following multiple surgeries and varying diagnoses. PT treatment and re-evaluation continued through April 2018. The client experienced a complicated series of diagnoses including Complex Regional Pain Syndrome and Functional Neurological Disorder as he continued to be seen by multiple providers and receive extensive medical testing.

OUTCOMES: Diagnostic procedures included: EMG (LE, UE, brachial plexus), LE and UE compartment pressure testing, MRI (spine, pelvis, brain with and without contrast), UE muscular ultrasound, CT scan (spine), blood testing, EEG, EKG, and muscle biopsy. Multimodal intervention approaches included muscular strengthening, neuromuscular re-education, balance and functional training, joint and soft tissue mobilization, guided motor imagery, cognitive behavioral and mirror therapy, pain science education and antigravity treadmill ambulation. The interprofessional team included an orthopaedic PT, neurological PT, ballet instructor, movement disorder neurologist, orthopaedic surgeon, physiatrist, sports medicine physician, and cognitive behavioral therapist. Repeated outcomes measures included Lower Extremity Functional Scale, Patient-Rated Tennis Elbow Evaluation, and grip strength.

DISCUSSION: This case study highlights the importance of providing flexible, client-focused, interprofessional collaboration when managing such a complex clinical case.

SP011

EXERCISE RECOMMENDATIONS FOR THE DEVELOPMENT OF CORE STABILITY IN ONLINE POPULAR FITNESS LITERATURE

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PURPOSE/HYPOTHESIS: Core stabilization is a key component of therapeutic exercise for a number of patient populations, including athletes and individuals with low back pain. With Americans increasingly looking to the Internet for health information, online magazine content has become a popular source of advice about fitness and exercise. This systematic appraisal seeks to identify what information Americans are receiving from online popular fitness literature about how to develop and maintain core stability. We hypothesized that the majority of recommendations would consist of resistance training techniques to strengthen muscles that serve as global stabilizers as opposed to local stabilizers.

NUMBER OF SUBJECTS: This study did not include research on human subjects.

MATERIALS/METHODS: The 30 highest US circulation fitness publications as of February 2017 were identified using audited circulation data. Each publication with a searchable online database was then searched using the query "core stab*." Articles were included if they mentioned core stability or stability of component areas of the core, operationally defined in this study as comprising the trunk from the shoulders to the gluteal region. Recommendations for development of core stability were compiled and categorized by type of exercise (eg, aerobics, resistance, etc) and the goal of the exercise with respect to the core (eg, local stabilization, global stabilization, etc). Categorization was reviewed by a second coder to ensure quality and consistency.

RESULTS: A total of 563 articles were identified, ranging from 3 articles identified in 2001 to a maximum of 83 articles identified in 2016. A total of 493 unique recommendations were identified, including 429 specific exercises (eg, planks), 17 activities (eg, running), 12 disciplines (eg, yoga), 17 general training strategies (eg, compound exercises), and 18 equipment recommendations (eg, kettlebells).

CONCLUSIONS: The frequency of publication of online popular fitness content regarding the topic of core stability has steadily increased over the past 15 years. Most of the recommendations provided in these publications have included movements that focus on either resistance training or combining a resistance challenge and a balance challenge within the same exercise. As hypothesized, the vast majority of exercise recommendations for the development of core stability focus on global stabilization between the spine and the pelvic or shoulder girdles as opposed to local stabilization of spinal segments.

CLINICAL RELEVANCE: By better understanding popular conceptions of how to improve core stability, clinicians can more effectively guide their patient education to support or challenge common understandings. This knowledge may also aid clinicians in identifying exercises to which patients likely already have exposure, potentially improving clinician-client communication during the development and instruction of physical therapy plans of care and home exercise programs.

SP012

FACTORS ASSOCIATED WITH COACHES' IMPLEMENTATION OF ANTERIOR CRUCIATE LIGAMENT INJURY PREVENTION MEASURES IN RURAL LOCATIONS

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PURPOSE/HYPOTHESIS: To determine whether association exists between factors internal to coaches in rural middle and high school settings and their implementation of ACL Injury Prevention Programs (IPP). The researchers hypothesized that greater levels of coaching experience, coach's education and training, and prior exposure to injuries would be associated with greater likelihood of ACL IPP implementation.

NUMBER OF SUBJECTS: Seventy-four head coaches of public school-based sports teams (21 female, 53 male), clustered in rural Southwestern Virginia and Northern Indiana. Inclusion criteria: adult head coaches of public school athletic teams. Exclusion criteria: Nonadult or student coaches.

MATERIALS/METHODS: An online survey using Google Forms was employed to collect data with 3 purposes (1) to determine coaches' knowledge regarding the ACL, (2) to inquire about coaches' practices regarding use of IPP, and (3) to learn coaches' background experiences with ACL injuries]. The survey consisted of 22 to 24 questions (variable depending upon responses). It was deployed March 15 to May 25, 2018. Initial contact was

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via offices of Superintendents of each school district. Permission was obtained to solicit Athletic Directors who then forwarded a link to their coaches. Data analysis was performed using chi-square test and Binary Logistic Regression.

RESULTS: Among 74 respondents, only 13 reported utilizing an ACL IPP. Despite the large proportion of "nonimplementers," 78.4% either agreed or strongly agreed that ACL injury prevention measures were important for their teams. As a fraction of respondents, coaches in the youngest age group (21-30) were most likely to implement preventative programs (7/14 coaches in this age group versus 6/60 in all other age groups combined). Female coaches were more likely to implement programs than were their male counterparts (chi-square $P = .025$). The majority of coaches who participated at either the high school or college level as athletes in the sport that they now coach were also more likely to implement IPPs. Initial logistic regression modeling supported coaches in the 21 to 30 age range ($P<.001$), female coaches ($P = .025$), those with the highest levels of injury prevention education ($P<.001$), and those who expressed a desire to learn more about injury prevention ($P = .029$) as more likely to utilize IPP.

CONCLUSIONS: This study suggests that certain factors internal to survey respondents are associated with use of preventative measures. Coaches' beliefs about the importance of injury prevention belie their actions as they may lack confidence about how to utilize or implement IPP. Physical therapists may be positioned to assist coaches in rural school settings to overcome obstacles to effective injury prevention.

CLINICAL RELEVANCE: Factors that impact coaches' decision making should be recognized by physical therapy clinicians. These insights may serve as guides during physical therapist interaction with athletic coaches, athletes and parents toward the end goal of assisting with implementation of injury prevention measures.

SP013

PROFESSIONAL-LEAGUE ATHLETIC TRAINERS' KNOWLEDGE AND UTILIZATION OF THE VESTIBULAR OCULAR MOTOR SCREENING TOOL IN CONCUSSION MANAGEMENT

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PURPOSE/HYPOTHESIS: Early identification and treatment of visual/vestibular dysfunction following concussion has been shown to decrease the time that players experience symptoms and decrease the time missed from sport. The Vestibular Ocular Motor Screening Tool (VOMs) is a validated outcome measure utilized in concussion assessment with 0.89 area under the curve for positively identifying concussed patients and internal consistency of $\alpha = .92$. Athletic trainers (ATs) are vital in their role in early identification of symptomology as they are most often the first health care provider encountered after injury. Knowledge of vestibular and/or ocular deficits following mTBI and utilization of the VOMS by professional ATs has not been investigated. This will provide valuable information regarding assessment techniques as well as clinical management for these deficits. The purpose of this study is to establish a baseline of professional league AT knowledge and usage of the VOMS tool.

NUMBER OF SUBJECTS: One hundred seventeen.

MATERIALS/METHODS: An online survey instrument was created, and 7 ATs with expertise in survey methodology assisted in establishing criterion validity (0.95) of the instrument. A pilot survey was administered to 20 ATs to establish internal consistency of knowledge items ($\alpha = .84$) and usage items ($\alpha = .83$). The survey was distributed to members of professional league AT associations via an online survey system. Demographic questions along with 15 true/false/unsure knowledge questions related to vestibular ocular dysfunction as well as usage of VOMS components were included. Statistical analysis utilizing SPSS Version 24 was completed.

RESULTS: A total of 117 professional league ATs (mean ± SD age, 40.32 ± 0.873 years) were surveyed with a response rate of 33%. Total knowledge score was 8.35 out of 15 ± 2.66 and ATs usage of the VOMS components across baseline to return to play varied from 17.09% to 70.01%. There was no correlation between knowledge scores and age ($r = -0.113$, $P = .22$) or knowledge scores and years' experience ($r = -0.103$, $P = .27$). There was no difference in knowledge scores between ATs who were Impact Trained ATs versus those who were not ($z = -0.329$, $P = .74$).

CONCLUSIONS: Professional league ATs knowledge and utilization of the Vestibular Ocular Motor Screening Tool has not been previously studied and our results assist in identification of an area of practice that can be targeted for improved collaborative care in sports related concussion. Vestibular ocular deficits have been associated with prolonged recovery and earlier identification can lead to decreased time with symptoms as well as decreased time loss from play. It appears that knowledge translation from recent literature has not reached clinical practice at this time and continued efforts for dissemination are needed.

CLINICAL RELEVANCE: ATs play a crucial role in early identification of vestibular ocular deficits and the VOMS is a validated tool to assist in clinical decision making for earlier referral to a vestibular specialist.

SP014

EMERGING CLINICAL SUBTYPES OF CONCUSSION AND THE ROLE OF PHYSICAL THERAPISTS IN INTERPROFESSIONAL CARE

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PURPOSE/HYPOTHESIS: Symptoms of sport-related concussion (SRC) have traditionally been categorized into distinct clusters including cognitive, emotional, physical, and sleep. Recently, clinical trajectories or subtypes of SRC were introduced to assist clinicians to focus rehabilitation of patients with SRC. Theses subtypes include cognitive, anxiety and mood, posttraumatic migraine, vestibular, oculomotor, and cervicogenic pain. New evidence points to integrating early physical activity and graded exercise testing into the rehabilitation of SRC when warranted. The APTA describes the role of a physical therapist (PT) in managing the patient with a concussion as part of a multidisciplinary team. However, there is limited evidence regarding PTs' specific role in SRC management. The purpose of this study is to assess the knowledge, confidence, and experience of PTs in the rehabilitation of patients with SRC across clinical subtypes.

NUMBER OF SUBJECTS: One hundred ninety-one physical therapists (97 male, 90 female, 4 did not report) with a mean ± SD age of 39.3 ± 10.9 years participated.

MATERIALS/METHODS: Respondents completed an online anonymous survey distributed by e-mail to PTs via the APTA Sports Academy. The survey consisted of 3 blocks of questions: (1) demographic information and concussion experience/training background; (2) self-reported knowledge, confidence, and experience with SRC clinical subtypes; and (3) a 20-question knowledge self-assessment quiz. Ratings for the clinical subtype questions were on a Likert scale with anchors of 1 as "not at all" to 5 as "very" for participant knowledge, confidence, and experience in managing patients with SRC.

RESULTS: PTs rated cervicogenic pain as the clinical trajectory of SRC in which they were most knowledgeable, confident and experienced (mean, 4.05, 3.91, 3.75, respectively). The vestibular clinical subtype was ranked second highest in terms of PT knowledge, confidence and experience (mean, 3.68, 3.37, 3.34). The anxiety and mood clinical subtype (mean, 3.38, 2.94, 2.89) was rated the lowest.

CONCLUSIONS: These data further underline PTs' role as movement specialists trained in the rehabilitation of musculoskeletal pain and improving mobility resulting from peripheral imbalance and dysfunction. Physical therapists with advanced training in concussion are well positioned to be on that concussion management "team" and PTs with vestibulo-ocular rehabilitation certification can serve a very specialized role in concussion care. Neurocognitive dysfunction and changes in anxiety and mood are often some of the most striking signs and symptoms postconcussion, and close attention should be given to these SRC patients and referred to the appropriate medical or psychological professional.

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CLINICAL RELEVANCE: The findings of this investigation support PTs' role in the rehabilitation of sports-related concussion. PTs are encouraged to seek continuing education opportunities in order to make appropriate treatment and referral decisions for their patients with concussion.

SP015

PHYSICAL THERAPISTS' COMPETENCE AND EXPERIENCE IN SPORT-RELATED CONCUSSION CARE

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PURPOSE/HYPOTHESIS: The first recorded study on concussion in 1818 presented a young naval officer who fell from a ship, hit his head, and remained unconscious until his death the subsequent day. Since this first publication, nearly 10 000 (n = 9932) papers on the topic have been published and the majority (n = 7224) have been published since 1994. The increased focus on concussion matches the amplified media and public concern with immediate and long term sequelae following sport-related concussion (SRC). Emerging best practices of SRC include focused vestibulo-ocular rehabilitation and cervicogenic pain management. Thus, physical therapists (PT) are well positioned to play an integral role in SRC management teams. Evidence shows that over 90% of PTs correctly identify hallmark signs and symptoms of concussion. However, with the recently updated SRC consensus statement and evolving clinical subtypes of concussion, it remains unknown whether PTs can correctly identify subtypes of concussion, the proper referral source(s) and/or most appropriate evidence-based management. The purpose of this study was to survey members of the APTA Sports Academy related to their knowledge of concussion and current evidence-based rehabilitation management.

NUMBER OF SUBJECTS: One hundred seventy-three physical therapists (87 male, 86 female; mean ± SD age, 39.3 ± 10.9 years) participated.

MATERIALS/METHODS: Respondents completed an online anonymous survey distributed via e-mail to PTs who were members of the APTA Sports Academy. Participants completed 3 blocks of questions: (1) demographic information and concussion experience/training background; (2) self-reported knowledge, confidence, and experience with SRC clinical subtypes; and (3) a 20-question knowledge self-assessment quiz consisting of multiple choice, select all that apply, and case study questions.

RESULTS: The mean score on the concussion self-assessment quiz was 10.09 ± 4.19 (50.45%). Participants that indicated they were either Athletic Trainers (AT) or with vestibular rehabilitation certification (AIB or Herdman) scored significantly higher ($P \leq .05$) on the knowledge assessment than participants who were not either AT or AIB/Herdman certified. There was no significant difference ($P \geq .05$) between PTs with specialty certifications in Orthopaedic Certified Specialist (OCS), Sports Certified Specialist (SCS), or Neurological Clinical Specialist (NCS) compared to those who do not.

CONCLUSIONS: The mean of the SRC knowledge self-assessment underscores the need for continuing education for PTs practicing in a sports setting. These findings identified that those with AT or AIB/Herdman certifications have a greater knowledge of concussion management in SRCs than those that do not.

CLINICAL RELEVANCE: The evolving management of patients with SRC requires an interprofessional team. PTs with specialized training, especially in neck pain and dysfunction and vestibulo-ocular rehabilitation would greatly enhance the comprehensive concussion care teams. A complete and detailed statistical analyses of our data will be presented.

SP016

THE RELATIONSHIP BETWEEN FUNCTIONAL MOVEMENT ASSESSMENTS AND INJURY RISK IN DIVISION I MALE SOCCER PLAYERS

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PURPOSE/HYPOTHESIS: Injury rates in collegiate soccer players have been reported to occur at high rates as compared to collision sports. Identifying factors that influence injury risk may allow for early detection and injury prevention. Functional movement assessments may provide information regarding movement dysfunctions that may not be identified with traditional clinical examinations. While the association between injury risk and performance on individual functional movement assessments have been studied, a gap in the literature exists in understanding the utility of performing a battery of such tests to better predict an athlete's injury risk. Thus, the purpose of this study was to explore the relationship between functional movement assessments and (1) a player's previous history of injury and (2) the relative risk of subsequent injury.

NUMBER OF SUBJECTS: Thirty-one.

MATERIALS/METHODS: Thirty-one healthy, Division I male soccer players, between the ages of 17 and 22 years (mean ± SD, 20.10 ± 1.35 years) participated in this study. During the soccer preseason, players performed a 1-time assessment of the following functional movement assessments: Functional Movement Screen (FMS), Lower Extremity Functional Test (LEFT), Y Balance Test (YBT), and closed-chain dorsiflexion range of motion (DF). Nineteen of the 31 subjects completed an online survey providing information about previous soccer-related injuries over the preceding 4 years. During the subsequent soccer season, injuries sustained and time lost from athletic participation were recorded.

RESULTS: Significantly lower FMS composite scores were found among players with a previous history of knee injury ($P = .009$). No significant differences were found among any of the assessment scores and previous history of injury at other regions of the body. Seven injuries occurred during the season among 6 players, accounting for 206 hours lost from practices/games. The majority of the injuries involved the foot and ankle (42.8%) and concussions (28.6%). Increased injury risk was associated with players who measured less than 30.1° of DF on either ankle (RR = 5.55; 95% CI: 4.22, 7.29). When examining the results of 2 or more assessments, players with less than 99.1 on the YBT, and greater than 6° DF difference between ankles were almost 3 times more likely to sustain an injury in the subsequent season (RR = 2.9; 95% CI: 1.28, 6.56). Furthermore, players with a score of less than 14 on the FMS, less than 99.1 on the YBT, and greater than 6° DF difference between ankles were 6 times more likely to sustain an injury in the subsequent season (RR = 6; 95% CI: 3.99, 9.03).

CONCLUSIONS: A marked reduction in DF may significantly predispose an athlete to a future injury. However, examination of combined performance scores on multiple functional movement assessments may provide a better insight into increased risk of injury among Division I male soccer players.

CLINICAL RELEVANCE: Identifying players who perform poorly on specific functional movement assessments may prove beneficial to developing an injury risk profile of athletes, improving the prediction of injury and reducing the injury risk.

SP017

THE RELATIONSHIP BETWEEN VISUALLY IDENTIFIED MOVEMENT ERRORS AND FRONTAL PLANE KNEE MOMENTS DURING SIDESTEP CUTTING

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PURPOSE/HYPOTHESIS: High rates of anterior cruciate ligament (ACL) tears among adolescent athletes has made risk assessment for ACL injury a popular topic. High knee abduction moments (KAM) during a drop vertical jump (DVJ) are known to accurately predict ACL injury risk. The development of clinical tests that can accurately predict high KAM may

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be critically important to developing effective injury risk screening tools. Studies have demonstrated the reliability and validity of 2-dimensional (2-D) and qualitative assessments of ACL injury risk during jumping and hopping tasks. To the author's knowledge, there are no clinical screening tools that evaluate a cutting task. The purpose of this study is to determine the relationship between visually identified movement errors and frontal plane knee moments during side step cutting.

NUMBER OF SUBJECTS: A convenience sample of 23 male and female subjects' aged 12 to 17 years involved in a cutting or pivoting sport were recruited. Subjects with history of lower extremity surgery or injury in the last 6 months were excluded.

MATERIALS/METHODS: Subjects were asked to perform a 45° side step cut to the right and left and a DVJ. Kinematic and Kinetic data were collected and processed using VICON workstation software and an 8-camera BTS SMART 7000DX 3-D Motion Analysis System respectively. One experienced clinician used a 2-D motion analysis application on an iPad (anterior and lateral views) and a clinically established 45° cut qualitative checklist to view and score the cut on all 46 limbs. Normative biomechanical values and KAM scores of greater than 25.25 Nm and greater than 21.74 Nm were used to create a high- versus low-risk group. SAS version 9.3 was used to calculate sensitivity and specificity.

RESULTS: Visual identification (VI) of decreased knee flexion accurately identified those with knee flexion values less than 20° at both initial contact and peak with specificity of 90 and 85.71, respectively. VI of decreased knee flexion accurately identified subjects with KAM greater than 21.74 Nm and greater than 25.25 Nm with specificity of 92.31 and 92.86, respectively. VI of hip internal rotation (IR) accurately identified subjects with KAM greater than 21.74 Nm and greater than 25.25 Nm with specificity of 92.31 and 85.71, respectively. VI of wide cut width accurately identified subjects with KAM greater than 21.74 Nm with specificity of 75.

CONCLUSIONS: The findings of this study show that VI of hip IR, decreased knee flexion and wide cut width during a side step cut were able to accurately detect athletes classified as high risk based on KAM greater than 21.75 Nm and greater than 25.25 Nm with moderate to high specificity.

CLINICAL RELEVANCE: The results of this study support the use of a qualitative checklist to evaluate movement errors during a cutting task. Combining this visual assessment of cutting mechanics with other valid tests may provide a more comprehensive testing battery for ACL injury risk assessment.

SP018

COMPARISON OF GLENOHUMERAL TRANSLATIONS DURING SIMULATED SWIMMING IN SWIMMERS DIAGNOSED WITH MULTIDIRECTIONAL INSTABILITY AND HEALTHY CONTROLS

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PURPOSE/HYPOTHESIS: Multidirectional instability (MDI) is a common diagnosis in swimmers with shoulder pain. Shoulder pain and MDI are associated with increased laxity in swimmers. Passive clinical tests and patient history are used to diagnose MDI. The purpose of this study is to determine if swimmers diagnosed with MDI using passive tests demonstrate differences in joint stability during a simulated swim stroke.

NUMBER OF SUBJECTS: Five symptomatic competitive swimmers diagnosed with MDI and 5 asymptomatic nonswimmer, matched controls without MDI were analyzed for this study. Competitive swimmers were included if they had a composite laxity score from the anterior and posterior drawer and sulcus laxity tests greater than 1.5 and shoulder pain present for longer than 6 weeks. Healthy, nonswimming controls with composite laxity scores less than 1.5 were matched to the swimmers for age, BMI and sex.

MATERIALS/METHODS: Dynamic single-plane fluoroscopic images of the humerus and scapula were obtained during a simulated catch phase of a freestyle stroke. Three-dimensional reconstruction of the humerus and scapula obtained from magnetic resonance images were matched to the 2-dimensional fluoroscopic images. Kinematic data were derived from the shape matching process in open source software. Instantaneous center of rotation (ICR) displacement and contact path descriptions of joint surface interactions were used to characterize joint stability. After checking statistical assumptions, a 2-way repeated-measures ANOVA of phase (first 10% and last 90% of internal rotation) and group (swimmer and control) was performed for ICR displacement. Contact path length was normalized across each subject as a percentage of glenohumeral height and width and groups were compared using a 2 sample independent *t* test.

RESULTS: Contact path length calculated by centroid demonstrated no significant differences between swimmers (149.5%) and controls (131.5%) ($P = .62$; SE, 54.2%). No difference in contact path length calculated as a minimum distance was present; swimmers, 253.9%; controls, 218.0% ($P = .75$; SE, 50.5%). There was no significant interaction for ICR displacement; $F_{1,8} = 0.72$, $P = .42$. ICR displacement demonstrated no significant differences between swimmers (22.6 mm) and controls (20.3 mm) ($P = .77$; SE, 5.4 mm).

CONCLUSIONS: This study is novel as it examined the ability of passive clinical tests to identify joint stability differences between groups during active movement. There was no conclusive evidence that swimmers diagnosed with MDI demonstrate signs of decreased joint stability during a simulated swim stroke. Lack homogeneity within groups and a small sample size may have decreased the likelihood of identifying differences in joint stability. Descriptively, the results demonstrated signs of decreased joint stability amongst swimmers in both contact path length measures and phase 2 of ICR displacement.

CLINICAL RELEVANCE: These descriptive differences in swimmers with MDI require further assessment to consider relative to clinical decision making.

SP019

FEAR MAY NOT PREDICT FUNCTIONAL PERFORMANCE, ACTIVITY LEVEL, OR SECOND INJURY AMONG ATHLETES WHO MEET OBJECTIVE RETURN-TO-SPORT CRITERIA AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Athletes after ACL reconstruction (ACLR) who return to their preinjury sport level, versus those who do not, exhibit less fear and greater motivation, confidence, and psychological readiness. Adding psychological measures like fear of movement to objective functional criteria may be important when determining readiness for return-to-sport (RTS). Paterno et al found that young athletes with high versus low fear were more likely to exhibit lower activity levels, lower hop and quadriceps strength symmetries, and higher reinjury rates. Paterno's study evaluated athletes who were cleared for RTS but did not necessarily meet objective functional criteria. The purpose of the present study was to investigate, among athletes who met stringent RTS criteria, the effect of fear at RTS on functional performance, activity level, and second injury at RTS and 1 and 2 years after ACLR.

NUMBER OF SUBJECTS: Seventy.

MATERIALS/METHODS: Athletes after primary ACLR were eligible if they were 13 to 55 years old, previously played a level I or II sport 50 hours per year or more, and met RTS criteria including 90% or greater limb symmetry index (LSI) for quadriceps strength and 4 hop tests. Participants completed surveys, isometric quadriceps strength, and single hop for distance at RTS clearance and 1 and 2 years after ACLR. The Tampa Scale of Kinesiophobia (TSK-11) assesses fear of movement and reinjury (11 [low] to 44 [high]). The Marx Scale assesses frequency of running, cutting, decelerating, and pivoting on a scale from 0 to 16 with 16 indicating participation in each

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activity 4 times per week or more. Variables were dichotomized using previously defined cut scores: TSK-11 score of 16 or less, quadriceps LSI of 90% or less, single hop LSI of 95% or less, and Marx score of 15 or less. Chi-square tests, odds ratios, and *t* tests tested outcome variables in the High versus Low fear groups based on TSK-11 scores (17 or greater versus 16 or less) at RTS ($\alpha = .05$).

RESULTS: No differences existed in demographics, functional performance, activity level, or second injury rates between the High and Low Fear groups at any time (High/Low: n = 36/34 [men, 18/19]; mean ± SD age, 20 ± 6 and 22 ± 10 years; BMI, 26 ± 4 and 26 ± 3 kg/m^2; time to RTS, 35 ± 11 and 36 ± 16 weeks). At 2 years, the majority in both groups exhibited greater than 90% quadriceps LSI (High, 69%; Low, 83%) and greater than 95% single hop LSI (High, 79%; Low, 78%) but not high Marx scores (High, 45%; Low, 45%). second injury rates did not differ between groups (High, 6/36; Low, 4/34; $P = .56$; odds ratio = 1.5; 95% CI: 0.4, 5.8). Results were similar during secondary analyses on only those younger than 25 years (High/Low: n = 29/27 [men, 13/14]; number of second injuries, 5/4).

CONCLUSIONS: In contrast to previous work, self-reported fear via the TSK-11 at RTS did not predict concurrent or future functional performance, activity level, or second injury risk among athletes after ACLR who met objective RTS criteria.

CLINICAL RELEVANCE: Among athletes who meet stringent objective RTS criteria, fear of movement/reinjury as assessed via the TSK-11 at RTS may not provide additional value in determining functional performance, activity level, or second injury risk in the 2 years after ACLR.

SP020

CHILDREN DEMONSTRATE ASYMMETRIC FRONTAL PLANE KINEMATICS DURING A LATERAL STEP-DOWN AFTER PEDIATRIC ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Movement pattern asymmetries in the frontal and sagittal planes have shown to be predictive of second injury in young, active individuals after anterior cruciate ligament reconstruction (ACLR). Whether asymmetrical movement patterns are present in children after a pediatric ACLR procedure (pACLR) is not known. The purpose of this study was to examine the frontal and sagittal plane movement patterns of children after pACLR during a single-leg (SL) lateral step-down task, a commonly utilized intervention during rehabilitation following ACLR. We hypothesized that between-limb asymmetries would be observed during the lowering phase of a SL lateral step-down.

NUMBER OF SUBJECTS: Eight skeletally immature participants were evaluated following primary, unilateral, physeal-sparing pACLR (100% male; mean ± SD age, 11.4 ± 1.87 years; iliotibial band autograft; mean time from pACLR, 5.30 ± 2.23 months) as part of an ongoing longitudinal study.

MATERIALS/METHODS: Sagittal and frontal plane lower extremity kinematics were calculated using 3-D motion analysis during a SL lateral step-down from a 4-inch box. Each participant performed 3 trials on each limb. Variables identified during the lower phase of the lateral step down and included: peak knee flexion angle (PKFA), peak knee abduction angle (PKABA), peak pelvis drop (PPD), pelvis drop excursion (start of task to PKFA), and knee abduction excursion (start of task to PKFA). Differences in kinematic variables between limbs were compared using paired-samples *t* tests ($P \leq .05$).

RESULTS: PKFA was lower on the involved limb (52.71° ± 7.04°) compared to the uninvolved limb (9.92° ± 8.36°, $P < .001$). In the frontal plane, the involved limb (2.39° ± 4.85°) had greater PKABA compared to the uninvolved limb (0.45° ± 3.84°, $P = .034$), but there was no difference in knee abduction excursion between the involved (8.28° ± 3.28°) and uninvolved limbs (6.74° ± 2.80°). At the pelvis, involved limb PPD (4.83° ± 4.08°) was lower than the uninvolved limb PPD (5.36° ± 4.04°, $P = .023$), but involved limb pelvis drop excursion was higher (9.69° ± 4.85°) than the uninvolved limb (7.30° ± 3.20°, $P = .029$).

CONCLUSIONS: Participants exhibited between limb asymmetries in the frontal and sagittal planes at both the pelvis and knee during a SL lateral step-down task. As hypothesized, the involved limb demonstrated decreased knee flexion, increased knee abduction and increased pelvis drop compared to the uninvolved limb. Between limb differences in PKABA was minimal and future studies should examine this measure to determine if knee frontal plane asymmetries persist with more demanding tasks.

CLINICAL RELEVANCE: Five months post-pACLR is typically when running and jumping tasks are reintroduced, according to time-based rehabilitation guidelines. Evaluation of movement quality and interventions to facilitate landing movement symmetry should be considered with rehabilitation to optimize outcomes in the pediatric population. Further study of the movement patterns of this patient population and potential impact on outcomes and second ACL injury risk is warranted.

SP021

THE EFFECTS OF CONCUSSION ON THE RISK FOR SUBSEQUENT LOWER EXTREMITY INJURIES IN ATHLETES

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INTRODUCTION: Although a concussion is most commonly associated with cognitive impairments, motor control deficits can also occur, especially as a task becomes more complex. This is particularly important to consider in athletics and contact sports, which contain complex dual task movements that potentially place athletes at risk for injury. As athletes prepare for return to play, it is important to consider the residual effects of concussion on lower extremity motor control. The purpose of this review was to examine the effects of concussion on the risk for subsequent lower extremity injuries in athletes.

METHODS: Article searches were conducted using the electronic databases PubMed Central, SPORTDiscus, ProQuest, Science Direct, CINAHL, BioMed Central, and Google Scholar. Key words included concussion, motor control, lower extremity injuries, athletes and contact sports. Articles were reviewed through April 2018 and the inclusion criteria included: articles from peer-reviewed, English language journals; retrospective or prospective cohort design; use of a control group for comparison; athletes competing in sports at any level; and an assessment of the occurrence of lower extremity injuries postconcussion. The GRADE (Grading of Recommendations Assessment, Development and Evaluation) format was used to evaluate the quality of the evidence.

RESULTS: Seven articles met the inclusion criteria and assessed high school, collegiate and professional athletes in a variety of sports including football, soccer, ice hockey and lacrosse. Common variables evaluated included gait sway, balance, navigating obstacles, and performance of dual tasks. The motor control deficits commonly found included decreased gait speed, increased sway during gait, postural instability, decreased static and dynamic balance, and difficulty navigating obstacles.

DISCUSSION: Concussions had a negative effect on every variable, especially the performance of dual tasks that mimicked athletic movements such as cutting, jumping and running. Dual task performance remained impaired for a substantially longer time even after single task activities had returned to normal. All 7 studies reviewed concluded athletes who suffered a concussion were twice as likely to sustain a subsequent lower extremity injury even at 1 year postconcussion compared to matched controls.

CONCLUSION: The results of this review indicate motor control changes occur after a concussion that increase the risk of lower extremity injuries. This is relevant considering athletes demonstrate motor control deficits even after being asymptomatic for over a year and cleared for return to competition. The elevated potential for injury should be taken into account when making decisions related to return to play and rehabilitation protocols.

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SP022

DIFFERENTIAL DIAGNOSIS AND MANAGEMENT OF GROIN PAIN IN A MALE MARATHON RUNNER

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BACKGROUND AND PURPOSE: The assessment and treatment of groin injuries remains elusive due to a lack of standardization in terminology, classification, and diagnosis. As a result, there is no consensus on a standard of care in the management of athletic groin injuries. The purpose of this study is to describe a case of the management of groin pain in a competitive marathoner by integrating pelvic floor interventions as part of a comprehensive core and hip treatment program.

CASE DESCRIPTION: This case describes the management of a competitive male marathon runner with an onset of groin pain while running the New York City Marathon. Extensive medical workup was performed by multiple providers which including advanced imaging and multiple referrals. The patient was given a different diagnosis by 3 different medical providers. The patient is a competitive marathoner and plans to begin training for his next marathon in 5 months but is currently unable to run due to pain.

OUTCOMES: Prior to treatment range of motion (ROM), manual muscle testing, and functional movement assessment were performed. Extensive history of the pelvic floor was taken as part of a standard hip and groin examination and external exam was performed. Additional groin specific measures were taken with a squeeze test and functional outcomes measures were recorded with the hip and groin outcomes scale (HAGOS). The patient was seen for 12 sessions consisting of manual therapy targeted at active release of the distal one third of the adductors. Traditional physical therapy was complemented with 6 sessions of internal pelvic floor soft tissue work by a separate therapist. A comprehensive core and hip stabilization program was also implemented. Posttherapy results showed improvement of HAGOS scores from 72 to 93 and squeeze test results improved from 200 mmHg with pain to 275 mmHg and pain free.

DISCUSSION: Proper treatment of any orthopaedic diagnosis relies on an accurate assessment. Understanding the complexities of the hip including the role of the pelvic floor is crucial for proper referral and effective management. The combination of internal soft tissue techniques and traditional therapy including distal adductor release and combined core and hip stabilization programs resulted in improved functional outcomes and return to sport.

SP023

RETURN OF BILATERAL QUADRICEPS MUSCLE STRENGTH FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING A CONTRALATERAL PATELLAR TENDON GRAFT

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PURPOSE/HYPOTHESIS: Return of quadriceps muscle strength after anterior cruciate ligament (ACL) reconstruction can be difficult. Patients often do not return to pre injury level of function due to quadriceps weakness. Many ideas exist for restoring quadriceps strength, but there is no consensus on how to achieve that goal. We hypothesized that restoring full ACL knee range of motion (ROM) would allow the return of full quadriceps strength, and using a patellar tendon graft (PTG) from the contralateral knee would facilitate return of quadriceps strength in both knees.

NUMBER OF SUBJECTS: Two hundred seventeen.

MATERIALS/METHODS: Between 2009 and 2013, 217 patients underwent primary ACL reconstruction using a PTG from the contralateral knee, and were enrolled in the study. Before surgery, ROM and strength (isokinetic testing at 60°/s) were measured bilaterally. The preoperative noninvolved knee ROM and strength, values were recorded as the baseline normal values for each patient. Each patient underwent an ACL reconstruction with contralateral PTG in the same clinic. Goals postoperatively were divided between knees. The ACL knee focus was to restore full extension followed by flexion. The donor knee focus was to restore tendon strength through low load, high repetition exercise. Once knees were symmetric for ROM and strength, patients progressed to preop values for strength bilaterally, and returned to pre injury levels of activity. Strength and ROM were recorded bilaterally at 1 month, 2 months, 3 months, 6 months and 1 year postoperatively. IKDC criteria for normal ROM compared to opposite knee was used.

RESULTS: Full ACL knee extension was restored early (98% were normal at 1 month), and maintained at 1 year post operation (100% were normal). ACL knee flexion compared to normal returned more gradually over the first year as expected (17% at 1 month, 85% at 6 months, 94% at 1 year). Combined normal extension and flexion compared to opposite knee was achieved in 94% of the patients by 1 year post operation. Quadriceps strength in both knees also returned over the first postoperative year. Compared to preoperative baseline values, mean ACL knee quadriceps strength was 91% by 6 months (CI: 88%, 94%) and 101% by 1 year (CI: 98%, 104%). Donor knee strength compared to baseline was 84% by 6 months (CI: 81%, 87%) and 95% by 1 year (CI: 92%, 97%).

CONCLUSIONS: Return of quadriceps muscle strength following ACL reconstruction is possible. With focus on return of ROM prior to return of strength, patients were able to restore ACL knee quadriceps strength to preoperative baseline values within the first year after surgery. Dividing rehabilitation goals between knees also allows the donor site quadriceps strength to return during the first postoperative year.

CLINICAL RELEVANCE: Restoring ROM prior to strengthening allowed this patient population to restore quadriceps strength after ACL reconstruction. Donor knee quadriceps strength was also restored, and using a contralateral PTG provides a predictable return to normal strength in both knees.

SP024

LONGITUDINAL CHANGES IN FUNCTIONAL MOVEMENT QUALITY AMONG FIREFIGHTER RECRUITS: AN OBSERVATIONAL COHORT STUDY

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PURPOSE/HYPOTHESIS: Previous research has utilized the Functional Movement Screen (FMS) to identify relationships between functional movement quality and measures of health and fitness within the tactical athlete population of firefighters. Previous research has also demonstrated significant improvements in health and fitness among firefighter recruits during their training academy, but a significant loss of these adaptations during their subsequent probationary period of active-duty service. However, potential longitudinal changes in functional movement quality among firefighter recruits have yet to be examined. Therefore, the purpose of the current study was to observe longitudinal changes in functional movement quality among firefighter recruits. It was hypothesized that a significant ($P \leq .05$) increase in FMS scores would be observed from the beginning (W1) to the end (W14) of their training academy, but that a significant decrease in FMS scores would be observed at the end of their probationary period of active-duty service (W38).

NUMBER OF SUBJECTS: Twenty-six male firefighter recruits enrolled in the same firefighter recruit training academy volunteered to participate in the current study (mean ± SD age, 30.1 ± 4.1 years; height, 179.8 ± 4.7 cm; body mass, 87.6 ± 9.7 kg).

MATERIALS/METHODS: All participants completed all 7 subtests of the FMS at W1, W14, and W38. A repeated-measures ANOVA test and follow-up pairwise comparisons were performed to identify significant differences in

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Total FMS scores (0-21) across time. Repeated-measures Friedman tests and follow-up Wilcoxon tests were performed to identify significant differences in FMS subtest scores (0-3) across time.

RESULTS: A statistically significant effect of time was observed among Total FMS scores ($F_{2,50}$ = 40.372, P<.001), with significant increases (P<.001) in Total FMS scores observed from W1 (11.92 ± 1.83) to W14 (13.62 ± 1.56) and from W14 to W38 (14.46 ± 1.27). In addition, significant changes were observed among the Hurdle Step (HS) (χ^2 = 22.800, P<.001), In-Line Lunge (ILL) (χ^2 = 13.765, P<.001), Push-Up (PU) (χ^2 = 7.319, P = .026), and Rotary Stability (RS) (χ^2 = 38.083, P<.001) subtests across time. While only the RS subtest significantly increased from W1 to W14 (P<.001), all 4 of these subtests significantly increased from W1 to W38 (P<.05).

CONCLUSIONS: Similar to previous research, the functional movement quality of firefighter recruits significantly improved from the beginning to the end of their training academy (W1 to W14). However, unlike previous research, the functional movement quality of these recruits continued to significantly improve during their probationary period of active-duty service (W14 to W38).

CLINICAL RELEVANCE: Although previous research has identified relationships between functional movement quality and health and fitness within the firefighter population, changes in these measures may be independent from each other. It is also possible that the mastery of firefighter skills facilitates improvements in functional movement.

SPO25

THE RELATIONSHIP BETWEEN REPEATED VERTICAL AND BROAD JUMPS: AN EXPLORATORY ANALYSIS

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PURPOSE/HYPOTHESIS: An athlete's ability to recycle energy they previously created from another movement is termed energy reutilization. Currently, there is little literature on procedures and tests that accurately determines an athlete's energy reutilization ability. In the rehabilitation setting, there is ample literature on discharge testing specific to power but a limited amount on testing for energy reutilization. The purpose of this study was to identify the gold standard, field ready energy reutilization test, which is currently hypothesized to be measured via Reactive Strength Index (RSI). It is hypothesized that an athlete who jumps farther or with greater height during repeated jumping will also have a decreased ground contact time (GCT) during jumping.

NUMBER OF SUBJECTS: Forty-three.

MATERIALS/METHODS: Forty-three participants, 22 males and 21 females, mean ± SD age of 25.58 ± 4.24 years participated in a cross-sectional design was used to examine the relationship between GCT and jump height or distance, and Just Jumps jump 4 times protocol in healthy recreational athletes. A standard warm-up of 10 minutes was completed. Each participant then completed a series of jumps that were randomized via a random number generator. The protocol included: broad jump, double broad jump, triple broad jump, and Just Jumps jump 4 times protocol. Each participant performed 3 trials of each jump except for the Just Jumps jump 4 times protocol, which consisted of 4 trials. Statistical analyses were performed using a series of Pearson correlation coefficients for all raw and height normalized jump distances, jump contact times, and RSIs (P<.05).

RESULTS: There were high correlations between all tests for height and distance jumped (r = 0.817, P<.0001 to r = 0.931, P<.0001). There was high correlation between GCT for double and triple broad jump (r = 0.769, P<.0001), and no relationship between neither GCT double and triple broad jumps and Just Jump's GCT protocol (r = 0.137, P = .382 and r = 0.385, P = .011, respectively). Just Jump's average GCT was lower than the double or triple broad jumps GCT (0.473 ± 0.026 seconds, 0.341 ± 0.0135 seconds, 0.351 ± 0.0212 seconds, respectively). The triple broad jump and Just Jump's protocol's RSI had high correlation (r = 0.666, P<.0001).

CONCLUSIONS: These findings show there was a relationship between the distance and height, and RSI between the different repeated jumps; however, there was no relationship between the GCT and the repeated jumping tests, however Just Jump's protocol had a higher average GCT.

CLINICAL RELEVANCE: These repeated jumping components may be useful in the ability of a field ready and repeatable test for energy reutilization that would allow a coach to find and work on an athlete's deficiencies. Identifying and addressing these deficiencies before an athlete returns to sport following an injury are crucial to prepare the athlete in all domains of their sport. Since height/distance jumped is correlated, but there is a higher average GCT in the Just Jump's protocol, RSI could be considered a gold standard with the triple broad jump.

SPO26

QUANTIFYING EXTERNAL LOAD IN WOMEN'S COLLEGIATE LACROSSE PLAYERS: NORMATIVE DATA FOR REHABILITATION MANAGEMENT AND RETURN-TO-PLAY DECISIONS

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PURPOSE/HYPOTHESIS: Quantifying external loads during athletic activities, particularly game level competition, can provide objective data for the management of late-stage rehabilitation and return-to-sport decisions after lower extremity injury. To date, no studies have quantified these data in collegiate women's lacrosse athletes or whether the external loads differ among positions. Thus, the purpose of this study was to quantify normative values for collegiate women's lacrosse players, and identify any positional differences in activity demands during game competitions. We hypothesized that there would be positional differences, such that midfielders would travel a greater distance than defenders and attackers, yet have a lower frequency of high-intensity accelerations and decelerations.

NUMBER OF SUBJECTS: Eighteen female Division I collegiate lacrosse athletes that participated in at least 75% of the season's games were included in the study.

MATERIALS/METHODS: Activity demands were collected using a wearable global positioning system unit during 19 games over the course of a season. Descriptive statistics of distance (total distance, distance at high-intensity speed [greater than 15 km/h]), speed (peak), and frequency [sprints (greater than 10 km/h), high-intensity sprints (greater than 15 km/h), high-intensity accelerations (3 m/s^2 or greater), high-intensity decelerations (−3 m/s^2 or less) measures were computed. Mean values were calculated for attackers (n = 5), midfielders (n = 7), and defenders (n = 6), and 1-way ANOVA models were used for positional comparisons (α = .05).

RESULTS: On average, players travelled 4733 ± 2294 m per game (range, 1259-7811 m), of which 656 ± 446 m (range, 60-1633 m) occurred at high-intensity speeds, and reached a maximum speed of 24.1 ± 2.6 km/h (range, 19.2-27.7 km/h). Each game, subjects averaged 124 ± 68 sprints (range, 20-201), 6.1 ± 4.1 high-intensity sprints (range, 1-14), 51 ± 34 high-intensity accelerations (range, 9-97), and 38 ± 25 high-intensity decelerations (range, 6-74). No positional differences were identified in any external load variable (P>.05).

CONCLUSIONS: During game competition, collegiate women's lacrosse demands significant external load, much of which occurs at high intensities. The demands analyzed in this study were comparable amongst positions.

CLINICAL RELEVANCE: These data provide normative values for reference during late-stage rehabilitation and return-to-play testing, allowing clinicians to quantitatively progress load tolerance throughout rehabilitation and guide when return-to sport is safe and feasible. Female lacrosse

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athletes need to be prepared for high external loads before returning to the level of game competition. These data suggest that the activity demands for those participating in collegiate women's lacrosse differ from other women's multidirectional sports. Understanding the activity demands during game competition, and whether they differ among positions, is imperative for clinicians as they progress injury rehabilitation programs and return-to-sport decisions.

SP027

THE EFFECTS OF BLOOD FLOW RESTRICTION RESISTANCE TRAINING ON THE FUNCTIONAL AND PHYSIOLOGICAL IMPROVEMENTS IN A RECREATIONALLY ACTIVE SUBJECT WITH PARKINSON DISEASE

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PURPOSE/HYPOTHESIS: Blood flow restriction (BFR) applied during low intensity resistance training (LIRT) exercise produces hypertrophy and strength gains equivalent to traditional training. Previous research has shown the positive effects of BFR on younger and older adults. However, the effectiveness of BFR -LIRT on subjects with Parkinson Disease (PD) has not been investigated. The purpose of the study was to determine the effects of BFR-LIRT on a recreationally active person with PD in regards to functional improvements, restless leg syndrome (RLS), and safety. The hypothesis was that BFR-LIR will demonstrate improvements in function, body composition, while decreasing symptoms associated with RLS in a subject with PD.

NUMBER OF SUBJECTS: A single-subject, A-B-A design was utilized.

MATERIALS/METHODS: The subject was a 66-year-old recreationally active man with a diagnosis of PD for 8 years and classified Level 2 on the Hoehn and Yahr scale. The design included a preintervention baseline phase A, intervention phase B, and postintervention phase A, all 6 weeks in length. Outcome measures included 30-second sit-to-stand, timed up-and-go (TUG), RLS Questionnaire, 3-RM of Cybex leg press (LP), leg curl (LC), and leg extension (LE) measured at weeks 1, 3, 6, 9, 12, 15, and 18 (DEXA performed only on weeks 1, 6, 12, and 18). The intervention phase (B, weeks 6-12) included 4 lower extremity resistance exercises (LP, LC, LE, calf presses on the LP) starting at 30% of the subject's 3-RM for each exercise, 3 by 15 repetitions, when the subject exceeded 15 repetitions the weight was increased by 10 lb. BFR began with 50% of the subject's SBP and increased by 10% each week as per subject's tolerance to a final pressure of 100% SBP during week 12.

RESULTS: Visual analysis of the data collected showed that the subject's scores on all outcome measures except the TUG and DEXA measurements showed the greatest improvement at week 12, the end of the intervention Phase B. The LP and LC 3-RM were maintained, while most other outcome measures regressed by week 18, the end of the postintervention Phase A. Our subject did not experience any adverse effects over the 6-week intervention phase.

CONCLUSIONS: The subject tolerated the intervention well without any adverse effects. The results of this single subject design were that BFR training can produce significant strength gains; functional improvements reduce RLS symptoms and can be safely utilized with a patient with PD.

CLINICAL RELEVANCE: The combination of low intensity resistance training and BFR can produce the same physiological benefits at 35% to 50% less intensity than traditional high intensity training. The results demonstrate that the combination of BFR with LIRT can lead to an increase in lower extremity strength and function in a subject with PD, while decreasing their RLS (improvement from moderate to mild symptoms) resulting in a better quality of life for the subject.

SP028

INTERLIMB ASYMMETRIES OF ECCENTRIC MEAN FORCE DURING THE COUNTERMOVEMENT JUMP: SEX DIFFERENCES IN COLLEGIATE ATHLETES

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PURPOSE/HYPOTHESIS: Female athletes are 3 to 5 times more likely to suffer a noncontact lower extremity (LE) injury than males, with risk factors linked to discrepancies in interlimb strength and jump-landing mechanics during sporting activities. As such, limb-symmetry indices are suggested to help determine return-to-sport readiness and risk of future injury, with frequent recommendations of a 10% or less difference between limbs. Specifically, asymmetrical LE eccentric strength during dynamic activities has been correlated to the degree of athletic performance, rehabilitative progress, and even injury susceptibility. The countermovement jump (CMJ), an assessment of explosive LE power, is commonly used to monitor dynamic eccentric strength production. Unfortunately, investigations evaluating sex differences in percent asymmetry of LE eccentric mean force (EccMF), a valuable indicator of eccentric strength, in high-risk athletic populations are limited. The aim of this study was to examine if sex differences exist in percentage of interlimb EccMF asymmetry during the CMJ in collegiate athletes. We hypothesized that among collegiate athletes, females will demonstrate a greater percentage of interlimb EccMF asymmetry than males during the CMJ.

NUMBER OF SUBJECTS: Forty-one.

MATERIALS/METHODS: A total of 41 healthy NCAA Division I athletes participated in preseason testing, with groups including 24 males (basketball, n = 7; baseball, n = 17) and 17 females (basketball, n = 6; softball, n = 11). Following routine warm-up, participants performed 2 CMJ in series. The CMJ was completed with hands on hips and subjects instructed to jump "as high and as fast as possible." Jumps were recorded by two, 1-dimensional ForceDecks force plates to obtain EccMF (Newtons) per limb during the initial take-off phase, with results averaged between trials. Interlimb asymmetry was measured as the difference in EccMF between LE, divided by the sum of EccMF from both legs. This value was then multiplied by 100 and reported as a percentage. Independent-samples *t* test was used to compare percent of interlimb EccMF asymmetry between females (n = 17) and males (n = 24), with statistical significance accepted at $P<.05$.

RESULTS: All data are presented as mean ± SD. Female athletes demonstrated statistically significant differences in percentage of interlimb EccMF asymmetry as compared to males during the CMJ (female, 17.76% ± 8.07%; male, 8.92% ± 8.22%; $P<.01$).

CONCLUSIONS: Collegiate female athletes displayed nearly double the percentage of interlimb EccMF asymmetry during the CMJ as compared to male counterparts, with scores well beyond the recommended 10% threshold of similarly reported measures.

CLINICAL RELEVANCE: This study underscores the value of utilizing objective and efficient screening tools to monitor lower limb asymmetries in high-risk populations, with a call for further investigations to examine the specific role of EccMF in the prediction and prevention of future injury.

SP029

EARLY PSYCHOLOGICAL READINESS AND SELF-EFFICACY FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION PREDICT KNEE FUNCTION AT RETURN TO SPORT

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PURPOSE/HYPOTHESIS: Anterior cruciate ligament reconstruction (ACLR) has a significant psychological impact on the athlete which may affect

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performance in rehabilitation and return to sport. Lower psychological readiness (PR) and self-efficacy (SE) during the early phase of rehabilitation may potentially translate to decreased performance at the time of return to sport. To date, the impact of lower PR and SE early in recovery on knee function and return to sport is not well understood. Thus, the purpose of this study was to define how early psychological response to recovery affects knee function as well as patient-reported outcomes (PROs) at the time of return to sport. We hypothesize that higher PR and SE at 3 months after ACLR will predict knee function and PROs at 6 months.

NUMBER OF SUBJECTS: Thirty subjects (13 female, 17 male; mean ± SD age, 18.4 ± 4.5 years; BMI, 23.8 ± 2.6 kg/m^2) who underwent ACLR.

MATERIALS/METHODS: At 3 months post ACLR, psychological response was evaluated using the ACL Return to Sport After Injury (ACL-RSI) and Knee Self-Efficacy Scale (K-SES). At 6 months post ACLR, quadriceps strength was assessed via maximal voluntary isometric contractions (MVICs) on a Biodex dynamometer and knee flexion excursion was assessed with 3-D motion analysis while running. Patient-reported outcome measures included the International Knee Documentation Committee (IKDC), Lysholm Knee Scoring Scale, Knee injury and Osteoarthritis Outcome Score (KOOS) sports/recreational activities (KOOSSport) and quality of life (KOOSQoL) subscales. Pearson product moment correlation coefficients and linear regressions were used to assess the relationships of 3-month and 6-month variables.

RESULTS: The ACL-RSI (58.4 ± 2.3) significantly correlated with the IKDC (P = .001, r = 0.565), Lysholm (P = .002, r = 0.550), KOOSSport (P = .002, r = 0.548), KOOSQoL (P = .017, r = 0.431), and quadriceps strength limb symmetry (P = .003, r = 0.528). The K-SES (6.5 ± 1.7) significantly correlated with the IKDC (P = .003, r = 0.528), KOOSSport (P = .018, r = 0.430), KOOSQoL (P = .024, r = 0.411), quadriceps strength limb symmetry (P = .010, r = 0.465), and knee flexion excursion (P = .008, r = 0.472). The ACL-RSI and K-SES at 3 months after ACLR significantly predicted 27.9% and 21.6% of the variance in quadriceps strength limb symmetry at 6 months after ACLR, respectively.

CONCLUSIONS: Subjects with higher early PR and SE demonstrated greater quadriceps strength, greater knee flexion excursion, and improved subjective function and quality of life at 6 months post ACLR. Psychological factors are potentially modifiable and addressing these factors early in rehabilitation should be considered in order to optimize outcomes and improve return to sport readiness after ACLR.

CLINICAL RELEVANCE: Understanding the interactions among PR, SE, quadriceps strength, knee mechanics, and PROs in patients with ACLR may aid clinicians in creating new treatment approaches, which may include both physical rehabilitation and early psychological counseling, to ensure that optimal recovery can occur.

SP030

TRAUMATIC ATLANTOAXIAL INSTABILITY IN A DIVISION I COLLEGIATE FOOTBALL PLAYER

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BACKGROUND AND PURPOSE: Injury and subsequent instability of the atlantoaxial joint (AAI) can be catastrophic. Included among the disturbances associated with AAI are a loss of bowel/bladder control, impaired gait, motor incoordination, sensory loss, and in extreme circumstance, death from spinal cord compression. Despite the severe consequences, the trauma associated with such injuries may be muted. The purpose of this case report to highlight AAI due to a subtle, yet traumatic injury of the transverse ligament during a football game. The acute on-field clinical presentation, related acute medical management, and surgical intervention will be discussed.

CASE DESCRIPTION: A 21-year-old Division I football defensive back was involved in a head-to-head collision with an opposing player during kickoff coverage. The impact of the collision appeared to be relatively inconspicuous. The player did remain on the ground to gather himself, but was able to walk off the field on his own accord. The team head athletic trainer, physical therapist, and physician were notified that he may have sustained a concussion. The player did report transient bilateral paresthesia at the time of impact. The sideline examination did not reveal any overt signs of a concussion and a quick neurologic assessment was clear (negative cranial nerve testing, normal myotomes and dermatomes). There were also no complaints of difficulty swallowing, vision disturbances, or headache. The player reported his desire to return to play, however he was held out.

OUTCOMES: After the initial sideline examination, the player began to complain of stiffness in his cervical spine and began to lose cervical mobility, specifically he was unable to rotate his head no more than 45°. Using the Canadian C-Spine Rules, the decision to attain radiographs was immediately enacted. Anterior-to-posterior open-mouth (AP-OM) radiographs with the head in neutral and in bilateral lateral flexion position were taken in the stadium. The AP-OM revealed an ipsilateral offset of the lateral margins of C1 on C2, indicating alar ligament laxity, a cause of AAI. The player was immediately placed in a Miami J Collar and advised him that it was to remain worn at all times. Subsequent radiographs revealed a 5-mm anterior translation of C1 on C2, due to a complete rupture of the transverse ligament. Several days later, the player underwent a posterior C1-2 fusion with screws and rods, which were combined with a structural tibial allograft, 1 titanium cables, and BMP.

DISCUSSION: Physical therapists working on the sidelines should be familiar with the signs and symptoms of upper cervical instability. In addition, familiarity with the Canadian C-Spine Rules, differential diagnosis of potential "at risk" pathologies, and ligamentous testing (Sharp-Purser, transverse and alar ligament tests) should be mandatory for the sports physical therapist.

SP031

TEST-RETEST RELIABILITY OF THE MOVEMENT SYSTEM SCREENING TOOL: A NOVEL MUSCULOSKELETAL SCREENING TOOL

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PURPOSE/HYPOTHESIS: The average injury rate per 1000 athletic exposures is 6.0 for NCAA collegiate athletes and 2.9 to 6.2 for 12- to 19-year-olds. During the 2008 Olympic Games, a large percentage of injuries were noncontact (20%) and overuse (22%). One potential risk factor for overuse and noncontact injuries is poor movement quality. Current research concluded there is no musculoskeletal screening tool that identifies athletes at high risk of injury. The purpose of this study was to establish test-retest reliability of the novel Movement System Screening Tool (MSST). We hypothesized the MSST composite score would have excellent test-retest reliability.

NUMBER OF SUBJECTS: Twenty-one collegiate athletes.

MATERIALS/METHODS: Collegiate athletes between 18 and 35 years of age were recruited. Inclusion criterion was healthy persons that participated in a sport activity 10+ hours per week. Subjects attended 2 testing sessions, with the second session occurring 2 to 14 days following the first session. The MSST was initially developed using a standardized iterative process and a rigorous modified Delphi expert panel. The MSST consists of 16 items that assess stability, mobility, and movement pattern control. The following tests were included: sidebridge hip abduction, active straight leg raise, unilateral hip bridge endurance test, trunk flexion/extension mobility test, rotary stability, shoulder Mobility, Glenohumeral

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internal rotation deficit, scapular dyskinesis test, closed kinetic chain upper extremity stability test, overhead squat, hurdle step, Y Balance Test anterior reach, double-leg lowering test, step-down, Single-leg hop distance, and seated trunk proprioception test. Testing sessions were organized to mimic a group-screening exam. The MSST items were divided into 4 stations and 1 tester/station was assigned 3 to 5 test items. Raters completed 2 hours of training in performance and scoring of the tests. Participants completed testing in the same order for each testing session. Raw scores were converted to an ordinal scale (0-3), with a maximum composite score of 78. The ICC (model 3,1) and minimal detectable change (MDC_{95}) were calculated.

RESULTS: Athletes, mean ± SD age was 21 ± 2 years, 13/21 male and mean participation was 13 ± 5 hours per week. First session average composite score was 51 ± 7 (range, 51-64) and second session 53 ± 7 (range, 41-67). Composite score had an $ICC_{3,1}$ = 0.87 (95% CI: 0.69, 0.95) with an MDC_{95} of 7 points (13.5% of mean score).

CONCLUSIONS: The 16-item MSST demonstrated good test-retest reliability in a group screening format. Composite score psychometric properties are similar to other musculoskeletal screening tools (eg, FMS, 9+ battery). Unlike other tools, the MSST did not show a ceiling effect in collegiate athletes.

CLINICAL RELEVANCE: The MSST provides clinicians with a reliable battery of tests that can be used to screen athletes for musculoskeletal and movement impairments in a practical format. The MDC_{95} provides a change score that needs to be exceeded to demonstrate true change in performance.

SP032

RISK FACTORS FOR SECOND ANTERIOR CRUCIATE LIGAMENT INJURY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A SYSTEMATIC REVIEW OF NATIONAL DATA SETS

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PURPOSE/HYPOTHESIS: Research suggests as many as 30% of young athletes suffer a second anterior cruciate ligament (ACL) injury after ACL reconstruction (ACLR) and return to sport (RTS). With the high risk for second injury, there is a need to recognize and address predictive risk factors. National registries and multicenter studies offer the opportunity to identify risk factor patterns that are consistent across health systems, and when sample sizes are large enough, perform deeper analyses of potential patient-specific factors. The purpose of this systematic review was to summarize and synthesize the evidence to identify potential predictive factors of second ACL injury from national registries and multicenter studies.

NUMBER OF SUBJECTS: Not applicable.

MATERIALS/METHODS: PubMed and Academic Search Premier databases were searched using key words (("anterior cruciate ligament" or "ACL" or "ACL reconstruction") and ("risk factors" or "risk" or "second injury" or "predictors" or "correlates" or "outcome" or "national registry") not ("animal" or "thrombosis" or "genome")). Accepted studies were reviewed for the following criteria: (1) written in English, (2) identified factors predictive of second ACL injury, (3) sourced from a national database or multicenter cohort. Two reviewers independently evaluated articles, extracted data, and assessed risk of bias for each study.

RESULTS: The initial search yielded 7593 articles, and 32 were ultimately included. Significant risk factors predicting second ACL injury included allograft tissue, hamstring autograft, smaller graft size, increased time from injury to primary surgery, younger age, lower BMI, contact sports, and Caucasian race. Risk factors with no significant effect were height and weight. Inconclusive evidence existed for risk factors related to (1) sex, (2) surgical technique, (3) injured side, (4) patient reported outcomes, (5) smoking status, and (6) concomitant injury. Notable limitations for the available studies included poor control for potential biopsychosocial confounding factors, unaccounted rehabilitation factors, and lack of known modifiable biomechanical risk factors.

CONCLUSIONS: Significant risk factors for predicting second ACL injury, identified in large data sets, include graft-related properties, timing of surgery, age, BMI, sport type, and race. Future registry and multicenter efforts should consider the addition of modifiable and biopsychosocial risk considerations to establish a more comprehensive consideration of the breadth of potential predictors of second injury.

CLINICAL RELEVANCE: The reported risk factors from national data sets associated with second ACL injury are demographic in nature or related to surgical technique. Modifiable rehabilitation factors, able to be addressed within the scope of physical therapy intervention, have not yet been captured at the scale of national registry and multicenter publications. The involvement of physical therapists in multicenter and national registry outcomes studies could greatly enhance the scope of evidence for enhancing ACLR rehabilitation and RTS programs.

SP033

THE EFFECT OF FATIGUE ON RUNNING CADENCE

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PURPOSE/HYPOTHESIS: Runners have been shown to select a cadence that maximizes their running economy yet fatigue has been shown to effect cadence during both over ground and treadmill running. Cadence has been proposed to be a modifiable factor in the prevention of and rehabilitation from running injury as well a contributor to mechanical efficiency. Numerous studies have investigated the effect of fatigue on cadence during constant speed treadmill running, however, little research is available when considering the effect of fatigue on running cadence when runners are permitted to modify their speed in a manner that is more similar to real-life. The purpose of this study was to examine the effect of fatigue on treadmill running cadence when runners were allowed to self-select and modify their speed. It was hypothesized that cadence would not change over the course of a run to fatigue.

NUMBER OF SUBJECTS: Nine uninjured recreational runners (5 female, 4 male; mean ± SD age, 29.56 ± 3.75 years).

MATERIALS/METHODS: A fatiguing run was performed at the participant's self-selected speed, at a pace similar to their 10K race pace. Participants were permitted to increase or decrease the treadmill speed as needed during the run. Runners were considered fatigue once reaching a 17/20 on the Borg Rating of Perceived Exertion Scale. Throughout the run, a 2-dimensional video camera recorded a sagittal view of the participants' running mechanics. Cadence measurements were taken via observational video analysis at the beginning, middle and end of the fatiguing run. Paired-samples *t* tests were used to statistically analyze the data between each time point.

RESULTS: The fatiguing run was performed for a duration of 29.02 ± 7.33 minutes with an average pace across each time point of 3.07 ± 0.43 m/s. No significant differences were found for the participants' cadence between each of the 3 time points ($P>.05$). Although runners did modify their speed during the fatiguing run, there were no significant differences found in running speed between each time point ($P>.05$).

CONCLUSIONS: When performing a treadmill run to fatigue at a self-selected pace and with the ability to modify running speed, cadence did not significantly change over the course of the run. This consistency in running cadence may relate to the runners' ability to self-optimize their running cadence for the greatest running economy. While there were no significant differences in speed between the 3 time points, there was a trend towards increased speed between the beginning and the end of the fatiguing

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run. Future studies with greater sample size should be performed to confirm these findings as well as examining for similar changes when using cadence manipulation as an intervention.

CLINICAL RELEVANCE: When allowed to self-select and modify their running pace, a runner's cadence may not naturally change over the course of a fatiguing run. This should be considered when implementing gait retraining interventions attempting to modify a runner's cadence.

SP034

CORRELATION OF PRESEASON ASSESSMENTS AND INJURY RISK IN ADOLESCENT RUGBY ATHLETES

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PURPOSE/HYPOTHESIS: Injury rates in rugby are substantial due to the frequency of contact and physical demands of the sport. The injuries sustained during sport causes a high physical, emotional, and financial burden to rugby athletes. Although contact rugby injuries are difficult to prevent, noncontact injuries (NCI) have been attributed to modifiable risk factors (MRF). Previously identified MRF's include lumbopelvic instability, lack of physical fitness, and previous injuries that may have caused range of motion restrictions, strength and balance deficits and poor movement patterns. MRF's can be measured with valid and reliable clinical tests, such as the Functional Movement Screen (FMS), Lower Quarter Y Balance Test (LQYBT), and hop testing (HT). A limited number of studies demonstrate that asymmetries (Asym) during functional tests are correlated with increased risk of injury in the rugby population. The purpose of this study is to identify if a relationship exists between limb Asym during preseason assessments (PSA) and risk for sustaining a NCI during a high school male rugby season. Preseason limb Asym was hypothesized to be positively correlated with increased risk for sustaining a NCI.

NUMBER OF SUBJECTS: Fifty-nine.

MATERIALS/METHODS: Forty-seven and thirteen subjects were tested in the 2017 and 2018 seasons, respectively. Subjects were male rugby players (average ± SD age, 16.6 ± 1.4 years). They were assessed by 9 trained clinicians. Athlete demographic and PSA (LQYBT, FMS, single-leg HT (SLHT), single-leg triple HT (SLTHT)) data were collected during 3 rugby practices. Injury data were monitored during the 2017 and 2018 seasons by coaches, who were trained on how to identify and categorize injuries.

RESULTS: Thirty injuries occurred during the 2017 and 2018 seasons: 4 NCI and 26 contact. Phi coefficients revealed FMS In-Line Lunge Asym had the strongest relationship to NCI (Φ = 0.338648, R^2 = 0.1146). The Asym during anterior reach of the LQYBT and FMS Rotary Stability had small negative relationships to NCI's (Φ = −0.2041, R^2 = 0.0417 and Φ = −0.0658, R^2 = 0.0043, respectively). The remainder of PSA's for Asym had little to no relationship to NCI (SLHT: Φ = 0.1375, R^2 = 0.0189; SLTHT: Φ = 0.2, R^2 = 0.04; FMS hurdle step: Φ = 0.23096, R^2 = 0.0533; FMS shoulder mobility: Φ = 0.2791, R^2 = 0.0779; FMS active straight leg raise: Φ = 0.1312, R^2 = 0.0172).

CONCLUSIONS: These results do not support the hypothesis and indicate there is little to no relationship between individual PSA Asym and NCI in adolescent male rugby athletes. Limitations to this study include small sample size, lack of controlled testing environment, and duration of PSA over 5 weeks. Suggestions for future research include larger sample size of rugby athletes, alternate subject populations involving noncontact sports, and performing assessments in a controlled test environment.

CLINICAL RELEVANCE: Although preseason Asym were weakly associated with NCI in male adolescent rugby athletes, the limitations of this study warrant a continuation of data collection to increase the power of the outcomes.

SP035

DIFFERENTIAL DIAGNOSIS AND MEDICAL REFERRAL OF A 32-YEAR-OLD FEMALE ATHLETE WITH INSIDIOUS CALF PAIN

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BACKGROUND AND PURPOSE: Deep vein thromboses (DVTs) are rare in the young, athletic population and can often be mistaken for muscle strains. Recent surgery or trauma, immobilization, long distance travel, and knowledge of hereditary are often the cause of suspicion for DVTs in those with insidious calf pain. Additionally, the use of oral contraceptives can be linked in the healthy population. The prevalence of DVT is 3 out of 10 000 in reproductive-aged females using oral contraceptives. Referral to physical therapy for lower extremity pain may be common in the athletic population, however, obtaining extensive medical and pharmacological history is crucial in order to rule out nonmusculoskeletal presentations. The purpose of this case report is to describe the differential diagnosis and emergent medical referral of a healthy, athletic female for probable DVT after insidious onset of right (R) calf pain.

CASE DESCRIPTION: A 32-year-old woman presented to physical therapy with progressive (R) posterolateral calf pain. Functional limitations included pain with ambulation and inability to extend her (R) knee. Although she previously performed CrossFit workouts, she reported no trauma. Past medical history included intermittent back and (R) leg pain with confirmed left (L) L4 spondylolysis. Past surgical and pharmacological history included diagnostic pelvic laparoscopy 2 months prior to symptom onset and current use of oral contraceptives. Lumbar spine exam included low back pain with trunk extension and (R) unilateral posterior-to-anterior assessment at the L4-S1 levels. Neurological exam was unremarkable. Straight leg raise was positive for calf pain. Further examination revealed moderate swelling and pain with palpation to the lateral gastrocnemius and soleus. Anthropometric proximal calf circumferential measurement was 1 cm increase on the (R). Homan's sign on the (R) was positive. Although her Wells and Autar scores indicated a DVT was unlikely, the patient was immediately referred to her primary care practitioner (PCP) for probable DVT.

OUTCOMES: Following referral, her PCP ordered testing for probable DVT including doppler ultrasonography, D-Dimer quantitative labs, basic metabolic panel, and activated partial thromboplastin time test. Results indicated elevated D-Dimer levels to 1.19 μg/mL fibrinogen equivalent units (FEU standard range, less than 0.54) and positive doppler findings for thrombosed branched vessel from 1 of the large calf veins measuring 7.3 cm in length. Patient was placed on blood thinners (Rivaroxaban) for a 6-month duration and taken off her oral contraceptives.

DISCUSSION: This case demonstrates the importance of accurate medical screening in a direct access clinic including medical, surgical, and pharmacological history as well as appropriate referral for vascular assessment in a healthy, athletic female for the proper diagnosis of a DVT. Thorough patient history and clinical screening are imperative for recognition of nonmusculoskeletal diagnoses and proper referral to the relevant medical professional.

SP036

BASEBALL PLAYERS WITH ULNAR COLLATERAL LIGAMENT RECONSTRUCTION DEMONSTRATE NO DIFFERENCE IN ROTATOR CUFF STRENGTH AT TIME OF RETURN TO THROWING WHEN COMPARED TO HEALTHY CONTROLS

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PURPOSE/HYPOTHESIS: The purpose of this study was to compare isometric internal rotation (IR) and external rotation (ER) strength of the throwing and nonthrowing shoulders at the time of return to throwing in baseball players following ulnar collateral ligament reconstruction (UCLR) with that of healthy, age-matched baseball players. It was hypothesized following UCLR, baseball players would demonstrate less IR and ER strength in the throwing and nonthrowing arm(s) compared to strength of the throwing and nonthrowing arm in healthy baseball players.

NUMBER OF SUBJECTS: Thirty-three participants who underwent a UCLR (mean ± SD age, 18.21 ± 2.5 years; height, 184.8 ± 7.0 cm; weight, 87.7 ± 10.0 kg) were compared to 33 healthy, age and positioned matched con-

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trols (age, 18.21 ± 2.5 years; height, 189.4 ± 7.0 cm; weight, 88.3 ± 7.2 kg). All participants played baseball at a competitive level (playing experience, 13.8 + 2.5 years) and volunteered for the study.

MATERIALS/METHODS: Isometric rotator cuff strength measurements for IR and ER were performed with the arm positioned at 0° of shoulder abduction and the elbow at 90° of flexion. Two measurements were taken bilaterally and the means of the throwing and nonthrowing arms for IR and ER in the UCLR group were compared to the means of the throwing and nonthrowing arms in the healthy group. Independent *t* tests were used to calculate differences between groups ($P<.05$).

RESULTS: At time of return to throwing (179.8 ± 31.5 days postoperation), baseball players following UCLR demonstrate no differences in throwing arm ER strength (UCLR ER throwing, 112.5 ± 18.0 N; Healthy ER throwing, 114.2 ± 22.3 N; $P = .72$), nonthrowing arm ER strength (UCLR ER nonthrowing, 113.4 ± 18.6 N; Healthy ER nonthrowing, 110.8 ± 23.0 N; $P = .62$) and in nonthrowing arm IR strength (UCLR IR nonthrowing, 146.2 ± 24.2 N; Healthy IR nonthrowing, 154.3 ± 22.8 N; $P = .17$). Significant differences exist in strength of throwing arm IR (UCLR IR throwing, 140.8 ± 27.2 N; Healthy IR throwing, 158.5 ± 26.0 N; $P = .009$), the IR difference between throwing and nonthrowing arms in UCLR and Healthy (UCLR IR difference, −5.4 ± 17.0 N; Healthy IR difference, 4.2 ± 18.2 N; $P = .03$), and the ER:IR strength ratio between UCLR and Healthy throwing arms (UCLR, 363.9 ± 70.2 N; Healthy, 321.2 ± 39.1 N; $P = .003$) at time of return to throwing.

CONCLUSIONS: Throwing arm ER and IR force output is normalized at the time of return to throwing compared to healthy controls as indicated by isometric strength measurements. Athletes following UCLR demonstrated a greater ER:IR ratio due to a significant decrease in throwing arm internal rotation strength.

CLINICAL RELEVANCE: Baseball players following UCLR are able to regain rotator cuff ER strength comparable to healthy controls at the time of return to throwing. Based upon the strength findings, these players may be ready to initiate an interval-throwing program following comprehensive rehabilitation. Further research is needed to identify the long-term implications of these findings.

SP037

FACTORS ASSOCIATED WITH INITIAL INTEREST AND TREATMENT SELECTION OF PATIENTS WITH HIP PAIN

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PURPOSE/HYPOTHESIS: Rates of arthroscopic hip surgery have risen significantly, but it is unclear whether surgical management yields superior outcomes to physical therapy (PT) alone. An understanding of potential factors related to initial treatment interest versus selected treatments may better inform treatment expectations to optimize patient outcomes. The purpose of this prospective study was to compare demographics and self-reported function between individuals with hip pain who (1) were or were not initially interested in surgery or PT, and (2) whether or not they had surgery within 3 months of evaluation.

NUMBER OF SUBJECTS: Sixty-two participants (41 female; mean ± SD age, 45.5 ± 14.4 years; BMI, 28.5 ± 6.7 kg/m^2).

MATERIALS/METHODS: After initial evaluation with their surgeon, enrolled participants reported initial treatment interests (surgery, PT, or other), previous participation in PT, and completed the Hip Outcome Score-Activities of Daily Living (HOS). Treatment within 3 months of initial evaluation (surgical group, SG; nonsurgical group, NSG) was collected from electronic health records. Independent *t* tests were used to compare age, BMI, and HOS scores between groups: (1) interest versus no interest in PT (2) Interest versus No Interest in Surgery, and (3) SG versus NSG ($P \leq .05$). Fisher's exact tests were used to assess differences in sex distribution, treatment interest, and previous PT treatment between SG and NSG groups ($P \leq .05$).

RESULTS: Sixty-two patients with nonarthritic hip disease (n = 38), osteoarthritis (n = 10), greater trochanteric pain syndrome (n = 4), or other diagnoses (n = 10) were included in this study. One third of participants were interested in surgery, 18 (29.0%) were interested in PT, 14 (22.6%) were interested in both, and 9 (14.5%) were interested in other treatment. Age, BMI, sex distribution and HOS were not different between those interested or not interested in surgery ($P \geq .14$) or physical therapy ($P \geq .16$). Nearly 90% of individuals with previous PT experience were not interested in additional PT (Previous PT, 10.5%; $P<.01$). Interest in surgery was not associated with whether or not individuals previously had PT ($P = .10$). None of the participants with interest in PT (0/18) underwent surgery ($P<.01$); 66.6% (14/21) with interest in surgery underwent surgery ($P<.01$).

CONCLUSIONS: Treatment interest was not associated with demographics or self-reported function in this cohort. Previous PT was negatively associated with interest in additional PT, but not interest in surgery. Treatment interest (surgery or PT) was associated with whether or not patients underwent surgery.

CLINICAL RELEVANCE: Previous participation in PT may increase interest in undergoing surgery for hip pain. Presumably, if patients seek treatment in a hip preservation clinic following PT, the PT did not yield the desired outcomes, which may be attributed to factors including anatomical variations, neuromuscular deficits, or inadequate rehabilitation. These data indicate an opportunity to reassess and refine current physical therapy intervention strategies with this patient population.

SP038

OSTEOCHONDRAL LESION OF THE DISTAL TIBIAL PLAFOND IN A COMPETITIVE RUNNER

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BACKGROUND AND PURPOSE: Osteochondral defects (OCD) of the tibial plafond (TP) are rarely described with little consensus on symptoms, objective findings or management. The mechanism of injury is generally trauma, but atraumatic cases have been reported. OCD of the TP are best seen with magnetic resonance imaging (MRI) as radiographs may miss 50% of cases. Nonoperative management is successful about half the time while surgical success is 54% to 85%. Lesion size, location, activity level and patient preference combine to determine treatment plan. This case report describes the diagnosis and subsequent conservative management of this injury in an elite runner.

CASE DESCRIPTION: A 44-year-old man presented with sharp, intermittent foot pain that developed during marathon training. He managed symptoms with relative rest but 6 weeks prior to race he could no longer replace running with biking. He had shoes ranging from 12- to 0-mm drop for walking/running but noted no change in symptoms based on footwear. Overall health was excellent. Past medical history included insertional Achilles tendinitis and hip pain that resolved with physical therapy. Radiographs were negative. numeric pain-rating scale (NPRS) scores ranged from 1 to 6/10; Tampa Scale of Kinesiophobia (TSK) score was 13 and Lower Extremity Functional Scale score was 71/80. Joint mobility testing was hypomobile at talocrural joint. He rested in calcaneal inversion bilaterally. Ankle and hip range of motion (ROM) were limited. Muscle length tests were positive for gastrocnemius, soleus, hamstrings and iliopsoas; Ober's test was positive. Lower extremity manual muscle testing was 5/5. Running gait analysis revealed dorsiflexion at initial contact, prolonged stance time and increased braking force on left. Patient was to be seen 1 to 2 times per week and prognosis was excellent.

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OUTCOMES: The patient was seen for 9 PT visits that included manual therapy, therapeutic exercise, neuromuscular re-education, gait training and patient education. He was given a lateral post to decrease calcaneal inversion. NPRS scores range from 1/10 to 6/10; TSK scores ranged from 13 to 17. Pain, limited ROM and muscle tightness persisted, and patient was sent to physician for follow-up. He had a cortisone injection prior to race and completed race. Postrace EMG was unremarkable; MRI revealed anterior impingement and an OCD of the TP. The patient continues to manage pain and symptoms conservatively.

DISCUSSION: This case study from an outpatient orthopaedic facility illustrates the importance of obtaining a detailed medical history and recognizing when response to treatment is atypical for the diagnosis. This patient presented with ankle pain secondary to overuse. Symptoms consistently worsened with loading and improved with rest, normalized ROM, and stretching. Though radiographic imaging is often helpful in diagnosis, it can tell an incomplete story. This case highlights the responsibility of physical therapists to recognize inadequate progression and to work with the interdisciplinary team to determine the source of the problem.

SP039

TRANSIENT OSTEOPOROSIS IN A PATIENT WITH GENERALIZED KNEE PAIN

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BACKGROUND AND PURPOSE: Patients with generalized knee pain may present with nonspecific pain, swelling, and loss of motion. They may, unknowingly, also have bone marrow edema (BME), which has been associated with osteoarthritis (OA), meniscal tears and trauma. This edema may also indicate transient osteoporosis (TO), an idiopathic, self-limiting disorder. Patients present with sudden, severe, atraumatic knee pain inconsistent with clinical patterns. After OA, meniscal tears and osteonecrosis have been ruled out, TO should be considered.

CASE DESCRIPTION: A 47-year-old woman presented with knee pain after initiating an exercise program. Stretching, exercise and massage were helpful. Past medical history included low back pain; health was excellent. Gait was antalgic with decreased flexion during swing phase and extension during stance phase. Structural valgus and 1+ effusion were noted. Tibial tuberosity and medial and lateral condyles were tender to palpation. Patrick's test caused knee pain. Range of motion (ROM), lower body strength (4/5), and special tests were limited by pain. Patient was to be seen twice weekly and prognosis was excellent. Interventions included therapeutic exercise, patient education, neuromuscular re-education, manual therapy and modalities. numeric pain-rating scale (NPRS) scores ranged from 1/10 to 10/10. Radiographs were unremarkable after 1 week. At fourth visit, patient was unable to exercise due to excruciating pain and was referred back to physician. Patient returned with axillary crutches, off-loader brace and magnetic resonance imaging (MRI) revealing transient osteoporosis of the LFC.

OUTCOMES: The patient was seen for 7 physical therapy visits. Knee flexion ROM improved from 60° to 70° with pain. Strength testing and NPRS scores were unchanged. Patient was educated on modifications for exercise program and elected to continue on her own. At 5-month follow-up she reported TO was improved but still present, and a fall resulting in a hairline fracture of her femur.

DISCUSSION: This case study illustrates that it is imperative that we remain diligent in our examination and evaluation of patients who appear to present with routine diagnoses. Multiple clinicians deemed her signs and symptoms consistent with generalized knee pain when it was actually a rare condition. A lag between clinical symptoms and imaging are typical in TO. Her job required walking long distances over uneven terrain and she started a vigorous exercise program making the diagnosis reasonable. Worsening ROM limitations, pain and gait deviations were concerning. Structural valgus may have been a contributing factor as LFC edema is consistent with changes in joint stresses due to mal-alignment. The brace was used to unweight the LFC to decrease stress and mitigate pain. It is critical that we recognize lack of progress and refer for follow-up until a correct diagnosis is reached. Transient osteoporosis requires symptomatic and supportive treatment including protected weight bearing, and management of the effects of gait deviations, disuse atrophy and functional limitations.

SP040

OVERHEAD THROWING PROGRAM IN A COLLEGIATE SOCCER PLAYER FOLLOWING LATARJET PROCEDURE

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BACKGROUND AND PURPOSE: The occurrence of glenohumeral instability in young active patients is estimated at a rate of 23.9 to 56.3 per 100 000 persons per year. Several studies are available for the return of unilateral overhead athletes to sport following a Latarjet procedure, but research is sparse addressing the return to throw-ins for soccer athletes. Soccer is associated with a high risk of glenohumeral instability. The act of performing an overhead throw-in requires anterior glenohumeral stability to allow for rapid acceleration without subluxation. Studies have determined that throw-in distances average between 22.85 and 26.35 yards, with 10% of goals scored after a throw-in. To the author's knowledge there are no published interval throwing programs (ITP) for return to soccer throw-ins. Thus, this case describes the adaptation of an ITP designed for baseball infielders, as used to model an ITP for soccer throw-ins.

CASE DESCRIPTION: This case describes an 18-year-old male collegiate soccer athlete with a history of right shoulder instability with recurrent subluxation and imaging revealing right shoulder anterior bony Bankart lesion, a posterior Hill-Sachs lesion, and posterior labral involvement. He underwent a right Latarjet procedure. The physical therapy evaluation occurred 2 weeks following surgery with a Disabilities of the Arm, Shoulder and Hand (DASH) score of 78/100. Early treatment was progressed by the Brigham and Women's Hospital Latarjet Protocol, per surgeon directive. After 12 weeks of physical therapy, overhead strength and ITP was initiated with the goal of returning to overhead throw-ins at 30 yards. The ITP was adapted from the University of Delaware infielder ITP.

OUTCOMES: The patient was progressed through the Brigham and Women's Hospital Latarjet protocol 6 over 20 weeks of physical therapy. The ITP was initiated postop week 12 with 11.28-oz ball throwing 10 feet. He was progressed through weighted ball throw-ins at 10 ft, with progression to increased distance throw-ins following University of Delaware soreness rules. The second stage of ITP involved the use of a regulation soccer ball thrown at progressing distances from 10 to 25 yards, with careful monitoring of the patient's soreness. At the last visit the patient demonstrated a DASH score of (7/100). He has since returned to throw-ins at 25 yards with 0/10 pain. He is currently in the offseason but has obtained clearance from his MD to return to full contact activities.

DISCUSSION: The lack of supporting data for the construction of an ITP for soccer throw-ins has left a gap in the rehabilitation of athletes returning to sports requiring overhead throwing with the use of bilateral upper extremities. The purpose of the ITP is to slowly increase the demands placed upon the shoulder through a systematic progression of forces. This unique case bridges the gap by modifying the construct of an ITP for infielders to use with soccer athletes for a regimented progression towards return to full athletic capabilities.

SP041

FAILED CONSERVATIVE CARE OF EXERTIONAL ANTERIOR COMPARTMENT SYNDROME IN A HIGH SCHOOL SOCCER PLAYER

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BACKGROUND AND PURPOSE: Chronic exertional compartment syndrome (CECS) is a cause of exercise induced lower-leg pain that is most often seen in young athletic populations who participate in running sports or

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military training. While the exact pathophysiology is unknown, it is theorized that the increased blood flow results in increased pressure and volume within the fascial compartment. Despite poor reported outcomes with nonoperative treatment, most patients with elevated intracompartmental pressure (ICP) are initially treated with conservative therapy. While recent case reports document success treating this condition conservatively, nonoperative treatment of CECS has been shown to be largely ineffective. This case study aims to outline a research based rehabilitation plan for conservative management of CECS, and the need for additional research on the physical therapy treatment of this condition.

CASE DESCRIPTION: This case study investigates a 16-year-old high school male soccer player with complaints of right leg pain for 1 year. Clinical examination and subjective history consistent with CECS of anterior compartment. Patient was referred to physical therapy for 8 weeks of conservative care. Patient was taken through previously researched running technique modifications and exercises shown to decrease symptoms and disability associated with CECS. Following 8 weeks of conservative care, physical examination and relevant outcome measures were repeated and compared to baseline.

OUTCOMES: Strength, range of motion, subjective lower extremity function scores, and patient's pain levels did not change significantly following the 8 weeks of physical therapy. He continued to have pain and symptoms with running after 1 minute on the treadmill at a moderate pace of 7.0 mph. His lower extremity functional scale (LEFS) score improved 2 points from 69/80 to 71/80, with greatest impairments noted in usual physical activities as well as running. Based on his poor response to conservative care, the patient was ultimately referred to orthopaedic surgery where he underwent formal intracompartmental pressure testing. The ICP testing revealed pressures of 55 mmHg at rest, and 120 mmHg 1 minute postexercise. Due to the extremely high nature of these pressures, a decompression fasciotomy of the right anterior compartment was performed.

DISCUSSION: This case study outlines failed conservative treatment of chronic exertional compartment syndrome of the lower leg. While recent case studies have documented successful treatment of these symptoms with gait retraining and specific posed running exercises, this patient was unsuccessful with similar intervention. His extremely high ICP readings warrant the question of whether or not higher than average pressures may be prognostic of which patients will benefit from conservative versus surgical intervention. Further research regarding the appropriate triage of care for athletes with CECS is needed.

SP042

LESS THAN HALF OF HEALTHY YOUTH ATHLETES CAN ACHIEVE 90% LIMB SYMMETRY ON A BATTERY OF SINGLE-LEG HOP TESTS

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PURPOSE/HYPOTHESIS: The incidence of anterior cruciate ligament reconstruction (ACLR) in youth athletes is rising. Current guidelines use a battery of single-leg hop tests (SLHT) to assess performance and assist in return to sport (RTS) decision making. Although there is agreement on the use of SLHT, the level of required limb symmetry varies. Historically, values of 85% to 90% were acceptable; however, some experts are now advocating for more strict values of 95% to greater than 100%. While higher performance thresholds are logical, and some data suggests reduced potential for reinjury using these more conservative criteria, previous literature shows that less than 25% of youth athletes demonstrate 90% or greater symmetry more than 1 year after ACLR. Furthermore, no studies have reported normal SLHT symmetry among youth athletes, making it difficult to compare postrehabilitation values to noninjured peers. The purpose of this study was to report limb symmetry in SLHT performance in healthy youth athletes.

NUMBER OF SUBJECTS: Three hundred forty (54% male [n = 184]; mean ± SD age, 10.9 ± 1.5 years) healthy athletes 8 to 14 years old.

MATERIALS/METHODS: This was a single episode cross-sectional study. All data were collected on-site during sports practice or games. Consent, demographics, injury history, and sports participation were obtained prior to testing. Each subject was instructed in a single hop (SH), triple hop (TrH), crossover hop (CH) and timed hop (TH) test and allowed 3 to 5 practice repetitions. Successful trials required a controlled landing, with 2-second hold, as previously described. Distance from starting line to the heel was recorded (cm) for the SH, TrH and CH. TH was recorded in seconds. Limb symmetry index (LSI) of nondominant to dominant leg,(self-reported kicking leg) was calculated for each hop. Descriptive statistics and frequency of pass/fail at 90% LSI threshold were calculated. Two-way ANOVA was utilized to analyze the effects of age and sex on LSI.

RESULTS: The mean LSI was greater than 95% for each SLHT (SH mean, 97.9; SE, 0.7; TrH, 96.6, 0.6; CH, 96.8, 0.8; TH, 96.5, 0.6). When analyzed as a test battery (ie, requiring greater than 90% LSI on all) only 45% of subjects achieved this level of symmetry. ANOVA indicated no significant effects ($P<.05$) for either age or sex on LSI for any of the individual hop tests.

CONCLUSIONS: Despite symmetry of greater than 95% on each SLHT component, individual performance among youth athletes varied such that the majority of subjects failed to achieve greater than 90% on the entire test battery. Age and sex did not affect hop performance.

CLINICAL RELEVANCE: SLHT are commonly utilized as a battery, requiring an athlete to achieve a threshold of LSI (eg, 90%) on each hop test, to satisfy RTS criteria. Although the mean LSI in our sample was greater than 95% for individual tests, less than half of healthy athletes could achieve a standard of 90% LSI when applied as a test battery. These results question the validity of requiring greater than 90% LSI on a battery of SLHT in youth athletes after ACLR and highlights the need for further research into the use and interpretation of SLHT during RTS decision making.

SP043

INCREASED STEP RATE IN RUNNERS FOLLOWING AN INDEPENDENT STEP-RATE RETRAINING HOME PROGRAM: A RANDOMIZED CONTROLLED TRIAL

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PURPOSE/HYPOTHESIS: Increasing running step rate 5% to 10% greater than preferred can attenuate lower extremity stress to reduce running related injuries, enhance rehabilitation and augment performance. Education and feedback have been used to change step rate clinically, however, evidence is limited regarding whether a home program can alter step rate in runners. The purpose of this study was to determine if the preferred step rate of recreational runners can be increased by 5% to 10% using a 6 week home training program.

NUMBER OF SUBJECTS: Thirty-eight.

MATERIALS/METHODS: Thirty-eight healthy runners running a minimum of 15 miles per week with a preferred step rate less than 85 steps per minute during baseline treadmill testing were randomized. The experimental group was educated in increasing step rate by 10% and provided a watch and foot pod for step rate feedback. The control group was instructed to continue running habitually. Compliance was tracked with a training log. Both groups returned for retesting following 6 weeks.

RESULTS: The experimental group exhibited a 9.0% increase in step rate from 80.1 ± 4.0 to 87.4 ± 6.1 steps per minute ($P<.001$) at the 6-week follow-up. The control group did not significantly change their step rate

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from 81.5 ± 2.5 to 82.0 ± 2.6 steps per minute (P = .577). No differences were present between groups at baseline.

CONCLUSIONS: In healthy runners with a slower step rate, preferred running step rate can be increased by 5% to 10% with a gait retraining home program consisting of education and step rate feedback from a watch and a foot pod at a 6-week follow-up.

CLINICAL RELEVANCE: The results from this study illustrate how step rate can be manipulated and changes can be carried over at a 6-week follow-up. The study may guide clinician decisions to use education and simple tools to provide feedback to modulate running step rate among runners. The study serves as a starting point for future research assessing the longevity of step rate changes and in identifying methods to attenuate the risk of running related injuries.

SP044

INFLUENCE OF KNEE-RELATED ABILITY AND CONFIDENCE AT TIME OF RETURN TO SPORT AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION ON 2-YEAR PHYSICAL ACTIVITY PARTICIPATION

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PURPOSE/HYPOTHESIS: Knee-related ability and confidence are identified factors contributing to the maintenance of physical activity levels following anterior cruciate ligament reconstruction (ACLR). The purpose of this work is to test the hypothesis that young athletes who did maintain participation in cutting/pivoting sports 2 years following return to sport (RTS) after ACLR rehabilitation would demonstrate higher knee-related ability and confidence at time of RTS compared to athletes who did not maintain participation.

NUMBER OF SUBJECTS: Fifty-five subjects (mean ± SD age, 17.4 ± 2.9 years; 40 female) with primary, unilateral ACLR. Subjects who suffered a second ACL injury were excluded. Subjects were enrolled at time of clearance to cutting/pivoting sports and tracked for 2 years.

MATERIALS/METHODS: At time of RTS, knee-related ability was objectively measured using 180°/s isokinetic quadriceps index (QI; percent), the International Knee Documentation Committee (IKDC) subjective knee form score, and 4 single-leg hop tests (single-leg hop [SLH], triple hop [TrH], timed hop [TiH], and crossover hop [CH]) (limb symmetry index; [percent]). Also at RTS, knee-related confidence was measured using Question 3 (Q3) of the Knee injury and Osteoarthritis Outcome Score Quality of Life subscale. At 2 years following RTS, physical activity participation level was measured with the Tegner Activity Level Scale (TAS) and subjects were categorized into 2 groups: those who maintained participation in cutting/pivoting sports (2-year TAS score of 7 or greater, yesPA group), and those did not (2-year TAS score less than 7, noPA group). Between-group differences in RTS knee-related ability and confidence variables were analyzed using independent-samples t tests (Mann-Whitney U tests for nonnormally distributed data) ($\alpha \leq .05$).

RESULTS: At 2 years following RTS, no differences in age, height, and weight (P = .37-.95) were found between groups (yesPA, n = 33; noPA, n = 22). No differences in knee-related ability were found between yesPA and noPA groups at RTS (P = .09-.98) (QI, 86% ± 13% versus 91% ± 15%; IKDC, 88.4 ± 10.2 versus 83.6 ± 15.0; SLH, 94% ± 7% versus 93% ± 7%; TrH, 97% ± 7% versus 95% ± 7%; TiH, 98% ± 7% versus 95% ± 7%; CH, 96.3% ± 7.2% versus 90.7% ± 12.4%, respectively), nor were differences in knee-related confidence found between yesPA and noPA groups (Q3, 1.09 ± 0.9 versus 1.14 ± 0.9, respectively; P = .77).

CONCLUSIONS: Athletes who did maintain participation in cutting/pivoting sports 2 years after RTS following ACLR rehabilitation did not demonstrate higher knee-related ability or confidence at time of RTS compared to athletes who did not maintain participation in such sports 2 years after RTS.

CLINICAL RELEVANCE: This study suggests that subjective and objective measures for knee-related ability and confidence at the time of RTS may not serve as an accurate predictor of cutting/pivoting physical activity participation 2 years following RTS. Future work should include the investigation of biopsychosocial factors that may identify patients who are at risk of decreased physical activity levels following RTS after ACLR.

SP045

HIGH-RISK DOUBLE-LEG LANDING MOVEMENT PROFILE IS ASSOCIATED WITH ELEVATED GROUND REACTION FORCE AND STIFF LANDING DURING SINGLE-LEG TASKS

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PURPOSE/HYPOTHESIS: Kinetic variables, specifically high peak vertical ground reaction force (GRF), braking (posterior GRF) force, and loading rate (LR) are associated with lower extremity injury. Kinematic variables are now efficiently assessed through clinical movement screens and are also linked to lower extremity injury. There is, however, little evidence demonstrating differences in kinetics between those with different movement quality profiles. This study compared kinetic and kinematic variables between subjects displaying "poor" and "excellent" movement profiles as evaluated by the Landing Error Scoring System (LESS). Our hypothesis was that "poor movers" would experience significantly greater LR, braking force and vertical GRF relative to the "excellent movers" and show decreased knee flexion with increased knee valgus at initial contact.

NUMBER OF SUBJECTS: Forty-one female athletes with an average age of 20.5 years (range, 18-25 years), average height of 167.5 cm (range, 152.0-183.5 cm), and average mass of 62.9 kg (range, 46.0-80.6 kg) participated in the study.

MATERIALS/METHODS: Participants were assigned to an "excellent" (n = 22) and "poor" (n = 19) movement quality group based on their LESS performance. Following group assignment, subjects then jumped down onto a single leg from a 30-cm box to a force plate directly in front of the box. Kinematic variables of interest included knee flexion and valgus angles at initial contact, peak, and total flexion and valgus motion displacement during the single-leg landing task. Kinetic data collected included braking force, vertical GRF, and LR, all of which were normalized by body weight (BW). t tests were carried out to evaluate differences between "excellent" and "poor" movement quality group differences.

RESULTS: "Poor movers" experienced greater vertical GRF during the single-leg landing (poor, 4.2 ± 0.5 BW; excellent, 3.9 ± 0.6 BW; P<.04) but neither LR (P = .17) nor braking force (P = .87) differed between the groups. "Poor movers" also demonstrated greater peak knee valgus (poor, −2.13° ± 4.9°; excellent, −5.6° ± 4.5°; P = .03) and decreased peak knee flexion (poor, 54.9° ± 9.5°; excellent, 65.4° ± 9.4°; P = .002) and total knee flexion dispersion (poor, 46.9° ± 12.0°; excellent, 35.2° ± 8.1°; P<.001) than did "excellent movers."

CONCLUSIONS: Subjects who display poor movement quality as measured by the LESS, a double-leg landing task, also display poor movement characteristics during a single-leg landing task. These findings implicate that poor movement quality profile characteristics transfer across double and single-leg tasks. Individuals with poor movement quality also display different kinetics, specifically increased vertical GRF.

CLINICAL RELEVANCE: Movement quality as assessed by double-leg clinical movement assessment like the LESS can be used to screen for biomechanics associated with injury risk during single-leg activities. Additionally, a movement quality screening instrument can be used to identify individuals who display greater loading profiles that have previously been associated with injury.

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SP046

BASELINE CONCUSSION ASSESSMENT IN DIVISION I COLLEGIATE ATHLETES: MEASURING NEAR POINT OF CONVERGENCE ACROSS SPORTS

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PURPOSE/HYPOTHESIS: To examine measurement properties of near point of convergence scores across multiple sports using a novel device in an athletic environment.

NUMBER OF SUBJECTS: Two hundred twenty-two Division I collegiate athletes.

MATERIALS/METHODS: Two hundred twenty-two Division I collegiate athletes (mean ± SD age, 20.22 ± 1.45 years) completed 3 trials of near point of convergence in a single testing session during preseason baseline testing. A standardized approach was performed for near point of convergence testing as suggested by recent evidence except that in this study a novel device was used. The test was performed using the Bernell Vergel starting the measurement at arm's length distance. Near point of convergence was measured when the athlete reported diplopia or if aberrant eye motion was observed. Sport included football, men and women's basketball, cross-country, track and field, swim and dive, men and women's tennis, women's soccer and golf. A full factorial model was specified to evaluate for all possible interactions to determine if sport, age, or vision affected convergence scores.

RESULTS: The average near point of convergence was 8.99 centimeters across all athletes. Across trials, women's soccer (10.3; 95% CI: 5.12, 15.5; 10.3; 95% CI: 5.12, 15.5; 9.6; 95% CI: 4.2, 15.0) and swim and dive (9.9; 95% CI: 8.5, 11.3; 10.3; 95% CI: 8.8, 11.9; 10.24; 95% CI: 8.8, 11.6) had the largest baseline near point convergence score. Analysis of a full factorial model using convergence scores as the dependent variable across the 3 trials identified significant main interactions for trial 1 ($F_{10,180}$ = 2.02, P<.03), trial 2 ($F_{10,194}$ = 2.02, P<.03), age by trial 1 ($F_{1,53}$ = 6.01, P<.02), and sport by trial 2 ($F_{9,181}$ = 2.08, P<.03). Pairwise differences were significant (P<.01) only for track and field athletes compared to swim and dive athletes.

CONCLUSIONS: Our findings suggest that baseline near point of convergence was higher in women's soccer and swim and dive compared to other collegiate contact and noncontact sports. Age of the athlete and if the athlete wears glasses or contacts did not affect near point of convergence scores. Additional studies will need to evaluate the concurrent validity of the Bernell Vergel measurement device.

CLINICAL RELEVANCE: Abnormal near point of convergence is considered greater than 6 cm from the tip of the nose, an important criterion in a multifaceted assessment to determine if an athlete has had a concussion. Baseline convergence testing of athletes is warranted as our findings suggest in collegiate athletes that the average near point of convergence of the standardized 3 trials would indicate that the athlete had a concussion. Additionally contact and noncontact sport athletes should receive baseline convergence testing as a reference score to compare to if the athlete sustains a concussion during the athletic season.

SP047

EPIDEMIOLOGIC INVESTIGATION OF NCAA TRACK-AND-FIELD INJURIES

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PURPOSE/HYPOTHESIS: The purpose of this study was to describe injury rates among collegiate track and field (TandF) athletes, while specifically examining injuries occurring among TandF runners.

NUMBER OF SUBJECTS: This study examines injuries among NCAA indoor and outdoor TandF athletes over a combined 367 285 individual student-athlete practices and competitions during a 5-year span beginning with the 2009 to 2010 seasons.

MATERIALS/METHODS: Data from the NCAA Injury Surveillance Program was used to calculate overall injury rates by sex, season (indoor versus outdoor), and event type (practice versus competition). Further descriptive analysis included injury frequencies, injury types, and time lost due to injuries among sprinters and distance runners.

RESULTS: Over the 5-year period the NCAA Injury Surveillance Program captured 717 injuries from men's indoor and outdoor TandF and 749 injuries from women's indoor and outdoor TandF, leading to injury rates of 3.68/1000 athletic-exposures (AEs) for men's TandF and 4.34/1000 AEs for women's TandF. Injury rates for indoor TandF tended to be higher than those for outdoor among both sexes (3.98/1000 AEs versus 3.31/1000 AEs among men's TandF; 4.52/100 AEs versus 4.08/1000 AEs among women's TandF). Additionally, injury rates were higher during competitions (6.29/1000 AEs) than practices (3.68/1000 AEs). A similar number of running injuries were reported among sprinting (336 injuries) as middle- and long-distance running (320 injuries). Hamstring strains were the most common injuries related to sprinting (20.5% of women's sprinting injuries and 36.7% of men's sprinting injuries), followed by quadriceps strains (7.7% of women's sprinting injuries and 3.9% of men's sprinting injuries). Iliotibial band injuries were the most common injuries related to middle- and long-distance running (5.8% of women's distance running injuries and 6.9% of men's distance running injuries), followed by medial tibial stress syndrome (4.2% of women's distance running injuries and 6.2% of men's distance running injuries).

CONCLUSIONS: Injury rates varied between men's and women's TandF, indoor and outdoor TandF, and practice and competitions. Injury types differed between sprinters and distance runners, with sprinters having a more homogenous injury profile with a high frequency of hamstring strains.

CLINICAL RELEVANCE: Clinicians may use information from this study to inform the development of injury prevention programs, whether they be aimed at reducing injuries in the indoor TandF season, higher-risk groups such as women's TandF, or hamstring strains among sprinters.

SP048

THE EFFECTS OF CORE STABILITY AND FATIGUE ON GAIT STABILITY IN LOADED AND UNLOADED CONDITIONS

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PURPOSE/HYPOTHESIS: Injury rates during basic training are above 49% and inversely related to fitness; most occur in the lower body and have been linked to marching dosage. Increased loads from a backpack changes gait and increases postural sway. This study examined the effect of fatigue on temporal-spatial (TS) gait stability in loaded and unloaded conditions following intense core muscle and cardiovascular (CV) exercise. Also, the effect of core stability was studied by comparing TS gait stability in subjects with stronger and weaker cores.

NUMBER OF SUBJECTS: Sixteen.

MATERIALS/METHODS: Subjects' core muscles were fatigue following a protocol with a circuit of dynamic planks and trunk extensions to self-reported fatigue. After a 30-minute rest, they completed a CV fatigue protocol by walking on an inclined treadmill loaded with 25% body weight (fatigue was defined as Borg RPE of 19/20). TS parameters (velocity, cadence, normalized step length and BOS) were recorded using a GAITRite mat at baseline, post core, and post treadmill, under 2 load conditions (with/without backpack). To study effects of core stability subjects were ranked based on the core fatigue test and assigned to weaker (lowest 8 subjects) and stronger groups. The effects of the backpack during each time interval were studied using paired t tests, the effects of core stability were studied using Student's t tests (differences between weaker and stronger groups), and the effects of muscular and CV fatigue were compared to baseline using a 1-way RM ANOVA.

RESULTS: When wearing the backpack all subjects walked slower with lower cadence and shorter step length under all test conditions. The stronger group walked faster than the weaker group with higher cadence both

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with/without the backpack at baseline ($P<.01$) and faster with the backpack after core fatigue ($P<.05$). The weaker group walked faster with higher cadence with and without the backpack following core muscle fatigue ($P<.01$) and CV fatigue ($P<.05$) compared to baseline. No differences were found in BOS.

CONCLUSIONS: All subjects walked slower with backpacks compared to without. The stronger group walked faster than the weaker group at baseline; however, the weaker group increased their velocity as they became fatigued due to higher cadence.

CLINICAL RELEVANCE: Subjects with weaker core muscles adapted differently to carrying loads, which became more pronounced with fatigue. Weaker subjects increased their velocity when fatigued thus had increased momentum, an adaptation likely needed to move the center of mass (COM) forward/upward during the gait cycle. Velocity was increased by higher cadence rather than step length. Longer steps would have required greater gait stability as the COM moves further downward and outside the BOS and require greater muscular effort to raise. Modulation of velocity by cadence is common in pathological gait. Walking with a forced velocity/cadence could pose an injury risk to people with weaker core muscles and/or fatigued, especially when carrying loads. Core weakness and fatigue could be a risk factor for injuries in military recruits.

SP049

TRAINING PROTECTIVE FACTORS FOR KNEE PAIN IN OLYMPIC-CLASS SAILORS

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PURPOSE/HYPOTHESIS: Knee pain is a common musculoskeletal condition in Olympic-class sailors. Hiking, an activity unique to sailing is a high-demand lower extremity and trunk activity used to control a sailboat, places high loads on the knees. Hiking is associated with increased knee pain in competition. The purpose of this study was to examine the association training participation with sailor knee pain

NUMBER OF SUBJECTS: Ninety-seven.

MATERIALS/METHODS: A convenience sample of sailors having finished competition was collected after a 5-day Olympic class regatta. A cohort (37 female, 60 male) completed a 61-item anonymous questionnaire on sailing-related activities, demographic information, and knee pain status. Risk factor exposures were in place at the beginning of racing. The subjects' mean ± SD age was 23.62 ± 4.74 years (range, 8-43 years), body mass index of 23.95 ± 5.8 kg/m^2 (range, 19.2-28.6 kg/m^2), had 11.49 ± 5.9 years (range, 3-45 years) of competitive sailing experience, and 4.72 ± 3.19 (range, 0-16 years) years of current class sailing experience. Younger age (less than 23 years) and high unloading (greater than 2 hours) times pre-regatta increase risk of injury in sailors. Female sex, obesity, and previous injury history are linked to knee pain in many populations. These factors were examined for confounding knee pain risk. Fifty (52%) subjects were hikers and 47 (48%) were nonhikers. Risk ratios (RR) and 95% confidence intervals (95% CI) for risk of knee pain among competing sailors, hikers and nonhikers. SAS 9.2 generated summary statistics, RRs, *t* tests, and chi-square comparisons.

RESULTS: Ninety-one of the 97 subjects, 91 (94%) reported on training. Training participation reduced overall risk of knee pain by 83% (RR = 0.17; 95% CI: 0.08, 0.34). Further, subjects participants with previous history of injury were 4.5 times more likely to develop knee pain during the regatta (RR = 4.5; 95% CI: 2, 10). Confounding analysis found previous history of injury to be the only variable significantly different in both exposure and disease groups. Stratifying by previous injury history, analysis found that training decreased the risk of incident knee pain 82% in sailors with no history of injury (RR = 0.18; 95% CI: 0.06, 0.61) and 74% in sailors with previous injury history (RR = 0.26; 95% CI: 0.12, 0.62). Adjusted for previous injury, training still reduced the risk of a new case of knee pain by 76% (RR = 0.24; 95% CI: 0.11, 0.93).

CONCLUSIONS: Analysis found that training is associated with a protective effect on incident knee pain over the course of a 1-week regatta. Adjusted for previous history of injury, a risk factor for knee injury, training still decreased the risk of incident knee pain. However, it appears that training has a greater protective effect on sailors without previous history of injury than sailors with previous history of injury. More data are required to determine the effect of training on hikers versus nonhiker sailors.

CLINICAL RELEVANCE: Training program participation in athletes with and without a history of injury may protect against new incidence of knee injury during competition. Position-specific study is warranted due to different knee demands.

SP050

OLYMPIC-CLASS SAILOR KNEE TRAINING HABITS

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PURPOSE/HYPOTHESIS: Knee pain is a common musculoskeletal condition reported by Olympic class sailors. Training is associated with reduced incidence knee pain in sailing in our previous studies. The purpose of this study was to examine if Olympic sailors are participating in training activities that mimic the demands and postures required of their position in the boat: hiking or nonhiking. Hiking, an activity unique to sailing is a high-demand, nearly isolated quadriceps activity. Hiking posture is theoretically best emulated by either knee extension on a fixed tibia or fixed femur against a perpendicular line of resistance, while nonhiking posture is best mimicked by squatting or simulated trapeze work against a vertical longitudinal line of resistance. Evidence suggests matching in-sport postures to training exercises improves transfer to performance. This study examines if sailors are training to match the performance and injury prevention needs in sailing.

NUMBER OF SUBJECTS: Ninety-seven.

MATERIALS/METHODS: A convenience sample of sailors having finished competition was collected after a 5-day Olympic-class regatta. A cohort (37 female, 60 male) completed a 61-item anonymous questionnaire concerning sailing-related activities, demographic information, participating in training, and knee pain status. Subjects' mean ± SD age was 23.62 ± 4.74 years (range, 8-43 years), body mass index was 23.95 ± 5.8 kg/m^2 (range, 19.2-28.6 kg/m^2), and 11.49 ± 5.9 years (range, 3-45 years) of competitive sailing experience, and 4.72 ± 3.19 years (range, 0-16 years) of sailing experience in their current class. Fifty (52%) were hikers and 47 (48%) were nonhikers. Subjects were asked: "What exercise do you feel best trained your knees for the demands of sailing? Please specify." SAS 9.2 was used for summary statistics and chi-square tests.

RESULTS: Seventy-eight sailors reported training participation, 66 (85%) were supervised. Twenty-eight (36%) reported engaging in training that matched the performance posture, that is, leg extensions/simulated hiking for hikers and squatting/simulated trapeze for nonhikers. Twenty (71%) of the 28 sailors participating in congruent training reported supervision during training. Supervised and unsupervised sailors were not different on congruence of theoretical position-specific postures to their perceived "best" training exercise for their positional demand ($P = .94$).

CONCLUSIONS: The majority of Olympic-class sailors in this study may not be training to meet the demands of in-boat postures. Supervision rates do not appear to be different, implying coaches, trainers, and athletes may not recognize the importance of sport-specific postures in training. Nuanced understanding of sailing demands may also be misunderstood

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from the theoretical sport science view. Further research is needed to determine if hikers versus nonhikers differ on training postures that match sailing postures.
CLINICAL RELEVANCE: Understanding the congruence of training postures with sailing postures and the influence of supervision on training provides insight on the safest, most effective training methods for these athletes.

SPO51

EFFECTS OF THE MODIFIED BROSTRÖM-GOULD PROCEDURE AND PHYSICAL THERAPY ON AN INDIVIDUAL WITH CHRONIC LATERAL ANKLE INSTABILITY: A CASE REPORT

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BACKGROUND AND PURPOSE: Chronic lateral ankle instability (CLAI) is one of the most commonly treated orthopaedic conditions seen in outpatient physical therapy. It can be defined as recurrent sprains, pain, swelling, and subjective reports of the ankle giving way. Currently, the Modified Broström-Gould procedure is considered the gold standard surgical repair for CLAI. At this time, there is a lack of research on ankle functionality and spatiotemporal characteristics of gait following the Modified Broström-Gould procedure in conjunction with physical therapy (PT). Therefore, the purpose of this study is to further explore this gap in the literature.
CASE DESCRIPTION: The subject was a 28-year-old woman with a body mass index of 43.08 kg/m^2, who sustained a right inversion ankle sprain on 6/16/16 when stepping off of a bus. The subject failed 6 weeks of conservative PT treatment in fall 2016. Upon magnetic resonance imaging, the patient was diagnosed with an ATFL rupture and osteochondral defect. The subject underwent the Modified Broström-Gould procedure and osteochondral repair on 4/11/17. She was evaluated for PT on 5/31/17, participated in 20 treatment sessions and was discharged on 8/30/17. Progression of exercises included PROM, AROM, balance, strength and agility training.
OUTCOMES: Two weeks prior to surgery, spatiotemporal measurements including base of support, step length, single/double support, and gait velocity were recorded using the GAITRite Portable Walking System. Self-reported disability was measured with the Foot and Ankle Disability Index (FADI). All measurements were repeated 4 months postoperatively. From pretesting to posttesting, the participant showed a 19-point increase in her FADI score, indicating a decrease in disability related to activities of daily living with the most significant changes found in walking on uneven ground, squatting and heavy work such as pushing, pulling and carrying. The participant's ambulation velocity increased by 0.28 m/s postsurgical and PT interventions. Additionally, the patient demonstrated increased step length (R, 0.130 m; L, 0.115 m) and stride length (R, 0.25 m; L, 0.24 m) bilaterally, indicating greater forward propulsion, with a less antalgic gait. Further data analysis revealed single limb support differential decreasing from 9.00% to 2.47% and stance differential decreasing from 8.93% to 2.37% of the gait cycle, supporting a normalization of gait symmetry.
DISCUSSION: The outcomes of this case study suggest that the Modified Broström-Gould procedure in conjunction with PT can decrease disability, and restore normalization of spatiotemporal gait characteristics. These trends suggest the need for a longitudinal study with an increased sample size to truly observe the effects of the Modified Broström-Gould procedure and PT in individuals with CLAI.

SPO52

THE EFFECT OF POSTOPERATIVE PAIN ON RESTORATION OF EARLY ISOKINETIC STRENGTH AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN YOUNG ATHLETES

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PURPOSE/HYPOTHESIS: Despite significant research on the importance of quadriceps femoris strength after ACL reconstruction, limited studies have addressed factors that may limit restoration of strength early in the rehabilitation process. The purpose of this study was to identify variables immediately postoperative (PO) that may affect subsequent quadriceps femoris strength outcomes. The primary hypothesis was that high self-reported pain on the numeric pain-rating scale (NPRS) would be associated with deficits in quadriceps strength on the involved limb at 3 months PO in youth athletes.
NUMBER OF SUBJECTS: Fifty-one young athletes, (mean ± SD age, 15.1 ± 2.1 years; 20 male, 31 female), who had an ACL reconstruction (48 hamstring grafts), initiated PO physical therapy, and planned to return to pivoting and cutting sports.
MATERIALS/METHODS: All subjects were identified from a larger ACLR outcome study. A retrospective chart review was completed to determine if patient self-report of pain (NPRS) at the initial PO evaluation affected isokinetic knee flexion and extension strength; assessed at 3 months PO. Patients were dichotomized into those who presented at their initial PO physical therapy appointment with low reports of pain (0-2/10) and those with moderate to high pain (3-10/10). Isokinetic testing was normalized to body weight (Nm/kg) and assessed at both 180°/s and 300°/s. One-way ANOVA (SLC1) was used to identify the relationship between early PO pain and early quadriceps and hamstring strength return at 3 months post ACLR.
RESULTS: No differences in age (P = .12) or sex distribution (P = .09) were seen between groups. Patients who presented with low pain at the time of initial PT evaluation had significantly greater quadriceps femoris strength normalized to body weight at 180°/s (1.50 ± 0.31 Nm/kg versus 1.22 ± 0.28 Nm/kg, P = .002) and 300°/s (1.17 ± 0.34 Nm/kg versus 0.97 ± 0.27 Nm/kg, P = .028) as well as greater hamstrings strength at 180°/s at 3 months PO (1.02 ± 0.33 Nm/kg versus 0.77 ± 0.20 Nm/kg, P = .002).
CONCLUSIONS: Subjects that self-reported 3/10 pain or greater on the NPRS at their initial PT evaluation demonstrated decreased quadriceps and hamstrings strength with their involved lower extremity 3 months PO when compared to patients with self-reports of low pain.
CLINICAL RELEVANCE: Previous research identified a correlation between delayed return of early quadriceps femoris strength, worse self-reported patient reported outcomes, and altered biomechanics at the time of return to sport. Factors such as control of PO pain, may contribute to early return of quadriceps femoris strength after ACLR and ultimately outcome at the time of RTS.

SPO53

RISK FACTORS FOR STRESS FRACTURES IN FEMALE RUNNERS: A SYSTEMATIC LITERATURE REVIEW

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PURPOSE/HYPOTHESIS: The purpose of this systematic review was to identify intrinsic and extrinsic factors related to the incidence of stress fractures in female runners.
NUMBER OF SUBJECTS: Not applicable.
MATERIALS/METHODS: Literature searches were performed using Ovid, MEDLINE, PubMed, Scopus and CINAHL. Inclusion criteria were female runners of all ages in studies identified as randomized control trials. cohort, or descriptive studies. Quality of studies was assessed using the Meta-Analysis of Statistics Assessment and Review Instrument (MAStARI). Scores were assigned based on group consensus. Data extracted from studies include subject population, variables measured, results, and conclusions.

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RESULTS: Searches resulted in 297 articles after duplicates were removed of which 282 were removed after title and abstract screening. Five articles were removed after full text screening, resulting in 10 articles being included that addressed intrinsic and extrinsic factors related to stress fractures in female runners, ages 13 to 55 years. Intrinsic factors that increased incidence included decreased body mass index, lean mass, fat mass, and bone mineral density; increased age of menarche and menstrual irregularities/dysfunction; and decreased dairy, calcium and vitamin D intake. Extrinsic biomechanical factors included increased forefoot pressure, hip adduction, free moment, rearfoot eversion, peak shock, peak braking and vertical ground reaction forces as well as decreased step width and wearing of minimalist shoes.
CONCLUSIONS: Stress fracture risk was increased by a combination of various body composition factors; however, decreased dairy, calcium, and vitamin D intake were concluded to be the primary intrinsic risk factors, resulting in negative long term effects on bone mineral density and body mass index. More research is needed on natural dietary intake versus supplementation on reducing risk of stress fractures. Various biomechanical factors correlated with an increased risk such as peak braking, peak shock, and vertical ground reaction forces. Furthermore, transferring to a minimalist shoe increased plantar pressure in the forefoot region; however, there was no difference in landing strategy between the 2 shoe types.
CLINICAL RELEVANCE: Female runners are at risk for developing lower extremity stress fractures. As the risks are multifactorial, understanding which risk factors have the largest influence on stress fracture occurrence can help guide health care professionals on identifying runners at increased risk in hopes of early detection and/or prevention.

SPO54

INFLUENCE OF PASSIVE SHOULDER RANGE OF MOTION ON SHOULDER AND ELBOW KINETICS IN BASEBALL PITCHERS

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PURPOSE/HYPOTHESIS: Shoulder range of motion deficits and joint kinetics at the shoulder and elbow during throwing have previously been linked to injury. However, the specific relationship between shoulder range of motion and joint kinetics remains unclear. The purpose of this study was to determine if shoulder range of motion deficits are correlated with increased elbow varus torque and shoulder distraction force during baseball pitching. We hypothesized that greater shoulder range of motion deficits will be associated with an increase in both elbow varus torque and shoulder compressive forces during the throwing motion.
NUMBER OF SUBJECTS: Twenty-eight.
MATERIALS/METHODS: Twenty-eight high school, collegiate, and professional baseball pitchers between the ages of 15 and 30 were recruited for participation in this study. Passive shoulder external and internal rotation was measured dominant and nondominant arms for each participant. Pitchers were recorded using an optical motion capture system at 300 Hz while throwing 5 fastballs from a pitcher's mound at "game-like effort" towards a target. Inverse dynamics calculations were performed to estimate joint torque and reaction force at the shoulder and elbow for the pitch with the highest hand velocity. Best subset analysis was run to determine which range of motion measurements were most associated with peak elbow varus torque and shoulder distraction force.
RESULTS: There was no relationship between shoulder range of motion and elbow varus torque, with peak velocity as the only predictor (R^2 = 0.711). After controlling for ball velocity and body mass (R^2 = 0.833), both dominant shoulder internal rotation, and the difference between passive shoulder external rotation and external rotation measured during the throwing motion, were significant predictors of shoulder distraction forces (R^2 = 0.906, P = .003 and .019), accounting for 4.93% increase and 2.98% increase in variance explained, respectively.
CONCLUSIONS: These findings are inconsistent with the hypothesis. Shoulder range of motion deficits were not associated with an increase in elbow varus torque. Additionally, while dominant shoulder internal rotation deficit contributed to an increase in shoulder compressive forces, the 2 biggest predictors of shoulder compressive forces during the throwing motion were velocity and mass.
CLINICAL RELEVANCE: While range of motion asymmetry should not be discounted due to its relationship to injury, absolute shoulder ROM is more important than shoulder asymmetry in the assessment and treatment of baseball pitchers. Addressing deficits in shoulder internal rotation may reduce shoulder joint distraction forces in pitchers.

SPO55

FATIGUE NEGATIVELY IMPACTS SINGLE-LEG FORWARD HOP PERFORMANCE AND BIOMECHANICS IN INDIVIDUALS WITH A HISTORY OF ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Isolated quadriceps fatigue can improve single-leg forward hop test sensitivity, but performing unilateral fatiguing exercise in a weight-bearing manner may be easier to reproduce in a clinical setting. The purpose of this study was to determine the effects of fatigue on single-leg forward hop performance and lower extremity biomechanics in individuals with a history of anterior cruciate ligament reconstruction (ACL-R) compared to healthy controls. We hypothesized fatigue will negatively impact jumping performance and decrease lower extremity forces during landing. We further hypothesize these changes will be of greater magnitude in ACL-R individuals.
NUMBER OF SUBJECTS: Eleven participants with a history of ACL-R (6 female, 5 male; mean ± SD age, 22.8 ± 4.5 years; height, 174.2 ± 7.5 cm; mass, 76.5 ± 14.8 kg; Tegner, 6.9 ± 1.4; time since surgery, 15.1 ± 7.7 months) and 11 healthy controls (7 female, 4 male; age, 23.4 ± 6.0 years; height, 175.5 ± 8.5 cm; mass, 76.5 ± 14.8 kg; Tegner, 6.9 ± 1.7).
MATERIALS/METHODS: Single-leg forward hop distance and lower extremity biomechanics were obtained before and after a brief bout of unilateral lower extremity fatigue. The preferred/uninvolved limb was tested prior to the nonpreferred/involved limb. Outcome measures included hop distance (cm) and peak ground reaction force (GRF; N/kg). A mixed-model ANOVA and associated post hoc t tests was used to determine differences between sides (involved/uninvolved; nonpreferred/preferred), groups before and after the fatigue protocol.
RESULTS: Single-leg forward hop distance significantly decreased (P<.001; ACL-R, −2% to −14%; healthy, −5% to −13%) in both groups following fatigue. Individuals with a history of ACL-R demonstrated significantly lower (P = .05) peak GRFs in both limbs (involved, 33.7 ± 5.0 N/kg; uninvolved, 39.0 ± 9.1 N/kg) compared to healthy individuals (preferred, 39.7 ± 6.7 N/kg; nonpreferred, 38.4 ± 7.8 N/kg). Following the fatigue task healthy individuals demonstrated a significant (P = .05) decrease in GRF (preferred, 36.6 ± 8.7 N/kg; nonpreferred, 37.8 ± 9.4 N/kg) compared to the ACL-R group (involved, 34.2 ± 6.1 N/kg; uninvolved, 36.3 ± 6.1 N/kg). There were no significant differences in time to stabilization between groups (P = .13) or across time (P = .35).
CONCLUSIONS: Although both groups had decreased single-leg forward hop performance, the impact of fatigue was greater in healthy individuals. While the decrease in jumping distance and GRF in healthy participants was expected, it was concerning that individuals with ACL-R did not demonstrate a concurrent decrease in GRF despite decreased single-leg forward hop distance. This suggests relatively greater lower extremity joint loading during landing, highlighting the need for additional rehabilitation.

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CLINICAL RELEVANCE: The relevance of this study is to assist informing return to sport decisions for individuals following ACL-R. Results suggest that individuals with a history of ACL-R may have been more resistant to fatigue related changes in jumping performance, but this may have negatively impacted lower extremity joint loading.

SP056

EXAMINATION OF AN UPPER EXTREMITY FUNCTIONAL TESTING BATTERY: CHANGE IN SCORE OVER TIME AND ASSOCIATION WITH SELF-REPORTED FUNCTION

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PURPOSE/HYPOTHESIS: Functional testing for the upper extremity (UE) is not standardized. Individual tests have been developed, but a battery of tests would provide a more comprehensive evaluation of function. The purpose of this study is to examine scores on an UE functional testing battery (UEFTB) over 2 time points and association with self-reported function. The hypothesis was that the UEFTB scores would improve over time and correlate with improvements in self-reported function.

NUMBER OF SUBJECTS: Subjects were 8 patients with shoulder instability (7 male, 1 female; mean ± SD age, 24.3 ± 5.1 years). All patients were right hand dominant; the right shoulder was injured in 4 patients.

MATERIALS/METHODS: Testing included the UEFTB and self-reported function questionnaires administered at baseline (10 or fewer days from physical therapy evaluation) and follow-up (6 weeks later). The UEFTB consists of: (1) total arc of shoulder ROM, (2) seated wall angel, (3) supine 90/90 shoulder internal rotation endurance (6-lb weight), (4) prone 90/90 shoulder external rotation endurance (2-lb weight), (5) prone unilateral row endurance (10-lb weight), (6) single-arm wall push-up endurance, (7) upper-quarter Y Balance Test, (8) single arm shot put (6-lb ball). For endurance tests, patients performed the movement with a metronome at 100 BPM until fatigue or 2 minutes. Single-arm wall push-up was performed at 50 BPM until fatigue or 30 seconds. All tests were scored from 0 to 3 points based on limb symmetry (0, less than 90%; 1, 90%-94%; 2, 95%-99%; 3, 100% or greater). Quality of movement (0, poor; 1, fair; 2, good) was assessed with predetermined criteria for all tests except total arc of shoulder motion, wall angel, and single arm shot put. The UEFTB score was computed (0-40 points); higher scores represent better function. Questionnaires included American Shoulder and Elbow Surgeons standardized shoulder assessment form (ASES, 0 to 100 points; higher scores mean better function) and Western Ontario Shoulder Instability Index (WOSI, 0 to 2100 points; lower scores mean better function). Paired *t* test evaluated change in scores over time. Pearson correlation tested the association of UEFTB score with ASES and WOSI scores at baseline in the change over time.

RESULTS: Mean ± SD scores at baseline and follow-up, respectively, were UEFTB, 16.9 ± 5.4, 28.9 ± 8.3; ASES, 81.0 ± 5.7, 93.1 ± 5.9; and WOSI, 989 ± 386, 599 ± 416. All scores improved over time ($P \leq .02$). UEFTB and WOSI scores were negatively correlated at baseline ($r = -0.81$, $P = .014$) and in the change over time ($r = -0.75$, $P = .052$). UEFTB and ASES scores were not correlated ($P > .05$).

CONCLUSIONS: Patients with shoulder instability scored less than half the points on the UEFTB at baseline, but scores improved over 6 weeks of rehabilitation. UEFTB scores were associated with self-reported function on a disease specific measure, but not a general shoulder measure.

CLINICAL RELEVANCE: These data provide preliminary support for the validity and responsiveness of the UEFTB for assessing UE function in patients with shoulder instability.

SP057

A PRINCIPAL-COMPONENTS ANALYSIS OF TORSO MOVEMENT PATTERNS IN RELATION TO SHOULDER LOADING IN LITTLE LEAGUE PITCHERS

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PURPOSE/HYPOTHESIS: The purpose of this study was to determine how motion patterns of the torso relate to shoulder loading in adolescent baseball pitchers. We hypothesized that kinematic patterns of trunk rotation are related to the peak net internal shoulder internal rotation moment during a fastball pitch.

NUMBER OF SUBJECTS: Twenty-four Little League pitchers (mean ± SD age, 11 ± 1 years; height, 1.55 ± 0.11 m; mass, 45.5 ± 11.9 kg).

MATERIALS/METHODS: Reflective markers were attached to bony landmarks, while marker clusters with at least 3 markers on them were attached to several body segments. Kinematic data were collected at 250 Hz with a motion capture system, and kinetic data were collected at 1250 Hz with 2 force plates imbedded into a pitching mound. Each player performed a static and dynamic calibration trial, which was used to calculate the normal and functional joint center of the shoulder, respectively. Each player was then allowed to warm up and pitch 15 fastballs at a strike zone 46 ft away from the pitching mound. Pitch velocities were monitored with a radar gun, and the 5 fastest strikes were used for analysis. Torso kinematics and shoulder kinetics were calculated from the point of maximum knee height to the point of ball release. The absolute, global torso positions and velocities in 3 dimensions throughout the entire pitching movement were extracted for analysis and time was normalized to 100 data points. The peak net internal shoulder internal rotation joint moment was also extracted. A principal components analysis was used to determine kinematic movement patterns of the torso and to calculate principal component scores for each pattern. These scores were then correlated with the peak shoulder internal rotation joint moment of each pitch.

RESULTS: Two torso velocity patterns correlated with shoulder internal rotation joint moment. The first pattern captured sagittal plane torso extension velocity during the wind-up and torso flexion velocity during the middle 30% to 70% of the pitch; the correlational analysis indicated that slower torso extension/flexion during that phase was correlated with lower shoulder internal rotation joint moments. The second pattern captured the rate of increase in transverse plane torso rotational velocity during the final 80% to 90% of the pitch; the correlational analysis indicated that a smaller increase in torso rotational velocity was correlated with lower shoulder internal rotation moments.

CONCLUSIONS: Torso segment velocities in the sagittal and transverse plane correlate with shoulder internal rotation moments.

CLINICAL RELEVANCE: Large shoulder internal rotation joint moments can increase the risk of humeral spiral fractures. The correlation results indicate that the shoulder internal rotation moments are lower in youth pitchers who exhibit slower sagittal plane torso extension/flexion during the middle 30% to 70% of the pitch and who display a lower rate of velocity increase in transverse plane torso rotation during the final 80% to 90% of the pitch.

SP058

EFFECTS OF PERONEUS LONGUS MUSCLE FATIGUE ON CORTICOSPINAL EXCITABILITY: A PILOT STUDY

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PURPOSE/HYPOTHESIS: More than 40% of athletic injuries occur at ankle joint. Most of these injuries occur usually when the muscle is fatigued. Specifically, fatigue of peroneus longus, a frontal plane stabilizing muscle of ankle, can impair stability in sports activities that involves frequent lateral movements and lateral landings. Understanding how fatigue affects

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the frontal plane stabilization in ankle may provide valuable information regarding the injuries related to sports. Thus, the objective of the study is to assess the fatigue-related changes in corticospinal excitability of peroneus longus muscle.

NUMBER OF SUBJECTS: Seven healthy younger adults (6 male, 1 female) participated in the study.

MATERIALS/METHODS: We used Transcranial Magnetic Stimulation (TMS), a noninvasive tool to measure corticospinal excitability. Resting motor threshold (RMT) was defined as the lowest TMS intensity required to elicit motor-evoked potentials (MEP) equal to or greater than 50 μV in 5 of 10 consecutive stimuli. We obtained MEPs at percentages ranging from 100% to 140% of RMT. We recorded corticospinal excitability before and after fatigue protocol to peroneus muscle that included concentric and eccentric movements at 40% maximal voluntary contraction (MVC) for 30 minutes using Biodex.

RESULTS: All the participants showed a reduced maximal voluntary contraction after the fatigue protocol (before, 24.5 ± 2.16 Nm; after, 19.25 ± 3.24 Nm). A paired *t* test was performed to see the difference between pre- and postfatigue protocol. MVC showed a significantly larger torque, prefatigue than postfatigue ($P = .05$). At 100% RMT there was no difference, whereas at 110%, 120%, 130%, and 140%, all the participants showed increased MEPs postfatigue ($P = .04$, $P = .05$, $P = .02$, $P = .03$), respectively.

CONCLUSIONS: Corticospinal excitability of peroneus longus increased after fatigue, while the MVC showed a reduced torque after fatigue. Our results suggest that increase in corticospinal excitability may be a compensatory response to attenuate the fatigue involved in peroneus longus muscle.

CLINICAL RELEVANCE: Corticospinal excitability increases after fatigue, while force of the muscle declines, suggesting greater-than-normal corticospinal excitability could cause greater mechanical insufficiencies as seen in fatigue-related injuries.

SPO59

KNEE ENERGY ABSORPTION CONTRIBUTION DURING JUMP LANDINGS IS NOT RELATED TO FUNCTIONAL CLINICAL OUTCOME MEASURES AT TIME OF RETURN TO SPORT AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: The purpose of this study was to determine if energy absorption contribution (EAC) of the knee during a jump landing task is correlated with clinical outcome measures used to determine readiness for return to sport (RTS) after ACL-R.

NUMBER OF SUBJECTS: A total of 63 participants were enrolled in the study (mean ± SD age, 16.1 ± 1.6 years; height, 1.71 ± .10 m; mass, 71.0 ± 16.1 kg) and were undergoing RTS testing after ACL-R.

MATERIALS/METHODS: Biomechanical data from initial contact to maximum knee flexion was assessed using an 8-camera Qualisys Motion Capture System and 2 ATMI force plates while participants performed 5 jump landings. The average of 5 repetitions was used to calculate EAC for the hip, knee, and ankle joints. Isokinetic peak torque and time to peak torque of the quadriceps (QUAD) at 60°/s was normalized to body weight (QUAD INDEX) and averaged across 5 trials. Participants performed single (SLH) and triple hop (TH) tests according to standard protocols. Pearson correlations were used to determine the relationship between QUAD, SLH, and TH and knee EAC. Independent *t* tests were calculated to examine the differences in knee EAC between those with limb symmetry index (LSI) greater than 90% and less than 90% on the SLH and TH. Independent *t* tests were also calculated to examine the differences in knee EAC between those with QUAD LSI greater than 70% and less than 70%, and for those with QUAD INDEX greater than 2.0 and less than 2.0. Alpha level was set at $P<.05$.

RESULTS: There were no significant correlations between knee EAC during jump landings and QUAD ($r = -0.043$, $P = .720$), SLH ($r = 0.009$, $P = .940$), and TH ($r = -0.013$, $P = .914$). There was a weak negative correlation between knee EAC during a jump landing and time to peak QUAD torque with isokinetic testing ($r = -0.240$, $P = .044$). There were no significant differences in knee EAC during jump landings between QUAD LSI greater than 70% and less than 70% (greater than 70%, 0.271 ± 0.201; less than 70%, 0.231 ± 0.190; $P = .394$) and QUAD INDEX greater than 2.0 and less than 2.0 (greater than 2.0, 0.173 ± 0.120; less than 2.0, 0.267 ± 0.205; $P = .104$). Similarly, there were no significant differences in knee EAC during jump landings between SLH and TH LSI greater than 90% and less than 90% (SLH greater than 90%, 0.248 ± 0.196; SLH less than 90%, 0.254 ± 0.193; $P = .934$) (TH greater than 90%, 0.250 ± 0.202; TH less than 90%, 0.244 ± 0.173; $P = .908$).

CONCLUSIONS: Loading of the knee during a jump landing after ACL-R does not correlate with clinical outcome measures of QUAD, SLH and TH. Grouping of participants based upon LSI guidelines does not appear to increase the ability to identify variables that may contribute to altered EAC strategies.

CLINICAL RELEVANCE: Decreased knee EAC during jump landings demonstrates a compensatory loading pattern after ACL-R as compared to healthy athletes. Current clinical outcome measures (QUAD, SLH and TH) that are used to determine readiness for return to sport do not adequately detect these compensations. Determination of outcome measures that are correlated with knee EAC may be beneficial in order to detect changes in loading patterns after ACL-R.

SPO60

DOES THE APPLICATION OF BLOOD FLOW RESTRICTION TO THE UPPER EXTREMITY IMPACT STRENGTH AND HYPERTROPHY? A SYSTEMATIC REVIEW

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PURPOSE/HYPOTHESIS: The purpose of this systematic review is to determine the ability of upper extremity (UE) blood flow restriction (BFR) training to improve strength and muscle hypertrophy compared to traditional resistance training (TRT). This new modality is quickly emerging in various sports performance settings. BFR is believed to create a fatigued state in the muscle faster than TRT. This may allow clinicians to utilize BFR with patients who cannot handle TRT due to medical conditions or precautions.

NUMBER OF SUBJECTS: Nine studies included.

MATERIALS/METHODS: A systematic review of recent literature was completed to identify evidence related to the clinical question. The search was completed by utilizing EBSCOhost. A PRISMA strategy utilizing key words yielded 56 articles. Thirteen additional articles were added from other sources. After applying screening criteria 9 articles were included for data extraction and analysis. Two reviewers assessed quality of evidence using the checklist developed by Downs and Black modified by Kennelly. A neutral third reviewer was utilized to resolve disagreements leading to a consensus quality rating of good/fair/poor.

RESULTS: Quality of articles were 1 good, 6 fair, and 2 poor. One hundred seventy-two subjects were included. Through various research methodologies, the effectiveness of UE BFR training was evaluated compared to TRT. Various clinical measures were used to quantify muscle hypertrophy and muscle strength gains. It was identified that a wide variety of protocols were used for UE BRF training. Through presented measures significant results were observed suggesting BRF does produce gains in both hypertrophy and strength for the UE over controls. Only 1 of the studies made direct links to clinically relevant functional outcome measures.

CONCLUSIONS: Weighted evidence indicates that there is not strong evidence to either support or reject gains from BFR training in the UE compared to TRT. All 9 studies demonstrated significant gains, however, the quality levels of most articles was fair at best. There were limitations to the study. 4 of the 9 studies were completed by the same research team using incon-

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sistent protocols. Protocols for BFR training varied across the remaining 5 studies as well, suggesting a need for a standardized protocol. Research on specific patient populations is scant as the studies were completed primarily on young, uninjured and otherwise healthy subjects. Limited functional outcomes measures were used to assess pre/post subject status. Further research is needed to establish a connection between hypertrophy, strength gains, and function in both healthy and impaired populations.

CLINICAL RELEVANCE: The integration of BFR in rehabilitation of the UE should be founded in sound evidence. Emerging evidence shows promising results related to improvements in muscle hypertrophy and strength following utilization in healthy populations as compared to TRT. Hypertrophy and strength gains in healthy populations and the connection to functional gains post BFR is still unclear.

SPO61

INFLUENCE OF RUNNING MECHANICS ON ANNUAL CHANGES IN LEG BONE MINERAL DENSITY OF COLLEGIATE CROSS-COUNTRY RUNNERS

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PURPOSE/HYPOTHESIS: Decreased bone mineral density (BMD) has been considered a factor increasing the risk of running-induced bone injuries. Running mechanics and associated ground reaction forces have been inconsistently associated with bone stress injuries in distance runners as well. The relationship between these running incurred loads and BMD, in particular of the legs, has not been well defined. The purpose of this study was to characterize the influence of running mechanics on changes in the leg BMD of collegiate cross-country runners throughout consecutive years.

NUMBER OF SUBJECTS: Fifty-three NCAA Division I cross-country runners (29 female; mean ± SD age, 20.1 ± 1.29 years) participated, and were non-injured at the time of testing prior to season. Athletes (n = 6) that sustained a stress fracture during the years of interest were not included.

MATERIALS/METHODS: Three-dimensional whole-body motion and ground reaction forces were collected during treadmill running at athlete-selected running speed. Leg BMD was measured on the same day from whole body dual-energy X-ray absorptiometry scans. Self-reported weekly running distance was obtained via questionnaires. Data were collected during the preseason of 3 consecutive years. Logistic regression models for repeated measures were used to assess the associations between running gait characteristics on the right leg and average leg BMD, and were adjusted for sex, age, year, and weekly running distance.

RESULTS: Preseason leg BMD values for males and females were 1.44 ± 0.15 and 1.28 ± 0.11 g/cm^2, respectively. From one season to the next, the leg BMD increased on average by 0.21% ± 2.44%, but the change was not statistically significant. Center of mass vertical displacement (vCOM) was associated with leg BMD (P = .04); for every 1 cm increase in vCOM, leg BMD increased by 0.02 ± 0.009 g/cm^2. No other gait variables (peak and cumulative vertical ground reaction force, impact peak, loading rate, horizontal COM to heel distance and initial contact, and braking and propulsive impulses) were found to be associated with leg BMD after adjusting for sex, age, year, and weekly running distance.

CONCLUSIONS: Leg BMD in collegiate cross-country runners displays minimal changes from one season to the next. Running mechanics, including kinematic and ground reaction force variables, were not associated with leg BMD, with the exception of vCOM.

CLINICAL RELEVANCE: These findings suggest that running mechanics and the associated ground reaction forces have a minimal association with leg BMD in healthy collegiate runners when considering age, sex and running volume. There were minimal changes in leg BMD over a 1-year period, suggesting that leg BMD remains fairly consistent in this population of healthy elite runners. In those with bone stress injury, the role of running mechanics needs to be further defined relative to known factors such as training volume and nutritional status.

SPO62

WHAT ARE THE MAIN BIOMECHANICAL RISK FACTORS FOR RUNNING-RELATED INJURIES? A SYSTEMATIC REVIEW WITH META-ANALYSIS

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PURPOSE/HYPOTHESIS: The aim of this study was to systematically review prospective cohort studies that investigated the main biomechanical risk factors for running-related injuries. Despite the great interest in the scientific and clinical communities, to our knowledge, no systematic review has investigated the main biomechanical risk factors for running-related injuries. Synthesis of the literature using rigorous methods and a comprehensive and up-to-date search may help clinicians, researchers, and the running community to understand which biomechanical variables are important to be observe or monitor during treatment, training, or injury prevention programs.

NUMBER OF SUBJECTS: A total of 891 studies were found through the database search. After application of the inclusion criteria and the selection process, 10 articles were included in this systematic review.

MATERIALS/METHODS: Electronic searches on MEDLINE, Embase, SPORTDiscus, Web of Science, and CINAHL databases until October 30, 2017. Each study included must have investigated the main biomechanical risk factors for running-related injuries. The meta-analysis was carried out on biomechanical variables that were reported in at least 5 cross-sectional studies and at least 3 prospective cohort studies. Only prospective cohort studies investigating the main biomechanical risk factors for running-related injuries were included in this review. Two independent reviewers screened each article and, if they did not reach a consensus, a third reviewer decided whether or not the article should be included. Injury type, if the injury was present during running biomechanical evaluation, symptom duration or time after injury, if the runner was pain free during running evaluation, running training characteristic, runner characteristics, running assessment condition, and biomechanical outcomes were extracted from the articles. A modified version of the Downs and Black Quality Index was used by the authors evaluated the risk of bias of the articles.

RESULTS: A total of 10 studies were considered eligible in this systematic review, resulting in 891 pooled runners and 133 biomechanical variables. The assessment of risk of bias showed that most of the studies included in the systematic review have small to moderate risk of bias. The meta-analysis was conducted with 4 biomechanical variables (2 kinematic and 2 kinetic variables). The results of the random-effects meta-analysis showed that there is none biomechanical risk factors associated with running-related injuries.

CONCLUSIONS: Despite the large variety of biomechanical variables identified, there is none biomechanical risk factors associated with running-related injuries.

CLINICAL RELEVANCE: Clinicians and runners should be aware that there is none biomechanical risk factors associated with running-related injuries at this moment. Since there is no difference in the biomechanical variables used at this moment, future studies can explore new biomechanical variables, as well as new methods of biomechanics analysis.

SPO63

THE INFLUENCE OF TRAUMATIC BRAIN INJURY ON SPORTS COLLISIONS IN WHEELCHAIR BASKETBALL AT THE 2018 DEPARTMENT OF DEFENSE WARRIOR GAMES

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PURPOSE/HYPOTHESIS: Military Adaptive Sports Programs were developed to improve the physical and mental quality of life of wounded, ill, or injured active duty and veteran service members. Recent conflicts have resulted over 320 000 service members with traumatic brain injuries including high rates of post concussive syndrome. These invisible injuries are not currently recognized as eligible impairments in Paralympic sports. To be more inclusive the Department of Defense Warrior Games added criteria to the wheelchair basketball code. The purpose of this observational study is to compare trends in wheelchair collisions and falls in athletes with invisible injuries to athletes with physical impairments.
NUMBER OF SUBJECTS: Twenty veteran and active duty servicemembers rostered on the wheelchair basketball team.
MATERIALS/METHODS: Deidentified data were collected on athletes of 2 teams competing at the 2018 Department of Defense Warrior Games. A playoff game was recorded and the number of collisions and falls during game play were recorded by research staff. Data analysis was used to determine if there were differences in minutes played, collisions, or falls in athletes with invisible injuries and those with physical injuries.
RESULTS: Athletes with TBI and no physical injury had a significant decrease in average minutes played during the game. There was no significant difference in falls or collisions based on invisible injury. However there were high rates of contact, chair tipping (near falls), and falls during play on both teams.
CONCLUSIONS: Inclusion of athletes with invisible injuries such as TBI and PTSD did not increase injury risk exposure. Due to the increasing rates of invisible injuries adaptive sports programs should consider inclusive modifications, such as those used by warrior games.
CLINICAL RELEVANCE: Physical therapists can provide important clinical insight to advocate for inclusion in sports.

SPO64

INFLUENCE OF FOOT POSTURE INDEX, PRIOR INJURY, SEX, AND SUMMER TRAINING ON MEDIAL TIBIAL STRESS SYNDROME IN HIGH SCHOOL CROSS-COUNTRY RUNNERS

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PURPOSE/HYPOTHESIS: Cross country is a popular high school sport but many participants will experience a running-related injury. Medial Tibial Stress Syndrome (MTSS) is a common injury among high school runners. While the causes of MTSS are likely multifactorial, a meta-analysis study concluded that pronated foot posture contributes to its risk. Prior injury and limited summer training have also been shown to contribute to MTSS. The primary purpose of this study was to investigate whether a more pronated foot posture was related to risk of MTSS in high school runners. We also examined the influence of prior injury and summer training on MTSS risk. We hypothesized that runners with a more pronated foot posture would have a higher incidence of MTSS during the cross-country season.
NUMBER OF SUBJECTS: Seventy-three cross-country runners (32 female, 41 male; mean ± SD age, 16.2 ± 1.1 years; BMI, 20.6 ± 2.6 kg/m^2) from 6 high school teams.
MATERIALS/METHODS: At the start of the season, runners had their foot posture assessed using the Foot Posture Index (FPI-6). They also completed a survey regarding demographics, prior injury and summer training. Runners were prospectively followed by the schools' athletic trainers during the interscholastic season to identify cases of MTSS that caused a runner to miss 1 or more practices or competitions. *t* tests were used to assess mean differences of continuous variables between injured and uninjured runners. Odds ratios (OR) and 95% confidence intervals (CIs) were used to assess injury risk.
RESULTS: During the season, 11 runners (15.1%; 9 female, 2 male) experienced MTSS. The difference in average FPI-6 scores between runners with MTSS (2.7 ± 4.0) and without (3.3 ± 3.4) was not significant (P = .61). Runners with a more pronated foot posture (FPI-6 score of 6 or greater) were not more likely to experience MTSS (OR = 1.1; 95% CI: 0.3, 4.6; P = .92). Runners who reported a prior shin injury (OR = 7.3; 95% CI: 1.8, 29.0; P = .002) and being female (OR = 7.6; 95% CI: 1.5, 38.4; P = .006) were more likely to sustain a MTSS injury. There was not a significant difference in average BMI between those with MTSS (20.9 ± 2.6) and those without (20.5 ± 2.6, P = .64). Runners who sustained MTSS reported running fewer average miles per week (10.0 ± 8.6) in the 4 weeks prior to the season than those without MTSS (17.1 ± 10.1, P = .03). There was not a significant difference in days run per week prior to the season for those who experienced MTSS (3.2 ± 1.7) and those without (4.1 ± 1.8, P = .10).
CONCLUSIONS: In this sample of high school runners, a more pronated foot posture was not related to MTSS injury. Prior history of shin injury, being female, and running low weekly mileage during summer training were associated with higher risk of MTSS.
CLINICAL RELEVANCE: Being of female sex, having a prior shin injury and lower weekly running mileage during summer training may place a runner at greater risk of MTSS during the cross-country season. Ensuring adequate summer weekly running mileage and that effects of prior shin injuries are resolved may mitigate this risk.

SPO65

A CASE STUDY: EXAMINING COUNTERMOVEMENT JUMP PERFORMANCE IN AN NCAA DIVISION I VOLLEYBALL PLAYER WITH A BAKER'S CYST

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BACKGROUND AND PURPOSE: Assessments of explosive lower extremity (LE) power, commonly measured by force plates, are linked to risk of future injury, return to sport readiness, and optimizing athletic performance. As a result, quantifying LE power in college athletes is of significant value, especially in the presence of musculoskeletal injury. Namely, few studies have examined the effects of a Baker's cyst on jump performance and to the author's knowledge, none have examined their impact within collegiate volleyball players. Specifically, understanding how a Baker's cyst may impact jump performance on an athlete cleared for collegiate play, offers health care providers insight into ongoing deficits or potential risk for reinjury. The purpose of this case study was to examine alterations in jump strategy and performance in a NCAA Division I volleyball player suffering a Baker's cyst to the right LE.
CASE DESCRIPTION: One female NCAA Division I volleyball player at a Midwestern university performed pre and post jump testing, prior to and following off-season training. The participant underwent 3 weeks of off-season LE conditioning, emphasizing eccentric resistance loading until onset of a Baker's Cyst to the right leg. This resulted in a 4-week rest period, being cleared for full activity by the staff athletic trainer 1 day prior for post jump testing.
OUTCOMES: Routine pre- and post-jump testing included a countermovement jump without arm swing (CMJWAS) on a 1D dual force plate system. The CMJWAS is performed with participants with their hands on hips, being instructed to jump as high as possible. Outcome measures included jump height (pre, 42.3 cm; post, 44.3 cm), concentric peak power (pre, 56.4 W/kg; post, 59.2 W/kg), eccentric rate of force development (RFD) (pre, 79 N/kg/s; post, 47 N/kg/s), eccentric mean power (pre, 6.7 W/kg; post, 5.9 W/kg), concentric asymmetry index (pre, 16% to right leg; post, 6% to left leg) and eccentric asymmetry index (pre, 16% to right leg; post, 17% to left leg).

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DISCUSSION: Upon re-evaluation, the participant maintained or slightly improved CMJWAS concentric measures and jump height, while eccentric outputs were diminished. Specifically, posttesting eccentric RFD was reduced by 41%, with a 12% reduction in eccentric mean power. Further, they demonstrated a 33% shift in force asymmetry during the eccentric phase away from the previously dominant right leg. If examining jump height alone, the athlete appears to be ready to return to sport, although significant alterations in limb recruitment and diminished eccentric force development are present. Such modifications should draw concern from the coach and sports medicine staff, considering she is cleared yet adopting a compensatory strategy to avoid the right LE. Due to the increasing evidential support for eccentric mean power and RFD to inform return to sport readiness, this case highlights the value of examining jump variables in the presence of LE pathology, beyond simple jump height and concentric measures.

SPO66

EXAMINING CONCENTRIC PEAK FORCE ASYMMETRIES BY COMPETITIVE LEVEL, SPORT, OR SEX IN COLLEGIATE ATHLETES

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PURPOSE/HYPOTHESIS: Countermovement vertical jump (CMJ) provides valuable estimates of lower extremity (LE) force during a dynamic assessment. Variations in interlimb concentric peak force (CPF) produced during the upward jumping phase may provide valuable information concerning limb asymmetries (LA) linked to injury risk or rehabilitative outcomes. As a certain amount of LA is expected, it is valuable to understand the acceptable degree of interlimb variation in high risk athletic populations. As a result, examining potential asymmetries in CPF during the CMJ is warranted since it may vary by division, sport, or sex in college athletes. We hypothesize that the amount of interlimb CPF asymmetry during the CMJ will vary significantly by competitive level, sport, and sex in collegiate athletes.

NUMBER OF SUBJECTS: Two hundred seventy-three.

MATERIALS/METHODS: Healthy college athletes from NCAA Division I (n = 157) (male, n = 78; mean ± SD age, 19.5 ± 1.34 years; height, 185.1 ± 9.14 cm; weight, 82.23 ± 9.06 kg and female, n = 79; age, 19.2 ± 1.31 years; height, 173.99 ± 6.1 cm; weight, 66.12 ± 8.12 kg) and NAIA (n = 116) (male, n = 53; age, 19.5 ± 1.34 years; height, 185.1 ± 9.14 cm; weight, 82.23 ± 9.06 kg and female, n = 63; age, 20.2 ± 1.4 years; height, 169 ± 6.7 cm; weight, 66.2 ± 14.42 kg) schools were evaluated. Female sport teams included basketball (n = 23), volleyball (n = 22), softball (n = 37), soccer (n = 39), and swimming (n = 21). Male sport teams included basketball (n = 29), baseball (n = 76), and wrestling (n = 26). Following routine warm-up, participants completed 2 CMJs on bilateral single-axis force plates, with the greatest CPF jump analyzed. Jumps completed with hands on hips. Participants were instructed to jump "as high and as fast as possible." CPF determined by force-time history and presented relative to body mass ($N \cdot kg^{-1}$). LA calculated as: [(dominant CPF – nondominant CPF)/dominant CPF × 100]. A sex by sport by competitive level (2 by 7 by 2) ANOVA was performed to analyze percent LA. Statistical significance accepted at $P<.05$.

RESULTS: No significant differences in interlimb CPF asymmetry during CMJ were seen when comparing groups based on competitive level, sport, or sex. The average LA for males was 6.1% ± 5.7% and females at 5.8% ± 4.3% ($P = .18$). Further, no significant interactions among major factors ($P>.35$) were seen. It was found that 6.1% of males (n = 8) and 4.9% of female (n = 7) athletes, demonstrated LA of 15% or greater.

CONCLUSIONS: This study indicates that participation level, sport, and sex do not exert a major influence on CPF asymmetry in collegiate athletes. However, based on accepted LA percentages, this showed that a small number of healthy young athletes may have CPF asymmetry predisposing them to future injury risk.

CLINICAL RELEVANCE: Dynamic movement assessments, such as bilateral CMJ, may be used to identify athletes at risk of injury to allow specific rehabilitation training with the objective of reducing the magnitude of bilateral LA. Asymmetries identified in this study may provide a preliminary basis for determining acceptable values when screening college athletes for potential injury risk.

SPO67

HEALTHY PEDIATRIC ATHLETES HAVE SIGNIFICANT BASELINE LIMB ASYMMETRIES ON COMMON RETURN-TO-SPORT PERFORMANCE TESTS

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PURPOSE/HYPOTHESIS: Return to sport (RTS) after anterior cruciate ligament (ACL) reconstruction in children is associated with a much higher risk (approximately 30%) of subsequent ACL injury than in adults. Most RTS testing protocols use limb symmetry indices (LSI) on physical performance tests (PPTs). This assumes that both lower extremities should be equal. We hypothesized that in the pediatric population, baseline limb asymmetry exists, limiting the clinical utility of LSIs. As LSI greater than 90% is often used as a clinical cutoff for RTS, we defined a test as valid if 80% of healthy volunteers had an LSI greater than 90%.

NUMBER OF SUBJECTS: Sixty-three.

MATERIALS/METHODS: This study included healthy volunteers aged 6 to 18 years (mean ± SD age, 10.7 ± 3.2 years; 34 female, 54%). Pubertal Maturity Observation Scores (PMOS), sex, age, height, weight, and body mass index (BMI) were collected. Subjects performed ten PPTs: lower quarter Y Balance, stork balance, stork balance on BOSU, single-leg squat (SLS), SLS on BOSU, clockwise and counterclockwise quadrant single-leg hop (SLH), forward SLH, timed SLH, and triple crossover SLH. Subjects performed the items in the same order, but were randomly assigned the starting test and the starting limb. We developed a composite score for each limb by averaging trials, then calculated the absolute value of the side-to-side difference, and normalized this difference to the test mean to obtain a percentage side-to-side difference (percent STS). Multivariable linear regression analysis was performed to assess the effect of age on limb symmetry while correcting for BMI, PMOS and sex.

RESULTS: Percent STS were not normally distributed for any PPT, therefore data were reported as medians and interquartile ranges. All PPTs showed baseline limb asymmetry, and none met our definition of validity. The most symmetric PPT was the clockwise quadrant hop test (STS in females: median, 9.85%; interquartile range, 4.63%-18.7%; STS in males: median, 6.9%; interquartile range, 3.64%-14.04%). The stork balance on BOSU test had the greatest limb asymmetry (STS in females: median, 41.4%; interquartile range, 10.1%-71.3%; STS in males: median, 47.6%; interquartile range, 18.2%-66.7%). PMOS was strongly correlated with age (Pearson's $r = 0.83$), and was excluded as a predictor variable. Age was an independent predictor of percent STS only for the stork test (b = –1.15; 95% CI: –1.92, –0.38; $P = .004$), with older subjects having less limb asymmetry.

CONCLUSIONS: Healthy children have significant baseline limb asymmetries on PPTs that are commonly used for RTS decision making after ACL reconstruction. None of the PPTs evaluated in this study met our definition of clinical validity. Limb symmetry was typically not affected by subject age.

CLINICAL RELEVANCE: In light of these results, limb symmetry indices (LSI) should be utilized with caution in this population. Functional recovery may be better assessed by comparison to age and sex-specific norms.

SPO68

DEVELOPMENT OF A CONCISE LOWER EXTREMITY PHYSICAL PERFORMANCE TEST SET FOR RETURN-TO-SPORT DECISION MAKING IN PEDIATRIC POPULATIONS

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PURPOSE/HYPOTHESIS: Common physical performance tests (PPTs) used in return to sport decision-making include the Y Balance LQ, stork balance, stork balance on BOSU, single-leg squat (SLS), SLS on BOSU, clockwise and counterclockwise quadrant single-leg hop (SLH), forward SLH, timed SLH, and triple crossover SLH. While each test assesses distinct characteristics of performance, the 10-item battery is not practical in clinical settings. The aims of this study are to (1) define which primary components of physical performance these 10 PPTs assess, and (2) derive a reduced item set of PPTs that efficiently and accurately measures performance on each component.

NUMBER OF SUBJECTS: Sixty-three.

MATERIALS/METHODS: Healthy volunteers aged 6 to 17 years (mean ± SD age, 10.7 ± 3.2 years; 33 female, 54.1%) performed 10 PPTs in the same order with randomized starting test and limb. For analysis, we developed a composite score for each test by averaging trials. All Y Balance, and hop tests were normalized to leg length. Item reduction was performed using principal components analysis (PCA). Kaiser Criterion (eigenvalue greater than 1) and scree plot visualization determined the optimal number of components to extract. Items with loadings greater than 0.55 were considered for the reduced item test. Cross-loaded items with less than 0.25 absolute difference in loading between components were dropped. If 2 or more factors loading on the same component were highly correlated (r>0.7), we dropped the item(s) with the lowest factor loading. The reduced item set was evaluated for internal consistency (Cronbach alpha) among the principal components, with a minimum criterion of 0.7 considered satisfactory.

RESULTS: PCA extracted 2 components with a cumulative response variance of 67.7%. Component 1 (neuromuscular control) included all balance, SLS and quadrant hop tests. The 2 quadrant hop tests were highly correlated (r = 0.94) and had the second and third lowest factor loadings (less than 0.78) and were not considered for the reduced-item set. The SLS had the lowest factor loading (0.69) and was also not considered. The Stork, Stork BOSU, and SLS BOSU had similar factor loadings (0.79, 0.90, and 0.88, respectively) and did not meet criteria for removal (all, less than 0.61). Component 2 (Power), forward SLH (0.94) and crossover SLH (0.79), demonstrated moderate correlation (r = 0.56). Timed SLH and Y Balance did not meet the loading criterion and were not considered. The final 5-item set had a cumulative response variance of 76.0%. The Cronbach α of the 3-item Component 1 (0.80), 2-item Component 2 (0.72), and overall 5-item set (0.70) were all satisfactory.

CONCLUSIONS: Neuromuscular control and power are most appropriately assessed with stork, stork BOSU, SLS BOSU, forward SLH and triple crossover SLH tests. Of these, the Stork BOSU and forward SLH may be most capable of evaluating components measured by the 10 PPTs.

CLINICAL RELEVANCE: These findings provide clinicians with efficient options for measuring lower extremity performance for the purposes of return to sport decision making in pediatric populations.

SPO69

PREVENTION OF TIBIAL STRESS FRACTURES AMONG RUNNERS: SUMMARY OF EVIDENCE AND CLINICAL RECOMMENDATIONS

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PURPOSE: There is no systematic review regarding prevention of tibial stress fractures (TSF). The purpose of this project was to summarize the evidence and provide recommendations for preventing TSF.

DESCRIPTION: A comprehensive literature search was conducted with keywords: tibial stress fracture, prevention, long distance runner, running injuries, running injury prevention. Primary outcome was TSF confirmed by radiology (X-ray); however, due to a low number of studies, physiology measures (eg, tibial compression and strain forces) were included. Evidence was rated as: Level 1a, at least 2 randomized control trials (RCT), PEDro at least 4; Level 1b, 1 RCT; PEDro at least 4; Level 2, at least 1 quasi-experimental study.

SUMMARY OF USE: A total of 12 articles were found: 5 RCTs and 7 quasi-experimental studies. Participant ages ranged from 17 to 44 years old. Calcium and vitamin D (2000 mg Ca2+ per day and 800 IU vitamin D per day for 24 months) decreased TSF incidence (X-ray) in a study of 3700 female navy recruits (level 1b). Pre-exercise stretching (20-second static stretch for 12 weeks) did not decrease TSF in a study of 1538 male army recruits (level 1b). Orthotics for persons with high or low arches did not decrease TSF incidence (X-ray) among 265 male military recruits (level 1b); however, orthotics reduced femoral stress fractures in high arched feet and metatarsal fractures in low arched feet. Adding orthoses to running shoes did not change tibial strain among 9 healthy adults but adding soft or semi-rigid orthoses to military boots did. In 2 separate studies, running on a treadmill (versus overground) resulted in lower tibial compression and tension strains among 12 healthy adults (level 2). Avoiding exercising past fatigue onset decreased tibial compression strain compared to exercising beyond fatigue among 4 healthy adults (level 2). The remaining studies suggest that changing running kinematics may decrease TSF risk. A 2-week verbal feedback program (told to "run softer") decreased tibial acceleration and forces among 10 college athletes (level 2). A 3-week visual and auditory feedback program decreased tibia acceleration and forces in a study of 22 male runners (level 1b). Decreasing stride length and increasing steps per minute reduced peak tibial impact force among 10 college cross-country runners (level 2). Although 1 study showed no difference in tibial strain between forefoot and heel-strike kinematics in 14 runners, another study showed that changing to a forefoot strike pattern or increasing cadence among 17 heel-strike runners decreased tibial loading rates (level 2).

IMPORTANCE TO MEMBERS: Research is limited but this evidence summary provides guidelines to prevent tibial fractures. Future research should use RCT study designs, follow participants long term, assess different running dosages (eg, distance, time, running surface), investigate types of running shoes and provide data by age and sex.

SPO70

THE RELATIONSHIP BETWEEN POSTURE AND UPPER EXTREMITY FLEXIBILITY IN INTERCOLLEGIATE BASEBALL, SOFTBALL, AND SWIMMING ATHLETES

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PURPOSE/HYPOTHESIS: Injuries involving the upper extremity (UE) are common among overhead athletes. Previous studies have indicated that changes in glenohumeral range of motion are linked to UE injury in overhead athletes. Differences in posture and shoulder complex muscle imbalance can contribute to pain and loss of function in the UE. UE flexibility and posture are frequently utilized assessments, but the relationship of these measurements in overhead athletes is not clearly understood. Therefore, the purpose of this study was to investigate relationships between posture and UE flexibility measurements among intercollegiate overhead athletes.

NUMBER OF SUBJECTS: One hundred fifteen intercollegiate baseball, softball and swimming student-athletes participated (males, n = 71; mean ± SD age, 19.9 ± 1.4 years; height, 183.0 ± 17.9 cm; weight, 86.8 ± 11.6 kg and females, n = 44; age, 19.6 ± 1.3 years; height, 169.5 ± 7.0 cm; weight, 69.3 ± 8.3 kg).

MATERIALS/METHODS: All flexibility and postural assessments were measured by a Certified Athletic Trainer who is proficient in assessment of the upper extremity. Flexibility assessments were measured in supine using pre-

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established techniques on the dominant (Dom) and nondominant (NDom) upper extremity. Flexibility assessments included: shoulder internal (IRF) and external (ERF) rotation, pectoralis minor length (PML), and posterior shoulder tightness (PST). Postural measurements on the Dom and NDom upper extremity included forward head posture (FHP) and forward shoulder posture (FSP). Lateral photographs of each subject were taken bilaterally and processed using ImageJ software. Normality was assessed and correlations were assessed using a Pearson correlation. Data were analyzed for all athletes, males, and females. Significance was set at $P<.05$ a priori.

RESULTS: The results of the Pearson correlation demonstrated significant correlations between Dom FSP and IRF; as Dom FSP decreased IRF increased (Dom, 0.347; $P<.001$ and NDom, 0.276; $P = .003$). Significant Pearson correlations were observed between NDom FSP and IRF; as NDom FSP decreased, IRF increased (Dom, 0.386; $P<.001$ and NDom, 0.273; $P = .003$). When sex was compared, male athletes demonstrated similar significant Pearson correlations; as Dom FSP decreased, IRF increased (Dom, 0.402; $P = .001$ and NDom, 0.254; $P = .033$). As NDom FSP decreased, IRF increased (Dom, 0.478; $P<.001$ and NDom, 0.284; $P = .016$). In females, as Dom FSP decreased, NDom IRF increased (0.327, $P = .030$).

CONCLUSIONS: Overall, athletes with lower FSP demonstrated more internal rotation flexibility. When sex was compared, females only showed a significant correlation between decreases in Dom FSP and increases in NDom IRF.

CLINICAL RELEVANCE: This study demonstrated significant relationships between FSP and IRF among overhead athletes, but the significance of the correlation showed that differences may exist between male and female athletes. Further research is needed to explore differences in shoulder measurements among male and female overhead athletes and its potential relationship to injury rates with the goal of improving current injury prevention programs.

SP071

MUSCLE ACTIVATION OF THE UPPER-QUARTER Y BALANCE TEST AND RELATIONSHIP TO TEST SCORE

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PURPOSE/HYPOTHESIS: The Upper-Quarter Y Balance Test (YBTUQ) is a closed-chain upper extremity (UE) test that allows clinicians to assess unilateral UE function in the reaching and the stabilizing limb. Previous research shows the YBT-UQ is reliable and valid, and other studies have gathered normative data in athletes, healthy service members, and healthy adult populations. No studies have analyzed muscle activation patterns of the upper extremity when performing the test compared to reach and composite score. Therefore, the purpose of this study is to compare the reach in YBT-UQ with scapulothoracic (ST) muscle activation via electromyographic (EMG) patterns. We hypothesize that as reach distance increases, ST muscle activation will increase.

NUMBER OF SUBJECTS: Fifteen healthy subjects without shoulder pain (mean ± SD age, 24.35 ± 2.03 years; height, 1.75 ± 0.25 m; weight, 74.59 ± 36.32 kg).

MATERIALS/METHODS: EMG signals were collected using wireless surface electrodes; electrode placements were standardized and recorded from 8 muscles on the back, shoulder girdle, and arm on bilateral UEs. The subject performed 3 trials of the YBTUQ on each side which consists of a 1-armed plank position while using the other arm to reach in 3 directions. The directions consisted of Medial (M), Superolateral (SL), and Inferolateral (IL). All directions were measured for distance, normalized to wingspan, and calculated into a composite score. Correlations were assessed using a Pearson correlation. Data were analyzed for all subjects and significance was set at $P<.05$ a priori.

RESULTS: Overall, the SA presented with the highest mean maximum voluntary isometric contraction (MVIC) among all muscles tested (Dom SA, 242.3 ± 187.11; NDom SA, 276.76 ± 145.71). The results of the Pearson correlation comparing activation and reach scores revealed significant moderate correlation between Dom LT and SL reach; as Dom LT activation increases Dom SL reach increases ($r = 0.59$, $P = .021$). No other significance was observed.

CONCLUSIONS: The SA plays a crucial role in stabilizing the UE during the test as observed by the highest activation among all muscles. However, this study did not find the expected correlations among mean MVIC values of the ST muscles and reach distance or composite score with the exception of the Dom LT in the SL direction. This correlation could be due to increase in activation needed to stabilize the dominant limb while the opposite limb reaches in the SL direction.

CLINICAL RELEVANCE: The YBTUQ is a proposed UE assessment tool used to assess unilateral function and stability, but continued EMG research needs to be done with increased sample size in order to determine correlations that will relate to clinical evaluation.

SP072

A NOVEL USE OF BLOOD FLOW RESTRICTION TRAINING IN POSTCONCUSSION CARE: A CASE SERIES

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BACKGROUND AND PURPOSE: Sports-related concussions may result in prolonged recovery in about 15% of athletes. Moderate aerobic exercise has been shown to improve postconcussive symptoms but may not always be well tolerated. Minimal research has looked at utilizing strength training for postconcussion recovery. Autonomic dysfunction following a concussion injury may be linked to postconcussion exercise intolerance. Blood flow restriction training can allow an individual to perform submaximal low intensity exercise with physiological responses similar to high intensity exercise. This case series aimed to evaluate the efficacy of BFR training to improve exercise intolerance in individuals with postconcussive symptoms.

CASE DESCRIPTION: Three subjects (2 male, 1 female) involved in contact sports (lacrosse, wrestling, ice hockey) were referred to physical therapy for postconcussion symptoms including headaches, vision changes, neck pain, exercise intolerance, and vestibular disturbances. Each subject had been experiencing symptoms for more than 8 weeks prior to being referred to PT. All 3 participants received traditional interventions for their symptoms including manual therapy, vestibular exercises, aerobic exercise (walking or stationary cycling). While symptoms generally improved, patients reported exercise associated headaches during attempts of increased activity. BFR training was offered as an optional treatment to allow the patients to perform body weight exercises as an additional form of exercise. Post Concussion Symptom Score (PCSS), orthostatic heart rate, and resting blood pressure were recorded in each session. Each subject performed approximately 4 body-weight exercises (eg, squats, lunges) with the BFR cuff applied at 80% occlusion and using standard BFR training protocols. Heart rate, rate of perceived exertion (RPE) and symptom report were monitored during the duration of the BFR treatment. While the RPE and HR increased during BFR exercise training, subjects were able to complete all exercises without increased symptom provocation.

OUTCOMES: All 3 subjects reported subjective improvement in their concussion symptoms following interventions based on their PCSS and global function rating scores. They also demonstrated objective improvements in their orthostatic HR and cardiovascular testing performance. Each subject was discharged with an independent home exercise program.

DISCUSSION: The results of these cases may be confounded due to use of concurrent concussion interventions. Therefore, it is difficult to determine the extent of improvement that can be attributed solely to BFR.

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Additionally, there is no comparison to determine if the outcomes would have been the same with traditional aerobic training. However, it is promising that all subjects were able to tolerate BFR and bodyweight training as an additional intervention without symptom provocation. Further investigation is warranted to determine the utility and benefit of BFR in postconcussion rehabilitation in relation to autonomic dysfunction and exercise intolerance.

SP073

HIGHER FEAR-AVOIDANCE BELIEFS ARE ASSOCIATED WITH LOWER RUNNING ABILITY IN INJURED RUNNERS

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PURPOSE/HYPOTHESIS: Psychological distress can negatively influence rehabilitation outcomes. Methods to identify psychological distress have been developed, but have not been examined in injured runners. The purpose was to evaluate psychological distress in injured runners and its association with running ability. The hypothesis was that higher psychological distress would correlate with lower running ability.

NUMBER OF SUBJECTS: Twenty-seven distance runners (8 male; mean age, 33.9 years; range, 15-59 years) seen in physical therapy for evaluation of a running-related injury.

MATERIALS/METHODS: Questionnaires completed at the initial physical therapy visit included the University of Wisconsin Running Injury and Recovery Index (UWRI), Athletic Fear Avoidance Questionnaire (AFAQ), and Optimal Screening for Prediction of Referral and Outcome-Yellow Flag Screening Tool (OSPRO-YF). The UWRI includes 9 items that quantify an individual's ability to run. The AFAQ includes 10 items related to fear-avoidance beliefs in athletes. The OSPRO-YF assesses pain-related psychological distress (ie, yellow flags) in 11 subscales divided into 3 domains: negative mood, fear avoidance, and positive coping. Scores that fall in the top quartile for negative or bottom quartile for positive psychological questionnaires are defined as yellow flags. Pearson correlation coefficient examined the association of AFAQ and UWRI scores. Spearman rank correlation examined the association of the number of yellow flags on OSPRO-YF with UWRI score.

RESULTS: Mean ± SD scores were UWRI, 14.8 ± 6.0 points and AFAQ, 22.6 ± 7.8 points. The median number of OSPRO-YF yellow flags was 2 (interquartile range, 1-6). Yellow flags were most common on the State Trait Anxiety Index (23/27, 85% of the sample) and least common on State Trait Anger Expression Inventory, Fear-Avoidance Beliefs Questionnaire-Work, and Pain Catastrophizing Scale (4/27, 14% of the sample). AFAQ score was significantly negatively correlated with the UWRI score (r = −0.44, P = .023). The number of yellow flags on OSPRO-YF was not correlated with the UWRI score (r = 0.09, P = .651).

CONCLUSIONS: Among injured runners, higher fear avoidance, measured by the AFAQ, was associated with lower self-reported running ability, but yellow flags on the OSPRO-YF were not. Most of the sample met the criteria for a yellow flag related to anxiety.

CLINICAL RELEVANCE: Addressing high fear-avoidance beliefs in injured runners along with physical impairments may be a necessary part of rehabilitation. The lack of association between current running ability and the number of yellow flags may indicate the OSPRO-YF is more suited to a general population, but it is yet unknown if yellow flags predict rehabilitation outcomes in runners. Psychological distress related to anxiety in this study is consistent with other studies showing anxiety in healthy or injured runners who are restricted from running.

SP074

EFFECT OF AUDITORY CUES ON RUNNING BIOMECHANICS IN HEALTHY INDIVIDUALS

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PURPOSE/HYPOTHESIS: Altering running cadence in individuals with patellofemoral pain syndrome (PFPS) has been shown to reduce knee joint forces and decrease pain. Typically, a metronome is used to provide an auditory stimulus to alter cadence. A limitation of the metronome is it may be perceived as boring relative to music which also has a set beat frequency. The purpose of this study was to determine the effect of listening to music at a specific beat frequency on running biomechanics in healthy individuals.

NUMBER OF SUBJECTS: Ten participants (mean ± SD age, 23.5 ± 2.5 years; height, 177.1 ± 3.5 cm; mass, 64.8 ± 6.5 kg; Tegner, 6.5 ± 1.1).

MATERIALS/METHODS: Participants performed a 5-minute jogging warm-up at a self-selected pace, followed by a 2-minute of running data collection with cadence determined during the last 30 seconds. After a 5-minute rest, participants performed a second 5-minute bout of running followed by 2 minutes of data collection, at the same speed, while listening to music with a beat approximately 5% to 15% higher than their cadence. A 7-camera motion-capture system (200-Hz Qqus 500; Qualisys, Göteborg, Sweden) and instrumented treadmill (1000 Hz; Bertec Corporation, Columbus, OH) were used to collect kinematic and kinetic data. The primary outcome measures were cadence, peak knee flexion angle (degrees), and peak external knee flexion moment (Nm/kg).

RESULTS: There was no significant change in cadence (P = .15; pre, 172.0 ± 9.0 steps per minute; post, 176.4 ± 5.5 steps per minute), peak knee flexion angle (P = .07; pre, 38.7° ± 3.4°; post, 37.6° ± 3.0°), or peak external knee flexion moment (P = .93; pre, 2.95 ± 1.10 Nm/kg; post, 2.91 ± 1.58 Nm/kg).

CONCLUSIONS: Listening to music at a specific beat frequency was not effective for all individuals to cause significant changes in running biomechanics. It is possible that the ability to match the beat frequency of song has an impact on outcomes. In this study only 2 participants were able to match their cadence to the beat frequency. These individuals also demonstrated increased cadence and decreased peak external knee flexion moments. Future studies should better determine individuals who may be likely to match beat frequency. An example would be the use of the beat alignment test (BAT).

CLINICAL RELEVANCE: While listening to music at a specific beat frequency did not have an impact on running biomechanics in healthy individuals, there were individuals who may benefit from listening to music to alter running cadence.

SP075

YOUNGER ATHLETES WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION SHOW BETTER PSYCHOLOGICAL READINESS FOR SPORT THAT IS NOT MATCHED BY FUNCTIONAL READINESS FOR SPORT

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PURPOSE/HYPOTHESIS: Risk for a second anterior cruciate ligament (ACL) injury after ACL reconstruction is increased with younger age and possibly high knee-related confidence or kinesiophobia. The purpose of this study was to examine the association of age with psychological readiness for sport and the prevalence of mismatch between psychological and

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functional readiness for sport. We hypothesized that younger patients would demonstrate high psychological readiness for sport, but more discrepancies between psychological and functional readiness for sport.

NUMBER OF SUBJECTS: Twenty-six patients (15 female; median age, 16 years; age range, 14-30 years) with primary ACL reconstruction (20 bone-patellar tendon-bone, 6 hamstring autografts) following traditional physical therapy and advanced return to sport training (mean ± SD, 31.9 ± 2.6 weeks postoperative).

MATERIALS/METHODS: Questionnaires were administered for psychological readiness for sport (Anterior Cruciate Ligament-Return to Sports after Injury [ACL-RSI]); kinesiophobia (Tampa Scale of Kinesiophobia-11 [TSK-11]); and knee-related confidence (Knee Activity Self Efficacy [KASE]). A battery of 4 hop tests (single, triple, crossover triple and timed) was administered, and the limb symmetry index [(involved side/uninvolved limb) × 100] was computed. Psychological readiness for sport was categorized as "yes" or "no" based on 2 ACL-RSI thresholds (low, 56 points or greater; high, 75 points or greater); functional readiness for sport was similarly categorized based on 90% or greater limb symmetry for each hop test. Pearson correlation examined the association of age and questionnaire scores. Agreement or mismatch in psychological and functional readiness categorization was coded. The sample was split into "younger" and "older" groups based on median age, and McNemar test examined mismatch between psychological and functional readiness categorization.

RESULTS: Mean ± SD questionnaire scores were ACL-RSI, 80.3 ± 13.2; TSK-11, 17.1 ± 4.6; KASE, 92.6 ± 6.2. Age was negatively correlated with ACL-RSI score ($r = -0.646$, $P<.001$) and KASE score ($r = -0.51$, $P = .008$), but not TSK-11 score ($r = -0.11$, $P = .589$). The younger group had more mismatches between psychological and functional readiness categorization than the older group using either low (younger, 17; older, 7; $P = .043$) or high (younger, 9; older, 4; $P = .039$) ACL-RSI threshold. Mismatches were "psychologically ready/functionally not ready" in the younger group and "psychologically not ready/functionally ready" in the older group.

CONCLUSIONS: At the time of return to sport, younger age was associated with higher psychological readiness for sport and knee-related confidence, but not kinesiophobia level. Younger patients showed a high prevalence of meeting psychological but not functional readiness for sport criteria.

CLINICAL RELEVANCE: In young patients with ACL reconstruction high psychological readiness may facilitate the return to sport, but they should be educated on the importance of achieving functional readiness to reduce risk for second ACL injury.

SP076

RETURN-TO-SPORT TESTING FOLLOWING AN ANTERIOR CRUCIATE LIGAMENT REPAIR WITH INTERNAL BRACE LIGAMENT AUGMENTATION: A CASE REPORT

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BACKGROUND AND PURPOSE: Anterior cruciate ligament (ACL) surgical techniques currently incorporate the use of different fixation types, various biological tissues, and artificial ligaments. Reconstructions with bone patella-tendon bone or hamstring grafts are the most utilized procedures. Yet, the ultimate objective of returning to previous level of function with these methods is not ideal. The purpose of this study is to examine return to sport (RTS) testing following internal brace ligament augmentation (IBLA).

CASE DESCRIPTION: Followed a 23-year-old woman, after primary ACL repair via IBLA and physical therapy (PT). Retrospective chart review performed to describe participants' PT protocol. Performance-based RTS testing and self-reported outcome measure taken at evaluation, 6 months, and 1 and 2 years postoperation.

OUTCOMES: A time and criterion based rehabilitation program was utilized. Visit frequency twice a week until normalized gait pattern achieved. After passing compulsory tests, patient returned to run using antigravity treadmill. Subject started at 60% of body weight, and progressed to 90% over 4 weeks. Last phase included progressive running, plyometric, and dynamic movement tasks. At 6-month follow-up, the patient passed 8 of 11 objective knee functional assessments and all 5 of the subjective measurements. During the 1 and 2 year follow-ups the subject passed 10 of 11 objective tests and all 5 of the subjective measurements.

DISCUSSION: The literature has shown that ACL reconstruction athletes that meet strict criterion cutoffs demonstrate a higher percentage of RTS. With IBLA this subject met or surpassed a more stringent criterion cutoff over a 2-year follow-up period despite commonly held views concerning the safety and efficacy of synthetic grafts. This case study demonstrates that for the appropriate candidate, successful RTS testing can be achieved with ACL primary repair via IBLA.

SP077

SCREENING RANGE OF MOTION AND STRENGTH TO PREDICT UPPER EXTREMITY INJURY IN OVERHEAD ATHLETES: A SYSTEMATIC REVIEW

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PURPOSE/HYPOTHESIS: Characterize the ability of preseason measures of range of motion (ROM) and strength to predict the in-season occurrence of upper extremity injuries in overhead athletes.

NUMBER OF SUBJECTS: Three thousand five hundred seventy-eight athletes (professional, 1155 [female, 193]; high school, 1709 [female, 144]; youth, 640 [female, 32]; competitive, 74 [female, 37]) of 5 different sports: handball, baseball, softball, volleyball, swimming.

MATERIALS/METHODS: The review followed PRISMA guidelines. Five databases were searched. 2 reviewers independently screened the retrieved articles to identify relevant studies. Inclusion criteria: (1) population included athletes; (2) preseason screening of ROM and strength; (3) tracked injuries at the shoulder and/or elbow throughout the season; and (4) used a prospective cohort design. Exclusion criteria: (1) not an Olympic or college sport (wide participation); (2) not overhead repetitive activities; (3) contact injury; (4) lower extremity, spine, and/or hand injuries. Quality of each study was scored using a modified version of the Downs and Black quality assessment tool (0%-100%, 100% is max quality). Measures of ROM and strength in internal and external rotation (IR and ER, respectively) were assessed by sport.

RESULTS: Of 9649 identified studies, 17 met inclusion and exclusion criteria. A total of 728 players (20.34%) suffered 796 shoulder and elbow injuries. The average quality score was 71 ± 11 (range, 57-90). Fifteen studies assessed shoulder ROM. A deficit greater than 5° ER ROM of the dominant arm with respect to the nondominant arm predicted shoulder injuries in professional baseball pitchers, but not in college or high school players. An IR ROM deficit greater than 13° predicted shoulder/elbow injury in youth baseball players. IR ROM deficit greater than 25° predicted shoulder/elbow injury in high school baseball and softball players. IR ROM deficit did not predict injury in professional baseball players. ER ROM greater than 100° or less than 93° predicted injury in swimmers. 6 studies examined shoulder strength. Imbalance of ER and IR strength in the dominant arm predicted shoulder injuries in handball players. In baseball players, greater ER strength in the dominant arm predicted a reduction in injury. In volleyball players, greater eccentric ER and IR strength in the dominant arm is protective against shoulder injury.

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CONCLUSIONS: Preseason screening of shoulder ROM and strength may be helpful to identify athletes at risk of shoulder and elbow injuries. Results from screening must be interpreted in the context of sport and level of playing. Limitations include methodological bias and the variation in injury definition. Results may differ from prior reviews based on the inclusion criteria of all upper extremity injuries and the use of prospectively designed studies only.
CLINICAL RELEVANCE: ROM and strength are clinical measures that can be easily collected as part of preseason screening. Some of these measures may predict future upper extremity injury in overhead athletes. Sport played, level of sport, and player age must be considered to identify potential at risk athletes.

SPO78

AGE AND CHARACTERISTICS OF SURGERY AND REHABILITATION AS RISK FACTORS FOR REINJURY IN ADOLESCENTS WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: Adolescents with anterior cruciate ligament reconstruction (ACLR) have a higher reinjury risk than adults, and little is known regarding the characteristics of adolescent patients that may be informative of reinjury. This study aimed to determine the influence of age on post-ACLR functional outcomes and identify risk factors associated with secondary ACL tears in adolescent patients.
NUMBER OF SUBJECTS: Two hundred twenty (122 girls and 98 boys; age, 10.4-21.6 years).
MATERIALS/METHODS: Patients who had first-time unilateral ACLR and received rehabilitation at Children's Healthcare of Atlanta Sports Medicine between 2013 and 2016 were identified. Demographics, injury history, surgical procedures, duration of physical therapy, and outcome measures (eg, pain, range of motion, time to discharge knee brace, strength, and hop tests) were extracted from medical records. The effect of age on functional outcomes was examined using multivariate linear regression while controlling for sex, injury history, and surgical techniques. Survival analysis using Cox proportional-hazards regression was conducted to explore risk factors of subsequent ACL tears.
RESULTS: Reinjury was recorded in 42 patients (19%) with a median follow-up time of 3.4 years. The median time of reinjury was 13.9 months postsurgery (range, 2.2-47.7 months). Thirty-eight percent of reinjury occurred in the contralateral leg, and 57% of reinjury occurred in girls. Age was not associated with any functional outcome measure (P>.05). Cox regression indicated that older age (hazard ratio [HR] = 0.78 per year increase in age, P = .004), receiving surgery longer than 1 month after injury (HR = 0.46, P = .018), and starting physical therapy at more than 3 days post-ACLR (HR = 0.17, P = .015) reduced the risk of reinjury. While results also indicated that increasing the total duration of post-ACLR physical therapy reduced reinjury risk, this protective effect was only significant within 1 year post-ACLR (HR = 0.85, P = .033).
CONCLUSIONS: Adolescent patients who are younger, receive surgery and post-ACLR physical therapy sooner, and are discharged from physical therapy earlier may be at a higher risk of reinjury. Given the retrospective design and influence of missing data in medical records, future prospective research is needed to understand the effects and mechanisms of these identified factors on reinjury risk in adolescent patients.
CLINICAL RELEVANCE: Our findings revealed that age and surgery/rehabilitation status may help identify adolescent patients who are at a higher risk of reinjury. Whether these risk factors are also present in adult patients requires further investigation. While younger age was associated with a higher reinjury risk, similar functional outcomes were observed across all adolescent patients, suggesting that commonly used outcome measures or rehabilitation milestones are not sufficient to identify patients at high risk of reinjury. Developing more sensitive assessments for discharge criteria is warranted to prevent secondary injury in young ACLR patients.

SPO79

AGE EFFECTS ON STRENGTH AND RANGE OF MOTION IN HIGH SCHOOL AND COLLEGE PITCHERS

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PURPOSE/HYPOTHESIS: Previous research has highlighted normative strength and range of motion profiles of asymptomatic high school baseball pitchers. These normative characteristics are important to assist with clinical interpretation of symptomatic and asymptomatic baseball pitchers. Previous work has shown shifts in arch of range of motion and altered strength profiles side to side, however we do not have these comparisons through the various levels of baseball pitchers. The purpose of this study was to evaluate the natural maturation of range of motion and strength in high school (HS) and (COL) pitchers, so we have a better understanding of pitcher profiles at differing levels of play.
NUMBER OF SUBJECTS: Ninety-eight HS pitchers (mean ± SD age, 16.3 ± 1.2 years) and 93 COL pitchers (mean ± SD age, 19.1 ± 1.8 years).
MATERIALS/METHODS: Asymptomatic pitchers completed preseason (98 HS and 93 COL) strength evaluations on both dominant (DOM) and nondominant (ND) arms; empty-can supraspinatus (EC), internal rotation at 90° (IR), external rotation at 90° (ER), scapular retraction (SR), and adduction (ADD) using a Lafayette Hand Held MMT (Lafayette, IN). Pitchers also underwent standard range of motion testing for internal rotation at 90° (IRROM), external rotation at 90° (ERROM), and sidelying posterior shoulder tightness (PST).
RESULTS: Strength differences were noted between groups in EC on the DOM (9.6 ± 2.9 HS versus 13.3 ± 2.6 COL, P = .001) and ND (9.9 ± 2.9 HS versus 13.9 ± 2.6 COL, P = .001), ER DOM (13.1 ± 3.9 HS versus 19.1 ± 4 COL, P = .001) and ND (13.2 ± 3.4 HS versus 19.8 ± 3.4 COL, P = .001), IR DOM (15.3 ± 4.3 HS versus 20.8 ± 4.3 COL, P = .001) and IR ND (14.2 ± 4 HS versus 20.8 ± 3.9 COL, P = .001), SR DOM (9.9 ± 3.2 HS versus 15.2 ± 3.6 COL, P = .001) and SR ND (9.9 ± 3.1 HS versus 14.9 ± 3.5 COL, P = .001), ADD DOM (12.5 ± 3.3 HS versus 17.6 ± 3.7 COL, P = .001). No side-to-side strength differences were noted between arms in either the HS or COL pitchers. No range of motion differences were seen between the HS and COL pitchers on either the DOM or ND side: ER DOM (118.6 ± 16 HS versus 118.5 ± 11 COL, P = .98), ER ND (108.1 ± 14.9 HS versus 106.1 ± 13.9 COL, P = .32), IR DOM (43.1 ± 7.9 HS versus 42.9 ± 5.8 COL, P = .82), IR ND (51.3 ± 8.6 HS versus 53.3 ± 6.4 COL, P = .07), PST DOM (22.9 ± 8.5 HS versus 21.3 ± 5.7 COL, P = .13), and PST ND (17.37 HS versus 16.1 ± 6.4 COL, P = .23).
CONCLUSIONS: Natural strength maturation from HS to COL pitchers is evident as both DOM and ND strength values increased for the COL level pitcher. On average, strength measures increased 28% to 34% from HS to COL pitchers, in the various test positions. Although the humeral arch shift is evident in the increased ER ROM on the DOM shoulder and decrease in IR ROM on the DOM shoulder, there appeared to be no significant ROM differences with pitcher profiles from HS to COL level. Although it appears that ROM changes plateau by the HS level, strength increases from HS to COL.
CLINICAL RELEVANCE: These findings suggest clinical ROM values of pitchers should be similar between HS and COL pitchers, however it should be expected that strength values will continue as physical maturation continues into the college years.

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SP080

THE UTILITY OF THE KERLAN-JOBE ORTHOPAEDIC CLINIC SCORE IN HIGH SCHOOL AND COLLEGE BASEBALL PITCHERS

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PURPOSE/HYPOTHESIS: The Kerlan-Jobe Orthopaedic Clinic (KJOC) Shoulder and Elbow questionnaire has been shown to be a validated subjective tool in the detection of upper extremity dysfunction in the overhead throwing athlete. The KJOC score has recently been used to establish normative baseline data in professional baseball positional players, as well as professional baseball pitchers. Research has shown that KJOC scores in professional baseball players are the lowest in pitchers, compared to positional players. Previous research has determined that professional baseball pitchers normative KJOC values should be a score of 90 or greater. The purpose of this study is to determine if normative KJOC values in asymptomatic high school (HS) and college (COL) pitchers are comparative to those of professional pitchers and to determine if the KJOC scores change by the end of the season.

NUMBER OF SUBJECTS: Ninety-eight HS pitchers and 93 COL pitchers.

MATERIALS/METHODS: Asymptomatic pitchers completed preseason (98 HS and 93 COL) and postseason (40 HS and 39 COL) KJOC surveys to determine normative baseline and postseason KJOC values.

RESULTS: Normative KJOC HS values were determined to be 88 ± 11, while the COL KJOC normative value was 86 ± 15. There was no significant difference (P = .58) in KJOC scores between asymptomatic HS pitchers and asymptomatic COL pitchers . There was no significant differences between the HS preseason and postseason KJOC (88 ± 11 to 82 ± 21, P = .82) or COL preseason and postseason (86 ± 15 to 83 ± 15, P = .16).

CONCLUSIONS: Normative KJOC scores in HS and COL pitchers appear to be lower than those previously documented in professional pitchers. The normative threshold for KJOC scores in HS and COL pitchers should be 88. Any score below this threshold should be considered for further medical assessment.

CLINICAL RELEVANCE: These findings suggest that 88 should be considered the normative value threshold for KJOC scores and little change should be expected throughout the season in asymptomatic pitchers.

SP081

USE OF A CONCUSSION CLINICAL TRAJECTORY MODEL FOR THE MANAGEMENT OF POSTCONCUSSION SYNDROME IN AN ADOLESCENT ATHLETE: A CASE STUDY

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BACKGROUND AND PURPOSE: One in 5 children will sustain a traumatic brain injury by the age of 16 and 11% to 29% of concussed youth will develop postconcussion syndrome (PCS). PCS is characterized by persistent symptoms beyond the normal course of recovery or 3-month timeframe. Symptoms may include fatigue, headaches, dizziness, sleep disturbance, irritability, and affective and personality changes. Given the persistence of symptoms recalcitrant to cognitive and physical rest, it is vital that physical therapists be well versed in examination and treatment of youth PCS.

CASE DESCRIPTION: A 16-year-old adolescent girl presented to physical therapy 5 weeks after being struck in the face with a soccer ball, experiencing neck pain, headaches, nausea, dizziness, blurred vision, decreased balance, and difficulty speaking. Examination revealed impaired balance; exacerbated dizziness, nausea, and neck pain with Vestibular/Ocular-Motor Screening; activity intolerance with the Buffalo Concussion Treadmill Test; and increased kinesiophobia measured by the Tampa Kinesiophobia Scale (TKS). The Sport Concussion Assessment Tool-5 (SCAT-5) revealed high symptom number, moderate symptom severity, and impaired delayed recall. Cervical spine examination revealed painful, limited active range of motion (AROM), decreased deep neck flexor (DNF) endurance, increased joint position error, and reduced function on the Neck Disability Index (NDI). Based on the Conceptual Model of Sport-Related Concussion Clinical Trajectories, symptoms were classified under vestibular, ocular motor, cognitive/fatigue, anxiety/mood, and cervical clinical trajectories. Patient presentation matched the emerging clinical trajectory of autonomic dysfunction post concussion. Neck pain was classified under exercise and conditioning per treatment based classification. An interprofessional approach was initiated. Intervention included cervical joint mobilization, addressing DNF endurance and proprioception, convergence training, vestibular ocular reflex and balance training.

OUTCOMES: Five weeks post initial evaluation, pain-free cervical AROM had been restored and the NDI score had decreased from 53% to 22%, indicating clinically meaningful change. DNF endurance had improved by 5 seconds. SCAT-5 Symptom Severity had decreased from 73 to 59 and the TKS decreased 7 points, exceeding minimal detectable change. Convergence had improved by 5 cm, and the patient demonstrated reduced sway with standing on foam. Complete outcomes data will be presented.

DISCUSSION: Symptom limited physical and cognitive rest play a role in PCS recovery, but should be augmented with rehabilitation to address concussion-related symptoms, and prevent deconditioning. This case highlights the importance of examination of the vestibular and ocular-motor systems, cervical spine, and cardiovascular endurance. Due to a multisystem presentation, the use of multiple assessment tools was indicated and an individualized plan with a team approach yielded a favorable outcome.

SP082

SECOND ANTERIOR CRUCIATE LIGAMENT INJURY AFTER PRIMARY ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION STRATIFIED BY PATIENTS' SEX AND GRAFT TYPE: SYSTEMIC REVIEW AND META-ANALYSIS

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PURPOSE/HYPOTHESIS: The rate of second anterior cruciate ligament (ACL) injury after ACL reconstruction (ACLR) is high and largely variable, with the reported rates varying between 3% and 30%. This high variability may be related to inclusion of data from patients with different ages, sex, graft types, and activity levels. The purpose of this study was to determine the rates of second ACL injuries, graft and contralateral ACL, after ACLR stratified by patients' sex and graft type.

NUMBER OF SUBJECTS: Four thousand nine hundred thirty-four.

MATERIALS/METHODS: A computerized search of MEDLINE, CINAHL, and SPORTDiscus was conducted using combinations of these terms: ACL, ACLR, reinjury, rerupture, revisions, contralateral tear, ipsilateral graft tear, and second injury. Additionally, 4 studies were identified through a hand search of relevant published studies. Twelve studies met the inclusion criteria of this meta-analysis, the corresponding authors were contacted to provide the demographic data and number of graft and contralateral ACL injuries per sex and graft types. Data from 6 articles were used in the analysis of this study with a total number of 4934 patients with ACLR. Modified Downs and Black checklist was used for quality of the included studies. Pooled rates of second ACL injuries were calculated using random-effect proportion meta-analysis (odds ratio [OR]; 95% CI).

RESULTS: The overall rate of second ACL injuries was 10.30% (graft, 5.65%; contralateral, 4.65%). The pooled rate of second ACL injury for men with bone-patellar tendon-bone autograft (BPTB) was 6.9% (graft, 3.8%; contralateral ACL, 3.1%), with pooled OR of 1.21 (95% CI: 0.84,

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1.75; P = .31), while for women with BPTB was 10.62% (graft, 3.96%; contralateral ACL, 6.66%) with pooled OR of 1.82 (95% CI: 1.23, 2.69; P = .0027). The pooled rate of second ACL injury for men with hamstring tendon autograft (HS) was 13.97% (graft, 9.3%; contralateral ACL, 4.7%) with pooled OR of 1.51 (95% CI: 0.95, 2.40; P = .083), while for women with HS was 6.3% (graft, 3.4%; contralateral ACL, 2.9%) with pooled OR was 0.94 (95% CI: 0.57, 1.55; P = .81).
CONCLUSIONS: No differences in the rates of graft and contralateral ACL injuries for men and women with BPTB, however, men with HS autograft demonstrate higher graft injury compared to contralateral ACL injury. Women with BPTB autograft have higher risk of sustaining a second ACL injury to the contralateral ACL after primary reconstruction surgery.
CLINICAL RELEVANCE: The surgical choice of BPTB autograft during the reconstruction surgery is not problematic for the graft rupture in men and women individuals with ACL injury. However, it might be problematic for the contralateral ACL injury as women with BPTB autograft tissues has higher risk of sustaining a contralateral ACL injury after primary ACLR. The HS autograft might not be the optimal choice for men with ACL injury.

SP083

"HIT COUNT" AND UPPER EXTREMITY PERFORMANCE IN NCAA DIVISION I VOLLEYBALL PLAYERS

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PURPOSE/HYPOTHESIS: Volleyball athletes are susceptible to upper extremity (UE) injuries. Monitoring UE workload (ie, pitch counts) is common practice in other sports, along with assessing UE performance. The purpose of this study was to investigate changes in shoulder mobility, strength, and UE pain, along with hit count volume in collegiate female volleyball athletes over a competitive season.
NUMBER OF SUBJECTS: Five healthy Division I female volleyball athletes (mean ± SD age, 19.6 ± 1.1 years).
MATERIALS/METHODS: Perceived hit counts were collected from athletes and 2 volleyball coaches on 2 separate practice days during weeks 1, 7, and 14 of the competitive season, respectively. Athletes provided an estimated hit count for themselves, while coaches provided perceived hit counts for all athletes. Actual hit count was collected from video recording of practices. Dominant shoulder internal (IR) and external rotation (ER) range of motion (ROM) and isometric strength, along with UE pain, were assessed on 5 occasions: baseline, in-season (weeks 1, 7, 14) and postseason (week 22). Paired samples t tests compared mean differences of UE performance measures at several timeframes. Cohen's d was used to determine effect size. Pearson correlations identified relationships between specific variables of interest.
RESULTS: Coaching staff perceived hit counts were significantly associated with actual hit count (r = 0.93-0.98, P<.05), while athlete perceived hit count was moderately correlated (r = 0.64, P = .25). Shoulder IR ROM significantly decreased from baseline to week 14 (P = .03), with a large effect size (d = –1.0). Moderate-large effect sizes were observed for increases in UE pain, shoulder ER ROM, and IR strength over the course of the competitive season (d = 0.8-2.3). Total shoulder ROM was relatively consistent from baseline to week 14 (0.0 ± 10.2; 95% CI: –12.7, 12.7). Shoulder IR strength significantly increased from baseline to week 14 (P = .001), but decreased during 8 weeks of postseason rest (P = .02). ER ROM gains were significantly associated with ER strength loss (r = 0.96, P = .01).
CONCLUSIONS: Perceived hit count volume by coaching staff may be more accurate when compared to volleyball athlete self-report, as measured against actual hit counts through video recording. Athletes experienced increased shoulder IR strength and ER ROM over a competitive season. Despite IR ROM losses, total shoulder ROM remained relatively consistent during the season. Some UE performance measures did not return to baseline values, even after an 8-week period of rest postseason. Monitoring the progression of UE performance measures and hit count volume may have implications for injury prevention and program development.
CLINICAL RELEVANCE: A "hit count" for volleyball athletes is a relatively novel concept in clinical practice. Rehabilitation professionals may monitor UE workload to guide safe return to play and prevent overuse injuries. Several of the in-season UE performance changes observed in volleyball players were similar to those in other overhead athletes.

SP084

FOOT AND ANKLE ELECTROMYOGRAPHIC ACTIVITY DURING COMMON FOOT-STRENGTHENING EXERCISES

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PURPOSE/HYPOTHESIS: Recently, additional attention has been given to strengthening of the lower leg and foot intrinsic muscles in both preventative and rehabilitative arenas noting the importance of the movement and stability of the foot. Foot strengthening is also of interest in athletes and community ambulators alike for preventative or rehabilitative measures. Previous research has examined the activation of intrinsic and extrinsic foot muscles before and after foot strengthening exercises, but there is limited research focused on the relative activation of foot and ankle muscles during common strengthening exercises. Foot muscle exercises have been shown to have an impact on navicular drop and may play a role in influencing foot intrinsic function in static stance and dynamic functional tasks. Foot strengthening has also been found to decrease pain in patients with plantar fasciitis. The purpose of this observational, basic research study was to evaluate intrinsic and extrinsic foot muscle activation during commonly prescribed foot and ankle strengthening exercises.
NUMBER OF SUBJECTS: Sixteen.
MATERIALS/METHODS: A total of 16 participants (5 male, 11 female) were instructed on commonly used foot and ankle exercises and practiced daily during a 2-week training period. The exercises consisted of the following: calf raise, foot dome, toe curl, first toe press, and toe splay. Surface EMG data were collected on the medial gastrocnemius (MG), peroneus longus (PL), tibialis anterior (TA), and abductor hallucis (AH). Average integrated EMG activity of 3 repetitions for each exercise determined as a percentage of peak activation during walking trial.
RESULTS: The calf raise exercise produced the greatest amount of total muscle activation within the investigated exercises. The PL was the most activated muscle in the calf raise and was more active than during walking. TA was most active during foot dome, toe curl, and toe splay. The calf raise exercise produced twice as much summated muscle activity as all other exercises. The AH was most active during the calf raise, toe splay, and first toe press, however, activation was still below that induced during barefoot walking.
CONCLUSIONS: Both extrinsic and intrinsic foot musculature assist to stabilize the medial longitudinal arch. Therefore, exercises to induce changes in the activation and strength of these muscles are common. Despite popularity, the exercises induced lower muscle activation than walking suggesting that these exercises for the most part, do not provide an overload more than barefoot walking. Other authors have exhibited similar findings.
CLINICAL RELEVANCE: Commonly employed exercises designed to strengthen the lower leg and foot intrinsic muscles may not activate muscle activity beyond that of peak muscle activity that occurs during barefoot walking. Their purpose may suggest they serve as a good foundation for neuromuscular reeducation.

SP085

ELECTROMYOGRAPHIC ACTIVITY OF THE HAMSTRING MUSCLES DURING VOLUNTARY ISOMETRIC CONTRACTION PERFORMED AT DIFFERENT INTENSITIES

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PURPOSE/HYPOTHESIS: Exercise-induced muscle damage more frequently occurs in the lower limbs than in the upper limbs. Most cases of lower limb muscle damage occur in the hamstrings. The 3 hamstring muscles each has unique anatomical and contractile properties. Hence, each muscle should be investigated separately. Previous studies on hamstrings investigated the magnitude of contraction of the muscles at different knee angles during maximum voluntary isometric contraction (MVIC). However, no studies have investigated submaximal contraction. The purpose of this study was as follows: (1) to compare the EMG activities of the biceps femoris (BF), semitendinosus (ST), and semimembranosus (SM) with respect to voluntary isometric contractions at different intensities and (2) to compare the functional aspects of the hamstrings before and after submaximal isometric contraction.

NUMBER OF SUBJECTS: Thirty-three.

MATERIALS/METHODS: Subjects (19 men, 14 women; mean ± SD age, 21.46 ± 1.57 years; height, 168.27 ± 9.15 cm; weight, 65.39 ± 14.39 kg) included in this study had decreased hamstring flexibility and active knee extension (AKE) of less than 20°. The contraction strengths in each group were set to MVICs of 60% (P60) and 20% (P20). The subjects were randomly distributed into the groups. Voluntary isometric contractions were performed 5 times for 6 seconds each. By using a surface EMG, muscle activities of the BF, ST, and SM were measured. The subjects were asked to perform vertical jumps before and after the EMG measurement.

RESULTS: Significant differences among the muscle activities of the BF, ST, and SM at P60 and P20 were observed. At P60 and P20, the muscle activities of the BF, ST, and SM were 58.9 ± 28.0 and 35.4 ± 11.4, 61.8 ± 16.0 and 44.9 ± 20.1, and 60.4 ± 19.5 and 40.4 ± 16.2, respectively. Although vertical jump height was significantly decreased after voluntary isometric contraction in the P60 group ($P = .030$), no changes were observed in the P20 group ($P = .162$).

CONCLUSIONS: At the SLR position, the gluteus maximus and hamstring muscles are the primary muscles that carry out hip extension. In the P60 group, all 3 muscles showed a decrease to 38.1% to 41.1% as compared with MVIC. On the other hand, the P20 group showed a decrease to 55.1% to 64.6%. The results indicate that the hamstring muscle activities are preserved at low-intensity voluntary isometric contraction. Although P60 caused a decrease in hamstring function, P20 did not.

CLINICAL RELEVANCE: To selectively activate hamstring muscles among the hip extensors, low-intensity isometric contraction would be helpful. Furthermore, when proprioceptive neuromuscular facilitation stretching, also called isometric contraction, is performed on the lower extremity to increase its flexibility, low-intensity hamstring contraction could be a wise choice, as it does not cause decreased muscular functions.

SPO86

A LONGITUDINAL ANALYSIS OF CONCUSSION INCIDENCE IN INTRAMURAL COLLEGIATE ATHLETICS

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PURPOSE/HYPOTHESIS: Concussions have been a major topic of interest in the sports medicine community in recent years due to the consequences associated with the injury and the complexity and evolution of management of athletes post concussive incident. Many organizations at multiple levels of competition now have developed infrastructures and procedures in place for comprehensive management. Many studies have been conducted examining incidence and relative risk within these professional, semi-professional, or intercollegiate organizations. However, no studies have been conducted to examine concussion incidence in intramural collegiate sports, where there is often high participation with minimal oversight by sports medicine professionals. Thus, the purpose of this study is to examine the concussion incidence among various sports in intramural athletics at a large university in the southeastern over a 10-year period.

NUMBER OF SUBJECTS: One thousand seven hundred forty-four.

MATERIALS/METHODS: A retrospective analysis of concussion was conducted through examination of the injury database for collegiate intramural sports, as maintained by an athletic trainer from 2008 to 2017. All data within the reports were coded, which included sport, sex, suspected concussive incident, etc. "Concussive incident" was coded for injuries in which the report specifically stated suspicion of a concussion, or if the athlete sustained an impact or injury to the head area and had associated symptoms (dizziness, blurred vision, etc). Risk ratios and confidence intervals were calculated to identify incidence of concussive injury in 1 sport compared to others. Chi-square statistic was calculated to determine statistical significance of the risk.

RESULTS: Upon analysis of the 1744 injury reports, 115 concussive incidents were identified, constituting 6.59% of injuries. Rugby possessed the greatest percentage of injuries that were suspected concussions (18.2%), followed by lacrosse (13.1%), softball (10.8%), soccer (9.0%), and volleyball (8.8%). Basketball represented the competitive sport with the lowest percentage (2.5%). Two sports were found to possess significantly greater risk of concussive injury: Soccer participants possessed a 1.50 times greater incidence (CI: 1.01, 2.23; $\chi^2 = 4.07$, $P = .04$), and rugby players possessed 2.89 times greater incidence (CI: 1.50, 5.55; $\chi^2 = 9.84$, $P = .002$) compared to other sports, while 1 sport, basketball, resulted in 67.3% reduced likelihood of having a concussive injury compared to other sports (RR = 0.327; CI: 0.17, 0.60; $P<.001$).

CONCLUSIONS: This study supports the notion that intramural athletics results in similar patterns of incidence and risk of concussion as formal competitive sports in the collegiate population.

CLINICAL RELEVANCE: While organized sports possess formal structures for identification and management of concussion, others that are more recreational in nature open athletes up to risk. Institutions that promote recreational sports in intramural mechanisms should strongly consider supporting adequate coverage of the athletic venue with sports medicine professionals.

SPO87

CLOSED-KINETIC-CHAIN VERSUS OPEN-KINETIC-CHAIN PLYOMETRICS IN THE UPPER EXTREMITY: A RANDOMIZED CONTROLLED TRIAL

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PURPOSE/HYPOTHESIS: The purpose was to identify the effectiveness of a 6-week training program on upper extremity power and dynamic stability using closed kinetic chain (CKC) versus open kinetic chain (OKC) plyometrics. There is limited literature on the impact of plyometric exercises in the upper extremity, therefore, this study was conducted to strengthen the understanding of exercise prescription. Our hypothesis stated the CKC plyometrics will demonstrate significant improvement in the selected outcome measures compared to the OKC and control group (CG).

NUMBER OF SUBJECTS: Thirty-one.

MATERIALS/METHODS: Thirty-one subjects between the ages of 18 and 35 years (15 men) who were considered physically active by the American College of Sport Medicine (ACSM) guidelines completed the study. The subjects were randomly allocated by computer generated numbers into a CG, a CKC group and an OKC group. The CG was instructed to maintain their current fitness routine. The CKC group involved progressive plyometric push up variations which have the extremities fixed on a surface. The OKC group included dynamic plyometric bench press exercises in

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the Smith squat rack, where the extremities were not fixed on a surface. Both groups trained 2 times per week for 6 weeks at 6 to 8 on the OMNI Resistance Exercise Scale. All 3 groups were pretested and posttested using the CKC upper extremity stability test (CKCUEST) and a seated shot put test (SSP).

RESULTS: The CKCUEST data Analysis of Variance (ANOVA) only showed there was a statistically significant interaction for the within-subjects effects time score ($F_{1,28}$ = 40.017, P<.001; effect size, 0.588). The right hand and left hand SSP ANOVA were not statistically significant. When comparing the results to the minimally detectable change (MDC), males in the CKC group and both the males and females in the OKC group surpassed the MDC value for the CKCUEST. None of the groups met the MDC values for the SSP. However, all 3 groups surpassed the normative data for the SSP before training began.

CONCLUSIONS: These findings are not consistent with our hypothesis that CKC plyometrics are significantly more effective than OKC plyometrics in improving our selected outcome measures.

CLINICAL RELEVANCE: Plyometrics can be used to improve power and dynamic stability of the upper extremity during the terminal stages of rehabilitation for those requiring a return to high level of activity. This study contributes to the understanding of the impact of using CKC compared to OKC plyometrics when prescribing exercise and provides a foundation for future research on the topic.

SPO88

INVESTIGATION OF AN 8-WEEK NEUROMUSCULAR TRAINING INTERVENTION ON BIOMECHANICAL PARAMETERS OF THE LOWER QUARTER IN COLLEGIATE PIVOTING ATHLETES

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PURPOSE/HYPOTHESIS: Rising evidence has influenced the efficacy of neuromuscular training (NMT) to improve biomechanics related to anterior cruciate ligament (ACL) injury during change of direction movements specific to collegiate athletics in pivoting populations, and the role that fatigue plays in increasing potential trauma. However, there is a lack of literature examining the ability of NMT interventions to reduce high-risk movement behavior during a fatigue state. This investigation examined strength, dynamic balance, and lower quarter biomechanics during functional movement assessments following a short-term fatigue protocol in collegiate athletes before and after an 8-week NMT intervention.

NUMBER OF SUBJECTS: Twenty-three.

MATERIALS/METHODS: Twenty-three Division II NCAA male and female soccer players aged 18 to 23 years participated in the study. Hip strength was measured with hand dynamometry, and single-leg stance modified balance (SLSM) was measured with eyes shut and in static heel rise conditions. The Noraxon MyoMotion system assessed peak hip and knee excursion in 3 dimensions during select movement assessments following execution of the functional agility short-term fatigue protocol. Training consisted of 16 NMT sessions, performed over 8 weeks, following which the tests were repeated.

RESULTS: Significant improvements postintervention were found in hip abduction strength R (P<.001) and L (P = .001), hip extension strength R (P = .001) and L (P<.001); SLSM with eyes-closed on R (P<.001) and L (P = .001); SLSM with heel rise bilaterally (P<.001) peak ROM for R hip internal rotation (P = .001), R knee flexion (P = .017), L knee flexion (P = .005), and L knee abduction (P = .005) during single-leg squat; peak ROM for L knee abduction (P = .019); and peak ROM for L knee flexion (P = .002) during single-leg hop assessment.

CONCLUSIONS: After the intervention, proximal hip strength, dynamic balance, and functional loading significantly improved, indicating positive neuromuscular adaptations in the lower limbs. The MyoMotion system identified improved kinematics during single-leg squat, bilateral hop, and single-leg hop under fatigued conditions. The findings support the hypotheses of NMT to positively influence the lower limbs biomechanical profiles of collegiate pivoting athletes and can improve performance that promotes resilience during states of fatigue in this population.

CLINICAL RELEVANCE: The link between high-risk movement behavior, ACL pathomechanics, and elevated risk for injury of pivoting athletes in a fatigued state is clear. The present study supports the premise that motion analysis can be used to quantify dysfunctional biomechanical traits of motion in the lower quarter, and offers evidence that NMT interventions can lower risk for injury collegiate athletes by improving motor control and functional resilience during dynamic closed-kinetic-chain loading under conditions of fatigue.

SPO89

AN ACCELEROMETRY-BASED RUNNING WATCH IS A VALID SURROGATE FOR MEASUREMENT OF LEG AND VERTICAL STIFFNESS DURING RUNNING

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PURPOSE/HYPOTHESIS: Leg stiffness (Kleg) and vertical stiffness (Kvert) relate to running economy and are lower in runners who are fatigued, older, or who have Achilles tendinopathy. To date, assessment of Kleg and Kvert during running is confined to laboratories, requiring force platforms to accurately assess. Global positioning system (GPS) running watches equipped with accelerometer technology may provide valid assessment of certain biomechanics, such as contact and flight time, necessary to calculate Kleg and Kvert. We sought to validate a GPS running watch equipped with a chest-mounted accelerometer for the calculation of Kleg and Kvert during running.

NUMBER OF SUBJECTS: Eighteen healthy, well-trained runners (9 male, 9 female; 9 nonrearfoot strikers; mean ± SD age, 26.0 ± 4.4 years; 54.2 ± 29.9 km/wk; routine training pace, 3.4 ± 0.3 m/s).

MATERIALS/METHODS: Trials were completed in a counterbalanced order (2.6, 3.3, 3.6, 4.0 m/s and routine training pace) while data were sampled simultaneously for 60 seconds via a force plate embedded treadmill (gold standard) and a Garmin 735xt running watch equipped with a chest-mounted accelerometer. Cadence, contact time and flight time were calculated from ground reaction force data from the treadmill and extracted from the accelerometer-derived data from the running watch. Flight time was not provided by the Garmin but was derived by subtracting contact time from step frequency in the Garmin data. These values, along with running speed, body mass and leg length, were used in previously validated formulas using the sine wave method to determine Kleg and Kvert. Criterion validity was assessed via mean absolute error bias (expressed as percent) and linear regression (expressed as R^2) with α = .05.

RESULTS: Compared with the gold standard treadmill, the running watch had excellent relationships and error biases that ranged from trivial to small for cadence (mean error bias, 0.2% ± 0.3%; R^2 = 0.99, P≤.001), contact time (mean error bias, 1.7% ± 4.3%; R^2 = 0.85, P≤.001) and flight time (mean error bias, −7.2% ± 17.4%; R^2 = 0.84, P≤.001). Subsequent calculations of Kleg (mean error bias, −5.2% ± 12.6%; R^2 = 0.81, P≤.001) and Kvert (mean error bias, −4.8% ± 11.6%; R^2 = 0.85, P≤.001) also yielded small biases.

CONCLUSIONS: These data indicate that an accelerometer-equipped running watch is a valid assessment of Kleg and Kvert across running speeds in well-trained runners. Further study is necessary to validate the running watch's validity of Kleg and Kvert during running on varying surfaces and in runners who are fatigued, older or with Achilles tendinopathy.

CLINICAL RELEVANCE: The Garmin 735xt and accelerometer chest strap provide a valid tool to assess several key running variables, most notably Kleg and Kvert. This technology allows for quantification of running biomechanics that relate to fatigue, aging or pathology during in the field runs

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or during clinic-based gait analysis. Furthermore, this technology provides the means to monitor biomechanical response to progressive return to running programs rather than more traditional metrics, such as running distance.

SP090

REPEATABILITY OF UPPER EXTREMITY SWAY MEASURES IN WEIGHT BEARING

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PURPOSE/HYPOTHESIS: Analysis of upper extremity weight bearing ability is important for athletes as some function largely in a closed chain capacity (eg, wrestling, football, gymnastics), but also, all require closed chain upper extremity function during strength and conditioning. Additionally, in a rehabilitation setting, closed chain upper extremity functional testing is often used as a return to play criterion. Lower extremity sway measures (biomechanical and clinical) have been published widely and have established reliability and validity; however, the reliability of upper extremity sway biomechanical measures have not been investigated to date. The purpose of this study is to determine the reliability of upper extremity sway measures in weight-bearing in a collegiate athlete population.

NUMBER OF SUBJECTS: Four hundred ninety healthy Division I athletes were tested for both their dominant and nondominant upper extremity at 1 of 2 testing sessions (980 limbs).

MATERIALS/METHODS: All data were collected using a force plate system with commercially available software (SpartraTrac). Subjects were instructed to stay as still as possible while maintaining a full plank position with 1 upper extremity on the force plate and the contralateral upper extremity behind their back. Two 20-second trials were performed for each extremity. Variables measured were average sway velocity (ASV), sway velocity in medial-to-lateral (SVML) and anterior-to-posterior (SVAP) directions, sway velocity at first and second time intervals for AP (VAP1 and 2) and ML (VML1 and 2) directions, and sway frequency in the ML direction for first and second time intervals (FreML1 and 2). Intraclass correlation coefficients ($ICC_{2,1}$) and their 95% confident intervals were calculated using SPSS Version 25 (SPSS Inc, Chicago, IL) based on a mean-rating ($\kappa = 2$), absolute-agreement, 1-way mixed-effects model, for all force plate variables.

RESULTS: No difference was seen between left and right extremities for any measure ($P<.05$). ICCs ranged from 0.61 to 0.90 for all variables, indicating moderate to excellent reliability for all variables.

CONCLUSIONS: Upper extremity sway biomechanical variables using a force plate system have moderate to excellent reliability.

CLINICAL RELEVANCE: These results are important prior to validation and clinical utilization of these measures including baseline testing, return to play guidelines, and injury prevention parameters.

SP091

DECREASED TRUNK STRENGTH AND ALTERED BALANCE PERFORMANCE IN MARINES WITH CHRONIC LOW BACK PAIN

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PURPOSE/HYPOTHESIS: Chronic low back pain (LBP) is a common injury of many military occupations which often require high physical demands and heavy load carriage. Typically, individuals with LBP demonstrate a range of physical compromises including reduced trunk and lower extremity (LE) strength and balance. Despite injury, military personnel often maintain high operational levels masking potential deficits. Even minor alterations in capabilities could have significant impact on performance, safety, and injury risk in highly demanding environments. Therefore, this study aims to identify deficits in strength and dynamic balance in fully operational Marines with chronic LBP compared to healthy-matched controls.

NUMBER OF SUBJECTS: Sixty total Marines: 20 full-duty male Marines with chronic, current LBP (cLBP; mean ± SD age, 30.60 ± 4.38 years; height, 1.77 ± 0.06 m; mass, 86.80 ± 7.97 kg) and 40 matched healthy Marines with no history of LBP and no LE injury within 1 year (CON; age, 28.71 ± 4.37 years; height, 1.79 ± 0.06 m; mass, 84.85 ± 7.75 kg).

MATERIALS/METHODS: Participants completed evaluations of isokinetic knee and torso flexion and extension strength (KF, KE, TF, TE) at 60°/s and dynamic postural stability during a forward jump single leg landing task. Variability in ground reaction forces (1200 Hz) in the anterior-to-posterior (APSI), medial-to-lateral (MLSI), and vertical (VSI) directions, as well as an overall dynamic postural stability index (DPSI) were calculated during the first 3 seconds following landing on a force plate. Independent-samples t tests or Mann-Whitney U tests were used to assess between group differences ($P<.05$). Effect sizes (Cohen's d) were also calculated.

RESULTS: cLBP demonstrated significantly lower TE strength compared to CON (3.88 ± 0.65 versus 4.21 ± 0.67 Nm/kg, $P = .03$, $d = 0.57$). On the dominant side, cLBP demonstrated lower APSI (0.12 ± 0.03 versus 0.15 ± 0.01 N, $P<.001$, $d = 1.36$) and DPSI (0.035 ± 0.03 versus 0.37 ± 0.03 N, $P = .04$, $d = 0.58$) compared to CON indicating improved stability.

CONCLUSIONS: Despite high overall trunk strength, cLBP demonstrated a 12.2% deficit in TE strength compared to CON. Reduced APSI and therefore overall DPSI demonstrated by cLBP compared to CON on the dominant side may be surprising as most studies have found poorer balance in individuals with LBP. However, on a complex task such as used in this study, decreased APSI may suggest stiffening of the trunk. Previous studies propose altered trunk muscle activation patterns found in individuals with LBP as a possible reason for decreased anterior posterior shear force and trunk displacement during balance tasks.

CLINICAL RELEVANCE: Addressing TE strength in cLBP military patients may be particularly important given the high physical demands and load carriage of many occupations. While further research is needed to understand if changes in strength and dynamic postural stability are predispositions to injury and/or compensations, in highly active individuals with cLBP evaluation of movement and balance during dynamic tasks may further inform treatment and recovery.

SP092

DECREASED PEAK LOWER EXTREMITY FLEXION AND KNEE EXCURSION NEGATIVELY AFFECT HOP PERFORMANCE BUT NOT PERCEIVED FUNCTION IN ATHLETES POST ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: The purpose of this study was to determine whether the sagittal plane kinematics during take-off were different (1) between athletes' limbs post ACLR and (2) from healthy controls. The hypotheses tested were that peak lower extremity flexion (PLEF) and knee excursion would be lowest in the reconstructed limb and associated with increased fear, lower self-reported function, and shorter hop distance.

NUMBER OF SUBJECTS: Seventeen athletes who completed criterion-based rehabilitation post ACLR (ACLR group; 10 female; mean ± SD age, 19.8 ± 5.6 years; Tegner, 8.4 ± 4.0) and 17 healthy control athletes (HC; 10 female; age, 24.5 ± 2.4 years; Tegner, 6.5 ± 0.9).

MATERIALS/METHODS: Three-dimensional motion analysis was used to capture sagittal plane kinematics during the SLH. Peak lower extremity flexion

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(PLEF) and knee excursion were calculated during the take-off phase. Hop distance was normalized to athlete height (meters). The comparative 'involved' limb of the HC group was randomly selected. Athletes post ACLR also completed the ACL-Return to Sport after Injury (ACL-RSI) and the International Knee Documentation Committee Subjective Knee Form (IKDC). Generalized estimating equations models were used to test group-by-limb interactions; post hoc *t* tests were used to determine where differences existed ($\alpha = .05$). Pearson's, and Spearman rank correlations where appropriate, were used to evaluate relationships between survey data and kinematic variables of the involved limb.

RESULTS: LSI was not different between groups ($P = .16$). There were significant group-by-limb interactions for SLH distance ($P = .04$), PLEF ($P = .01$), and knee excursion ($P<.01$). SLH distance was an average of 11.8% shorter on the involved limb of the ACLR group compared to their uninvolved limb ($P = .03$) and 11.5% shorter than HCs ($P = .03$). PLEF of the involved limb of the ACLR group was not different from their uninvolved limb ($P = .19$), but was an average of 13.0° less than that of HCs ($P = .01$). Knee excursion of the involved limb of the ACLR group was not different from their uninvolved limb ($P = .25$), but was an average of 8.8° less than that of HCs ($P<.01$). Decreased excursion of the involved knee was associated with decreased PLEF ($r = 0.72$, $P<.01$) and shorter SLH distance ($r = 0.68$, $P<.01$). Neither PLEF nor knee excursion were associated with IKDC ($P\leq.39$, $P = .12$) or ACL-RSI ($r\leq0.35$, $P = .17$).

CONCLUSIONS: PLEF and knee excursion during the take-off phase of the SLH were significantly reduced in the involved limb of the ACLR group compared to their uninvolved limb and the limbs of HCs. Deficits in PLEF and knee excursion were associated with decreased hop performance, but not self-reported fear or knee function.

CLINICAL RELEVANCE: Decreased lower extremity flexion and knee excursion in athletes at return to sport post ACLR may impair hop performance. For some athletes, heightened fear of reinjury or decreased confidence may also be associated with altered hop kinematics. This relationship should be evaluated in larger, prospective ACLR cohorts.

SPO93

THE EFFECT OF INCREASED RUNNING SPEED ON FRONTAL PLANE KINETICS IN FEMALE RUNNERS WITH STRONG AND WEAK HIP ABDUCTORS

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PURPOSE/HYPOTHESIS: Hip abductor strength has been identified as a key contributor to lower extremity frontal plane control during running. The forces exerted on the hip and the counteracting muscle forces may change with running speed, but there is little research describing the influence of speed on frontal plane mechanics. The purpose of this study was to determine if there are changes in hip kinetics in subjects with strong and weak hip abductors while running at "slow" and "faster" speeds.

NUMBER OF SUBJECTS: Fourteen.

MATERIALS/METHODS: Fourteen female runners from a larger study were identified as having a preferred pace greater than 5% faster than the fixed data collection pace of 2.7 m/s. These runners were separated into Strong (n = 8) and Weak (n = 6) groups based on gluteus medius strength measured isometrically using a handheld dynamometer. Three-dimensional gait analysis was performed on a treadmill at 2.7 m/s and at the faster preferred pace for all subjects, which range from 2.95 m/s to 3.35 m/s. *t* tests were performed to identify any significant differences between frontal plane kinetic factors in both the strong and weak groups the matched pace and the subject's preferred pace.

RESULTS: No significant differences were identified in the strong subject group between slow and faster running speeds. Average peak negative hip abduction power decreased in magnitude by 0.97 J/s ($P = .04$) and average impulse decreased by 0.08 Nm ($P = .03$) in the weak group at an increased speed.

CONCLUSIONS: The change in hip kinetics with an increase in running speed in weaker runners suggests that lower extremity frontal plane running mechanics vary with speed in subjects with weak hip abductors. Clinically, it may be important to test runners at speeds higher and lower than a runners preferred pace during gait analysis to evaluate the role of hip strength in running mechanics.

CLINICAL RELEVANCE: Gait analysis is an important part of any physical therapy practice and can help guide a plan of care or identify future injury risk. It is crucial that physical therapists complete a comprehensive gait analysis with their patients in order to provide optimal care. This study highlights the importance of utilizing multiple running speeds during gait analysis; specifically, to identify abnormalities in frontal plane running mechanics due to gluteus medius weakness that may only be present at certain speeds. By identifying deviations in proper running mechanics at the hip, physical therapists can clarify the etiology of or properly diagnose running related injury.

SPO94

THE EFFECT OF GAIT RETRAINING ON ACHILLES TENDINOPATHY

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BACKGROUND AND PURPOSE: Recent literature emphasizes adequate cadence and step length in addressing overuse injuries from running by modulating the rate and location of load on the lower extremity. Amateur runners typically present with a slow cadence and gait retraining using external cues can improve symptoms by increasing cadence. Achilles tendon pain is a common problem and runners that wear minimalist shoes or run on their forefoot may be at increased risk for Achilles tendinopathy. This case study presents an effective treatment approach that includes reducing running cadence, shoe modification, eccentric loading, and running drills to return a runner to pain-free running.

CASE DESCRIPTION: A 29-year-old male runner presented with 3 months of mid-substance left Achilles tendon pain after increasing his running volume to 10 miles a week. He also reported a history of plantar fascia pain when running in college that did not resolve for 2 years. Previous treatment included self-stretching and foam rolling of the calf muscle. He was diagnosed with Achilles tendinopathy by the referring physician 4 weeks ago and told to stop running. He reported at that time that prior to developing Achilles tendon pain, he transitioned to minimalist running shoes and purposefully increased his cadence.

OUTCOMES: Evaluation revealed a cadence of 190 steps per minute with a forefoot landing pattern and excess knee flexion throughout stance phases of running. Foot and ankle assessment demonstrated tenderness to palpation of left Achilles tendon, positive arc sign, positive royal London hospital test, reduced ankle dorsiflexion bilaterally, reduced great toe extension, and increased forefoot supination. Calf girth was 2 cm smaller on the left than the right and he could only perform 10 single-leg calf raises on the left compared to 25 on the right. Hip and core assessment did not demonstrate asymmetry. Initial treatment included visual feedback on gait mechanics, use of a metronome to adjust cadence, verbal cues to improve trunk position, running drills to promote proper landing pattern, and eccentric calf strengthening. The patient was also advised to consider running in shoes that had a slight heel drop to offload his Achilles tendon. After 5 visits over a 6-week period the patient was able to run 15 miles a week without any Achilles pain and demonstrated improved gait mechanics with midfoot strike pattern and a cadence of 180 steps per minute.

DISCUSSION: Achilles tendinopathy has been shown to respond to progressive loading, theoretically strengthening the tendon and reducing pain with activity. This case illustrates the importance of analyzing running gait to determine the most beneficial intervention for runners. Tendon loading may improve tendon strength, but addressing gait mechanics ultimately ensures reduced load at the injured tissue and allows the patient to continue running while performing exercises to address the tendon. This case

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study demonstrates a unique approach to gait analysis and retraining to reduce load at a specific tissue, thus enabling a return to pain-free running.

SPO95

HIP EXTENSOR STRENGTH IS NOT DIFFERENT IN RECREATIONAL FEMALE RUNNERS WITH HIGH AND LOW AVERAGE VERTICAL LOADING RATES DURING RUNNING

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PURPOSE/HYPOTHESIS: Higher average vertical loading rate (AVLR) of the ground reaction force (GRF) while running have been associated with an increased risk of overuse injuries. Additionally, hip extensor strength has been associated with improved running mechanics at the trunk. It is not well understood if maximum hip extensor strength (MHES) differs between individuals with high or low AVLR during running. The purpose of this study was to determine if MHES differed between women with either high or low AVLR during running. We hypothesized MHES would be similar between groups.

NUMBER OF SUBJECTS: Twenty-four.

MATERIALS/METHODS: Twenty-four novice uninjured female runners with a rearfoot strike pattern during running participated in this cross-sectional study. Twelve participants were in the low AVLR group (mean ± SD age, 20.9 ± 1.5 years; height, 1.66 ± 0.06 m; weight, 64.5 ± 16.6 kg) and 12 participants were in the high AVLR group (age, 21.2 ± 2.1 years; height, 1.62 ± 0.05 m; weight, 60.8 ± 7.4 kg). Participants gave written informed consent prior to participating in the study. Participants ran at a prescribed speed of 3 m/s on a force plate instrumented treadmill (Treadmetrix). After the running trial, MHES was measured concentrically (CON), eccentrically (ECC) using an isokinetic dynamometer at 60°/s (Humac, CSMi) and isometrically using a handheld dynamometer. Vertical GRF were low pass filtered at 25 Hz with a fourth order Butterworth filter. Foot strike and toe off events were identified when GRF exceeded 20 N. AVLR was calculated as the slope of the line between 20% and 80% from foot strike to both the impact peak and 13% of stance phase. Peak torque and force values from the isokinetic and handheld dynamometer were extracted. All variables were normalized by body weight for statistical analysis. Participants were split into high and low AVLR groups using 60 $BW \cdot s^{-1}$ as the cutoff. A 1-way ANOVA was then used to analyze the relationship between AVLR and leg-matched MHES variables.

RESULTS: Groups had different AVLR (high, 68.8 ± 9.0 $BW \cdot s^{-1}$; low, 44.9 ± 10.0 $BW \cdot s^{-1}$; $P<.001$) but similar MHES: peak CON torque was 2.56 ± 0.71 $Nm \cdot kg^{-1}$ for the low AVLR and 2.45 ± 0.53 $Nm \cdot kg^{-1}$ for high AVLR ($P = .66$); Peak ECC torque was 2.97 ± 0.61 $Nm \cdot kg^{-1}$ for low AVLR and 2.85 ± 0.63 $Nm \cdot kg^{-1}$ for high AVLR ($P = .66$); peak isometric force was 0.65% ± 0.21% BW for low AVLR and 0.67% ± 0.17% BW for high AVLR ($P = .5$).

CONCLUSIONS: MHES did not differ between high and low AVLR groups. This is consistent with previous literature that found lower extremity running mechanics were not changed with different levels of hip abduction and external rotation strength. However, gait retraining was able to lower the AVLR during running in a prior study. More research is needed to examine the relationship MHES plays altering running mechanics in gait retrained individuals.

CLINICAL RELEVANCE: Hip extensor strengthening alone may not influence AVLR. Gait retraining focusing on hip musculature activation may be a more appropriate intervention.

SPO96

TRUNK ABDOMINAL STRENGTH/ENDURANCE CORRELATES WITH FUNCTIONAL HOP TEST PERFORMANCE

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PURPOSE/HYPOTHESIS: For both injury prevention and return to sport criteria, trunk stability and the functional strength and power of the lower limbs are necessary for athletes. Impairments and asymmetrical performance can have both injury and performance implications. Side plank tests and hop tests can be used as part of both preseason assessments and return-to-sport (RTS) criteria. The purpose of this study was to test the association between performance on trunk stability and hop tests. A secondary aim was to investigate the relationship between performance asymmetry on hop tests.

NUMBER OF SUBJECTS: Twenty-five.

MATERIALS/METHODS: Study design was a cross-sectional study A convenience sample of active, healthy, subjects (6 male, 19 female; mean ± SD age, 25.36 ± 2.82 years; height, 168.1 ± 10.5 cm; weight, 68.1 ± 12.3 kg; BMI, 24.1 ± 2.9 kg/m^2) were included. Outcome measures: Maximal effort side plank (seconds) was used to measure the lateral trunk strength/endurance bilaterally. Dominance was self-reported based on handedness. Single hop (sHop), triple hop (tHop), and crossover hop (cHop) for distance (cm) were used as functional performance measures. All subjects completed 3 trials per leg for each hop test. The average of the 2 best scores was recorded. Pearson correlation analysis was used to determine correlation and symmetry of trunk and hop test performance.

RESULTS: Hop performance is related to trunk strength/endurance/performance. Dominant Plank is related to Dominant sHop ($r = 0.41$, $P = .04$), Dominant tHop ($r = 0.47$, $P = .02$), Dominant cHop ($r = 0.52$, $P = .008$), Contralateral cHop ($r = 0.50$, $P = .01$), Contralateral tHop ($r = 0.54$, $P = .006$). Contralateral Plank is related to Contralateral tHop ($r = 0.44$, $P = .03$). Asymmetry between cHop and tHop performance is related ($r = 0.52$, $P = .008$).

CONCLUSIONS: Hop performance is related to trunk strength/endurance/performance. Limb performance asymmetry is related. Asymmetry in trunk/core and hop performance may have injury and performance implications for athletes. Previous studies demonstrated abdominal strength corresponds with single-leg balance measures, but research is limited in associating trunk strength/endurance to hop test performance. Further research is needed to determine the effectiveness of using trunk strength/endurance and hop test performance as a screening tool for preseason assessment and RTS criteria.

CLINICAL RELEVANCE: It is important to identify possible modifiable risk factors in athletes. Impairments in strength, endurance, stability, power, are considered modifiable risk factors. Asymmetry in functional (core and hop) performance may have injury and performance implications for athletes. Additional research is needed to further identify the relationship between impairments and injury risk in athletes.

SPO97

HIP AND LUMBAR STRENGTH AND CONTROL TRAINING FOR SWIMMERS WITH SHOULDER PAIN

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BACKGROUND AND PURPOSE: Shoulders are the most commonly injured body part in swimmers, especially between the ages of 15 and 22 years old. Fifty-one percent of teenage swimmers have shoulder pain while training. Swimming requires use of the upper and lower extremities and trunk simultaneously, creating the need for shoulder pain in swimmers to be analyzed in relation to the entire kinetic chain, including the trunk and hips. Similarities between throwing athletes and swimmers' biomechanics and kinetic chain recruitment to transfer power between the upper and lower extremities suggest that deficits in trunk, hip, and leg strength and motor control may contribute to the development and

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persistence of shoulder pain in swimmers as it does in throwing athletes. Current evidence-based treatment of shoulder pain in swimmers involves neuromuscular re-education and proximal muscle strength and control; however, a specific progression for hip and lumbar strengthening and control training for swimmers has not been established. The purpose of this case series is to report on a more comprehensive approach to treating swimmers' shoulder injuries by including specific interventions targeting the hips and lumbar spine in addition to the current evidence-based shoulder treatment.

CASE DESCRIPTION: Four adolescent swimmers between the ages of 14 and 17 years old were treated in an outpatient physical therapy clinic for shoulder pain. Examination included shoulder and hip rotation range of motion, thoracic rotation and lumbar extension quality of movement, upper and lower extremity reflexes, and scapular quality of movement. All patients completed self-reported outcome measures, including Focus On Therapeutic Outcomes (FOTO) and the numeric pain-rating scale (NPRS), at evaluation and discharge. Patients participated in individualized treatment sessions that addressed their deficits using current evidence-based shoulder treatment and a stepwise progression of hip and lumbar treatment. Exercises were started in isolated planes of motion (sagittal, frontal, and transverse) and were progressed to combined, multiplanar movements for functional application as patients demonstrated adequate strength and motor control. All exercises initially focused on muscle endurance and motor learning and progressed to hypertrophy training.

OUTCOMES: Hip and shoulder rotation returned to full range of motion, and quality of scapular, thoracic, and lumbar mobility demonstrated increased motor control in all patients. Pain decreased to 0/10 in all patients, and all returned to full swim practice and competition without pain. FOTO scores show that all patients exceeded their predicted functional outcomes by 3% to 21%.

DISCUSSION: The results of this case series suggest that a comprehensive approach to a swimmer's shoulder pain through treatment of the lumbar spine and hips may assist with improving function and returning to sport. Future studies, including randomized control trials, are needed to determine effectiveness compared to shoulder treatment alone.

SP098

ACCURACY OF CLINICAL AND IMAGING TESTS FOR THE DIAGNOSIS OF HIP DYSPLASIA AND INSTABILITY: A SYSTEMATIC REVIEW

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PURPOSE/HYPOTHESIS: Evidence concerning the accurate clinical or imaging methods to diagnose hip instability or hip dysplasia is currently scarce. The purpose of this review is to summarize the diagnostic accuracy of clinical and imaging tests for the diagnosis of hip dysplasia and instability.

NUMBER OF SUBJECTS: Nine hundred sixty-five subjects (mean age, 33.8 years) across 7 studies.

MATERIALS/METHODS: A computer-assisted literature search of MEDLINE, CINAHL, and Embase databases using keywords related to diagnostic accuracy of the hip joint was conducted on March 6, 2018. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses of Diagnostic Test Accuracy Studies (PRISMA-DTA) guidelines was used for the search and reporting phases of the study. Quality assessment of bias and applicability was conducted using the Quality of Diagnostic Accuracy Studies tool (QUADAS). Diagnostic accuracy, including sensitivities (SN), specificities (SP), likelihood ratios (+LR and –LR) and 95% confidence intervals (CIs) were summarized.

RESULTS: Out of 3109 citations, 7 articles were included. Two studies reported on 5 clinical tests for hip instability and 5 studies reported on 5 radiographic measures for hip dysplasia. Only 1 study reached high methodological quality. The Prone instability test moderately improved positive posttest probability by 38% to diagnose hip instability. The Shenton line moderately to highly improved posttest probability by 41% to 60% to diagnose hip dysplasia.

CONCLUSIONS: This systematic review summarizes the diagnostic accuracy of various clinical tests and radiographic measures for hip instability and hip dysplasia. The evidence for these hip pathologies need to be strengthened with high-quality diagnostic studies. Consensus is required to standardize definition of these diagnoses and their reference standard.

CLINICAL RELEVANCE: The clinical examination can change the posttest probability of the likelihood of instability existence by a small to substantial degree. Single clinical examination tests can change the posttest probability of the likelihood of instability nonexistence by a minimal to small degree. The radiological examination can change the posttest probability of the likelihood of dysplasia existence by a minimal to large, and often substantial degree. The radiological examination can change the posttest probability of the likelihood of dysplasia nonexistence by a minimal to moderate degree.

SP099

ACCURACY OF THE LEVER SIGN TO DIAGNOSE ANTERIOR CRUCIATE LIGAMENT TEAR: A SYSTEMATIC REVIEW WITH META-ANALYSIS

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PURPOSE/HYPOTHESIS: The Lever Sign has gained recent notoriety for its purported diagnostic accuracy and simplicity of performance. The aim of this systematic review with meta-analysis is to summarize the diagnostic accuracy of the "Lever Sign" to diagnose anterior cruciate ligament tear.

NUMBER OF SUBJECTS: This review included 977 subjects across the 8 studies.

MATERIALS/METHODS: A computer-assisted literature search of MEDLINE, CINAHL, and Embase databases using keywords related to diagnostic accuracy of the knee joint. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used for the search and reporting phases of the study. Quality assessment of bias and applicability was conducted using the Quality of Diagnostic Accuracy Studies (QUADAS). Mixed effects models were used to summarize accuracy.

RESULTS: Eight articles, with only 2 demonstrating high quality, were included. Six articles qualified for meta-analysis. Diagnostic values, utilizing arthroscopy as a gold standard, were: pooled SN, 0.55 (95% CI: 0.22, 0.84); pooled SP, 0.89 (95% CI: 0.44, 0.99); positive likelihood ratio (+LR) = 9.2 (95% CI: 0.70, 46.1); negative likelihood ratio (–LR) = 0.58 (95% CI: 0.18, 1.28). Posttest probability with a positive finding (57% sampling prevalence) reached 92% (95% CI: 83%, 97%). Posttest probability with a negative finding (57% sampling prevalence) reached 43% (95% CI: 39%, 47%).

CONCLUSIONS: Based on limited evidence of heterogeneous methodological quality, the Lever Sign can moderately change posttest probability to rule in or rule out an ACL tear. Our results should be interpreted cautiously due to their basis on a limited number of studies, small sample size and study quality affecting test accuracy. Future investigation should be expanded to high-quality studies examining diverse clinical contexts to enable a more comprehensive clinical application of this test.

CLINICAL RELEVANCE: This test is simple to use and could complement a complete physical examination, specifically in contexts where the traditional tests may be difficult to execute. The evidence for this test remains scarce and further investigation is suggested to better guide clinical use.

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SP0100

DIFFERENCES IN LOWER EXTREMITY KINEMATICS BETWEEN HIGH SCHOOL CROSS-COUNTRY AND YOUNG ADULT RECREATIONAL RUNNERS

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PURPOSE/HYPOTHESIS: Many high school athletes participate in cross-country running every year, with approximately one third of these athletes sustaining running-related injuries that prevent them from participating in their sport. Several researchers have studied running kinematics to assess for age-related kinematic differences that could increase one's risk of experiencing a running-related injury. All of these studies used 3-D motion capture for data collection, which is not as feasible in the clinical setting. No study included high school aged runners as research participants, and, as such, a gap exists in the literature about running kinematics in this portion of the running population. The purpose of this study was to use 2-D video analysis to compare sagittal plane kinematic variables between high school cross-country runners and young adult recreational runners.

NUMBER OF SUBJECTS: Twenty-five high school cross-country runners (13 women, 12 men; mean ± SD age, 15.4 ± 1.3 years) and 25 young adult recreational runners (12 women, 13 men; age, 28.2 ± 4.1 years) participated in the study.

MATERIALS/METHODS: Participants ran shod on a treadmill at their preferred running speed, wearing reflective markers on selected lower extremity landmarks. Video data were recorded using a single high-speed camera at 240 frames per second, and assessment of 7 sagittal plane kinematic variables for each runner was performed by a single experienced rater. A series of *t* tests using an alpha of .01 were used to determine if significant differences existed between left and right extremities and between the high school cross-country and young adult recreational runners for all 7 kinematic variables.

RESULTS: There were no significant differences between left and right extremities. The young adult recreational runners exhibited significantly greater maximum knee flexion at midstance ($t = 2.63$, $P<.005$) and significantly greater vertical excursion of center of mass ($t = 4.64$, $P<.0001$) compared to the high school runners. There was no significant difference between the 2 age groups regarding the 5 other sagittal plane variables.

CONCLUSIONS: The greater maximum knee flexion exhibited in young adult recreational runners when compared to high school cross-country runners may manifest as a strategy to attenuate increased ground reaction forces associated with increased center-of-mass vertical excursion in the young adult runners. The data obtained from 2-D kinematics provided similar information when compared to previous 3-D motion analysis studies, suggesting that 2-D software is an appropriate tool for analyzing running kinematics in clinical settings.

CLINICAL RELEVANCE: Differences in running kinematics were observed between high school and young adult runners. Further research should investigate the possible relationship between running kinematics and injury risk in high school runners. The utilization of 2-D kinematic assessment for running gait analysis in the clinical setting is feasible and more affordable when compared to 3-D kinematic and kinetic analysis.

SP0101

THE IMPACT OF AEROBIC EXERCISE ON ESPORT PERFORMANCE: A NOVEL AND COMPLEX MOTOR LEARNING TASK

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PURPOSE/HYPOTHESIS: Esports, or competitive videogaming, is a growing sport. There are currently over 50 collegiate Esport teams across the US, and professional Esport viewing audiences already rival other professional sports. However, research on Esport performance is sparse. Acute bouts of aerobic exercise (AE) are known to improve acquisition and retention of novel motor tasks. Thus, the purpose of this study was to examine the effect of AE on Esport performance using a single-subject design. We hypothesized moderate aerobic exercise (M-AE) would improve immediate performance with minimal carry over, while intense aerobic exercise (I-AE) would result in long-lasting performance improvement.

NUMBER OF SUBJECTS: The subject was a 36-year-old male video-game player, who played an average of 20 hours per week. He had no prior exposure to the test game for this study.

MATERIALS/METHODS: Esport performance was defined as the number of scored goals in 100 attempts on the popular Esport title Rocket League. Performance was assessed twice weekly, with 1 session occurring immediately after either rest, 25 minutes of M-AE, or 15 minutes of I-AE at 65% or 80% of age predicted maximal heart rate respectively (Figure 1). The second assessment occurred 72 hours after the rest or exercise intervention. The subject was exposed to each condition twice. Physical performance measures of click speed, reaction time, grip strength, pinch grip strength, and hand-eye coordination were also measured at every session.

RESULTS: Large performance gains occurred over the first 3 sessions of baseline and rest conditions which were likely due to a learning effect. Mild gains were noted after the first round of M-AE, followed by a 26% performance increase after the first round of I-AE. The subsequent rest condition resulted in a 23% decrease in scoring. Reintroduction of M-AE resulted in another 22% increase, followed by a 4% increase after the final round of I-AE (Figure 2). Physical performance measures did not change between testing conditions.

CONCLUSIONS: Improvements in scoring were consistently observed during each of the AE conditions. There was a large decrement in performance with the removal of AE for the second rest condition. Therefore, it is likely that AE enhanced performance gains. AE may enhance Esport performance via different processes such as cognitive priming and increased corticomotor excitability which implicate biological and psychological pathways as performance facilitators (Figure 3).

CLINICAL RELEVANCE: These findings suggest AE may be a beneficial tool for the Esport athlete to improve performance. The term "Esport performance" as described in this study is interchangeable with the phrase "novel and complex motor learning task." As an adjunct to physical therapy interventions, it seems the application of AE has vast potential to create a faciliatory environment from which to engage in motor learning tasks with generalizability to numerous populations and settings of physical therapy practice.

SP0102

REHABILITATIVE ULTRASOUND IMAGING OF THE LOWER TRAPEZIUS MUSCLE: INTERRATER RELIABILITY COMPARISON OF 2 MEASUREMENT PROCEDURES

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PURPOSE/HYPOTHESIS: Ultrasound (US) imaging is commonly used to measure muscle thickness in orthopaedic practice and research. An established method to assess thickness of the lower trapezius involves measuring lower trapezius (LT) thickness at a fixed distance from a bony attachment. An alternative method, more consistent with traditional sonographic technique used in internal medicine, is to measure the muscle at the point of maximal thickness in the field of view. The purpose of this study is to determine if 1 of these 2 measurement methods results in higher interrater reliability.

NUMBER OF SUBJECTS: Images from 17 subjects who participated in a LT resistive exercise study were used. Eight images were assessed from each subject, resulting in the analysis of 136 deidentified images.

MATERIALS/METHODS: All images were assessed individually by 2 experienced sonography students. Both raters (R1 and R2) used 2 methods (M1 and

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M2) to obtain measurements on all images. M1 assessed LT thickness by measuring linear distance between the superior and inferior LT borders at a fixed distance of 2.25 cm from the lateral border of the 7th thoracic vertebra spinous process (T7 SP). M2 assessed LT thickness by measuring linear distance between the superior and inferior LT borders using the thickest part of the muscle on an image with the T7 SP in view. A Mindray DP-50 Digital Ultrasound Diagnostic Imaging System with 8.5-MHz linear phase-array transducer set in MSK B mode was used to capture and process images. Interrater reliability between R1 and R2 for M1 was calculated using a 2-way random-effects model with a repeated-measures ANOVA (ICC model 2,1). This procedure was repeated for M2. Descriptive statistics were calculated for M1 and M2 measurements for each group of images. An independent *t* test ($\alpha = .05$) was performed to determine if LT thickness differed depending on measurement method for each group of images.

RESULTS: Both methods demonstrated excellent interrater reliability (M1: $ICC_{2,1} = 0.927$; M2: $ICC_{2,1} = 0.989$). There was no significant difference in LT thickness measurement depending on method (all, $P>.327$).

CONCLUSIONS: These results suggest both methods result in a reliable LT thickness measurement. ICCs greater than 0.90 are generally considered to be excellent. M1 interrater reliability is consistent with previous studies. Although M2 demonstrated a slightly increased thickness, the difference was not significant. The results suggest that while either method is reliable, M2 may be more practical. The M1 procedure required 2 additional steps that demanded time and accuracy. Both R1 and R2 noted the M2 procedure took less time to complete.

CLINICAL RELEVANCE: Although both methods demonstrated excellent reliability, we recommend M2, measuring the thickest portion of the lower trapezius with the spinous process in view. Increased efficiency that results in an ICC = 0.989 indicates a trend toward superior methodology.

SPO103

ECCENTRIC HIP ROTATION STRENGTH IN HEALTHY ADULTS

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PURPOSE/HYPOTHESIS: Hip strength deficits have been show to contribute to increased knee valgus and hip internal rotation. Research investigating hip external rotation strength has primarily utilized handheld dynamometry with isometric strength assessment or concentric isokinetic testing. However, eccentric muscle action of the hip musculature is thought to be important in controlling undesired hip internal rotation and adduction associated with various lower extremity injuries. The purpose of this study was to assess test-retest reliability of isokinetic eccentric hip internal and external rotation strength in healthy young adults.

NUMBER OF SUBJECTS: Thirty-four healthy individuals (17 female, 17 male) participated in the study.

MATERIALS/METHODS: A descriptive laboratory study was conducted. Participants completed 2 isokinetic strength testing sessions. A 5-minute warm-up on a stationary bike was followed by isokinetic testing. With participants positioned prone with the knee of the side to be tested flexed to 90°, eccentric hip internal (IR) and external (ER) rotation strength was assessed through a range of motion from 20° IR to 20° ER at speeds of 60°/s and 180°/s. Five warm-up repetitions were performed followed by 10 repetitions at maximal effort for each test speed. Hip testing order (left versus right) was randomized and reversed at the second session. Additionally, the first test session included completion of the Marx activity questionnaire, height and body-weight measurements, and a determination of participant's dominant lower extremity. Peak torque and total work measurements were assessed for consistency by the intraclass correlation coefficient [ICC] model 2,1. Minimum difference (MD) was calculated as 1.96 × the standard error of measurements × √2. Pearson correlation coefficient was performed to assess the relationship between Marx activity scale scores and measurements of hip strength.

RESULTS: ICCs for both eccentric hip IR and ER peak torque and total work were excellent ranging from 0.91 (IR peak torque at 60°/s and IR total work at 180°/s) to 0.96 (ER peak torque at 180°/s). Standard error of measurements ranged from 3.6 to 5.4 Nm for peak torque and from 62.0 to 80.8 Nm for total work. Minimal difference (MD) values ranged from 9.9 to 15.0 Nm for peak torque. Marx activity scores ranged from zero to 16 (mean, 6.9). Pearson correlation coefficient indicated a fair relationship between Marx activity scores and all measurements of eccentric IR and ER peak torque ($r = 0.33$-0.45) and total work ($r = 0.32$-0.47).

CONCLUSIONS: Eccentric isokinetic dynamometry assessment of hip rotation strength (peak torque and total work) at 60°/s and 180°/s in the prone position is highly reliable in healthy adults.

CLINICAL RELEVANCE: This novel approach to assessment of eccentric isokinetic hip IR and ER strength may serve as a valuable adjunct in the thorough assessment of lower extremity strength. MD values may assist in determining significant muscle performance changes in peak torque.

SPO104

WEARABLE TECHNOLOGY FOR ANALYSIS OF THROWING MOTION IN A CLINICAL SETTING

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PURPOSE/HYPOTHESIS: Changes in shoulder rotation, arm slot, arm velocity, and elbow torque during throwing are associated with injury in upper extremity athletes, but are difficult to quantify clinically. Wearable technology, such as the MotusBASEBALL sleeve, can provide feedback on these variables in real time, but reliability of the device is not well known. The purpose of this study is to explore the within-session reliability of the MotusBASEBALL sleeve in detecting arc of shoulder rotation, arm slot, arm velocity, and elbow torque.

NUMBER OF SUBJECTS: Five.

MATERIALS/METHODS: Five male subjects (age, 26-33 years) completed 4 sets of 5 throws (20 total throws/subject) wearing the MotusBASEBALL sleeve. Subjects were asked to throw at a submaximal level of effort and arm slot which could be replicated for all throws. Between sets, the sleeve was removed and replaced according to manufacturer instructions. The sleeve uses a lightweight inertial measurement unit to measure arm slot and arm rotation relative to the ground, 3-D arm rotational speed, and provides an estimate of elbow varus torque for each throw. Means for each variable were calculated for each set of 5 throws. Intraclass correlation coefficients (ICC) were determined as single measures across all throws (ICCind) and average measures between the 4 sets of 5 throws (ICCpool).

RESULTS: The following individual ICCs were found: shoulder rotation (0.983; 95% CI: 0.951, 0.998), arm velocity (0.979; 95% CI: 0.939, 0.997), arm slot (0.866; 95% CI: 0.683, 0.982), and elbow torque (0.599; 95% CI: 0.321, 0.928). Pooled ICCs were found to be as follows: shoulder rotation (0.998; 95% CI: 0.993, 1.000), arm velocity (0.998; 95% CI: 0.991, 1.000), arm slot (0.986; 95% CI: 0.944, 0.998), and elbow torque (0.862; 95% CI: 0.432, 0.984). Shoulder rotation, arm velocity, and arm slot demonstrated excellent reliability as both single and average measures (ICC>0.90). Elbow torque demonstrated moderate reliability across individual throws, but good reliability across sets (ICC = 0.862).

CONCLUSIONS: Based on this preliminary data, the Motus sleeve provides excellent within-session reliability for measurements of shoulder rotation, arm slot, and arm speed across individual throws or batched throws in amateur subjects. Changes in elbow torque, however, require an average across throws to reliably detect changes. Further research is needed to evaluate the validity of the data collected from the Motus sleeve within a clinical setting.

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CLINICAL RELEVANCE: Wearable technology, such as the Motus sleeve, has the potential to improve immediate clinical decision making. By providing real time feedback on throwing mechanics, a clinician can evaluate the impact of interventions on the rehabilitation of the throwing athlete.

SPO105

GLUTEUS MEDIUS ELECTROMYOGRAPHY DURING BAREFOOT AND SHOD WALKING AND RUNNING

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PURPOSE/HYPOTHESIS: Running continues to be one of the most popular forms of exercise due to its relative ease and low cost. Gluteus medius weakness and/or reduced activation may lead to excessive pelvic drop which has been linked to running injuries in the lower extremities (LE). Research investigating electromyography (EMG) activity of the pelvic musculature during barefoot running is lacking in the literature, giving rise to the purpose of this study. The purpose of this study was to explore EMG activity of the gluteus medius (GM) during barefoot and shod (shoe) walking and running and to analyze differences found. Research hypothesis: EMG activity of the GM will increase during barefoot running (BR) and barefoot walking (BW) activities compared to shod running (SR) and shod walking (SW).

NUMBER OF SUBJECTS: Thirty-nine.

MATERIALS/METHODS: Thirty-nine subjects, 25 female and 14 male, with a mean ± SD age of 22.64 ± 1.4 years, completed 40 to 60 second trials of BW, BR, SW, and SR. The first 20 seconds of each trial were not included during the data analysis to allow for normalization of gait. Surface EMG electrodes were placed over the GM bilaterally through a standardized method. EMG data were collected using an 8 channel Noraxon Telemyo 2400 system during the stance phase of the gait cycle identified via a heel and metatarsal pressure switch. The EMG signals were rectified, smoothed (RMS 50), and then normalized to the respective maximal voluntary contraction prior to analysis.

RESULTS: Statistically significant differences in gluteus medius EMG activity were found between walking barefoot (L, 21.88: R, 24.11) and shod (L, 20.63; R, 21.73) bilaterally. A statistically significant difference in GM EMG activity was also identified during running barefoot (48.23) versus shod (43.30) during left LE stance phase. Statistical significance was not present in right GM during running shod versus barefoot.

CONCLUSIONS: Data illustrate a statistically significant increase in EMG activity of the GM musculature bilaterally in stance phase during walking barefoot compared to walking shod and also increased left GM EMG activity during running barefoot versus shod. Further research including a greater number of participants may strengthen this investigation.

CLINICAL RELEVANCE: This study provides insight into GM muscle activity during barefoot and shod walking and running. Results identified greater EMG activity in the GM musculature during barefoot activity compared to shod. Therefore, inclusion of barefoot activities within rehabilitation interventions may create greater firing of the gluteus medius musculature which may improve pelvic stabilization. Improved pelvic stabilization may reduce stresses placed through the LE kinetic chain; however, further research is needed in this area.

SPO106

MAPPING TENDERNESS TO PALPATION PREDICTS RETURN TO PLAY FOLLOWING ACUTE HAMSTRING STRAIN

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PURPOSE/HYPOTHESIS: Hamstring muscle injuries are among the most common injuries in sprinting sports with little evidence supporting the use of any objective tests, measures, or imaging to help predict return to sports following injury. The purpose of this study is to investigate the predictive value of tenderness to palpation for time to return to play (RTP) following hamstring muscle strain.

NUMBER OF SUBJECTS: Seventeen.

MATERIALS/METHODS: Seventeen male athletes (mean ± SD age, 29 ± 9 years) who sustained an acute hamstring strain underwent hamstring tenderness mapping on initial evaluation while lying prone, consisting of marking the gluteal and popliteal folds with a marker. The point of peak tenderness was identified and marked. The examiner then palpated 1 thumb's width at a time in the medial, lateral, superior, and inferior directions, marking how far the tenderness extended in each direction. A photo image of the posterior thigh including all markings was taken, from which the length of tenderness was calculated as a percentage of the distance from the gluteal fold to the popliteal fold. The width of tenderness was calculated as a percentage of the width of the thigh at the point of peak tenderness. The area of injury was calculated and expressed as a percentage of the area of the posterior thigh. All patients underwent the same hamstring rehabilitation protocol with remapping performed at specific stages in rehabilitation. The association between mapping tenderness indices and time to RTP was assessed by linear regression.

RESULTS: The length of tenderness measured on initial evaluation was a strong predictor of time to RTP (R^2 = 0.72, P<.0001; y = 2.70x – 12.25). Area of injury (R^2 = 0.40, P<.05) and age (R^2 = 0.23, P<.05) were also related to time to RTP, while width of injury (P = .73) and location of injury were not (proximal-distal P = .36, medial-lateral P = .69). Adding age with length of injury into a multiple regression analysis slightly improved the prediction of time to RTP (R^2 = 0.80). The relationship between return to play and length of tenderness was relatively unchanged when the additional mapping indices taken during the course of rehabilitation were added to the analysis (R^2 = 0.68, P<.0001; y = 2.50x – 6.71). This indicates that the regression equation can be used to estimate time to RTP regardless of when in the post injury/rehabilitation process the mapping is performed.

CONCLUSIONS: The length of tenderness to palpation of the injured hamstring muscle was highly predictive of time to RTP. The average length of tenderness was 22% with an average RTP of 45 days. Based on the regression equation a patient with a length of tenderness of 10% would be estimated to RTP in 15 days, while a tenderness length of 30% would be estimated to return in 69 days.

CLINICAL RELEVANCE: Hamstring injuries are among the most common in sport and it has proven difficult to predict time to RTP. This hamstring mapping technique described here was shown to be predictive of the time required to RTP and may be a useful clinical tool.

SPO107

PROSPECTIVE ASSESSMENT OF RETURN TO ACTIVITY FOLLOWING AN ATHLETIC KNEE INJURY

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PURPOSE/HYPOTHESIS: To obtain baseline values of perceived and objective preinjured physical function and determine if and when athletes return to those baseline levels following knee injury. We hypothesized that athletes returning to sport following an injury would not have a significantly lower level of physical function compared to their preseason baseline levels.

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NUMBER OF SUBJECTS: Seven hundred forty-six collegiate athletes currently participating in sport and medically cleared by a team physician for full participation participated in this study.
MATERIALS/METHODS: Potential subjects were approached during preseason physical examinations. Name, age, sex, race, height, weight, sport, years playing sport, and previous knee injury were collected. Subjects completed 4 subscales of the Knee injury and Osteoarthritis Outcome Score (KOOS): pain (PN), symptoms (SX), sport/recreation function (SP), knee-related quality of life (QL); the single-leg hop for distance (SLH); and anterior reach portion of the star excursion balance test (SEBT). Subjects were monitored for injury throughout the season. If a knee injury occurred in season, the athlete completed the KOOS subscales to determine if any change occurred from baseline testing to time of injury. When discharge occurred, the research team was contacted in order to distribute the KOOS and performance tasks from baseline testing. Each subject completed the KOOS at 1, 3, and 6 months following return to activity. Subjects completed the SLH and SEBT at each time point until the values were within the established minimal detectable change from baseline. Nonparametric sign rank and rank sum tests were used to assess differences within time points and between previous and no previous injury.
RESULTS: Thirty-eight subjects (mean ± SD age, 19 ± 1 years; height, 180 ± 9 cm; weight, 80 ± 14 kg) sustained a knee injury during the study period, missing 84 ± 123 days (range, 2-382 days). The KOOS subscales were significantly reduced at initial injury and discharge compared to baseline ($P \leq .01$) with the KOOSQL remaining significantly reduced at 1 month follow-up ($P = .03$). No statistical difference existed within the physical tasks at discharge or later compared to baseline. Fifteen of the 38 subjects reported a previous knee injury. The KOOSQL was significantly reduced across all time points for subjects with previous injury versus subjects without previous injury ($P \leq .04$). The SLH was significantly reduced at discharge for subjects with previous injury ($P = .02$) but returned to within baseline values at 1 month.
CONCLUSIONS: Perceived and objective measures were restored within 1 month of discharge except for KOOSQL which failed to recover to baseline values across the study in athletes with previous injury. Accounting for previous injury helped identify variations in baseline values and across the study period suggesting that previous experiences may need to be held in high regard clinically.
CLINICAL RELEVANCE: Using a prospective approach to capture perceived and objective physical function prior to injury and accounting for previous injury may assist clinicians with identifying individual return to preinjury status.

SPO108

PROSPECTIVE ASSESSMENT OF RETURN TO ACTIVITY FOLLOWING AN ATHLETIC ANKLE INJURY

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PURPOSE/HYPOTHESIS: To obtain baseline values of perceived and objective preinjured physical function and to determine if and when athletes return to those baseline levels following ankle injury. We hypothesized that athletes returning to sport following an injury would not have a significantly lower level of physical function compared to their preseason baseline levels.
NUMBER OF SUBJECTS: Seven hundred forty-six collegiate athletes currently participating in sport and medically cleared by a team physician for full participation participated in this study.
MATERIALS/METHODS: Potential subjects were approached during preseason physical examinations. Demographics including name, age, sex, race, height, weight, sport, years playing sport, and history of injury to the ankle were collected. Subjects completed the Foot and Ankle Disability Index (FADI) and the FADI Sport (FADISP) (perceived function) and the single-leg hop for distance (SLH) and anterior reach portion of the star excursion balance test (SEBT) (objective function). If an ankle injury occurred in season, the athlete completed the FADI and FADISP to determine if any change occurred from baseline testing to time of injury. When discharge occurred, the research team was contacted in order to distribute the FADI and FADISP and employ the physical performance tests performed during baseline testing. Each subject was contacted at 1, 3, and 6 months following return to activity to complete the FADI and FADISP. The subjects completed the performance tasks at each time point until the values were within the established minimal detectable change from baseline testing for both SEBT and SLH. Nonparametric sign rank and rank sum tests were used to assess differences within time points and between previous and no previous injury.
RESULTS: Forty-two subjects (mean ± SD age, 19 ± 1 years; height, 178 ± 10 cm; weight, 78 ± 14 kg) sustained an ankle injury during the study period, missing 31 ± 44 days (range, 1-200 days). FADI and FADISP scores were significantly reduced at initial injury (44% and 72%) and discharge (3% and 9%) compared to baseline ($P<.001$). There was no statistical difference in the performance of either physical task at any time point compared to baseline. Twenty-seven of the 42 subjects reported a previous ankle injury. No differences existed between subjects with and without previous injury at any time point for any measure.
CONCLUSIONS: Perceived and objective physical function is near normal for ankle injuries at discharge. Objective function appears to return to baseline at time of discharge while subjectively, subjects may have small deficits in perceived physical function when return to activity is permitted. Previous ankle injury did not influence perceived or demonstrable physical function.
CLINICAL RELEVANCE: The study revealed that patient perception of symptoms and pain aligned with a blinded clinician making the decision to return an injured athlete to sport following rehabilitation. Employing a prospective approach to establishing baseline physical function values for each individual athlete may help bolster the concept of identifying a return to preinjured levels of activity.

SPO109

BODY MASS INDEX IS NOT AN INDICATOR OF SPONDYLOLYSIS DIAGNOSIS OR TREATMENT TIME IN ADOLESCENT ATHLETES: A RETROSPECTIVE REVIEW

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PURPOSE/HYPOTHESIS: Spondylolysis, a bone stress injury in the lumbar spine, is the most common identifiable cause of low back pain in adolescent athletes. However, clinicians struggle to identify effective ways to diagnose spondylolysis without the use of advanced imaging. Body-mass Index (BMI) has been shown to be an effective predictor of lower extremity bone stress injury, and has been shown to impact recovery time. The impact of BMI on spondylolysis has yet to be assessed. Therefore, the objectives of this study were to determine (1) if BMI predicted the presence of spondylolysis in young athletes and (2) if BMI was associated with time to return to sport in athletes with a confirmed spondylolysis.
NUMBER OF SUBJECTS: Six hundred four adolescent athletes (mean ± SD age, 15 ± 1.8 years; 57% female) with low back pain were included in this review.
MATERIALS/METHODS: A retrospective chart review was performed on all adolescent patients (10-19 years) with low back pain treated by a sports medicine department from 2009 to 2016. The primary predictor variable of interest was BMI and the outcome variables were (1) diagnosis of spondylolysis, and (2) number of days to return to sport. The study's first objective was assessed using logistic regression analysis with age and sex

included as covariates, the second objective was assessed using an analysis of variance (ANOVA).

RESULTS: Adolescents with low back pain had a mean BMI percentile of 66 ± 25. One hundred forty-three patients had confirmed cases of spondylolysis (mean ± SD age, 14.5 ± 1.6 years; 49% female). BMI percentile was not predictive of spondylolysis (P = 1.00), the BMI percentile of patients with spondylolysis was 69 ± 24, and no spondylolysis was 66 ± 26. The mean numbers of days taken to return to sport did not differ between BMI categories (underweight, 159 days; healthy, 149 days; overweight, 144 days; and obese, 141 days; P = .08).

CONCLUSIONS: Previous literature has suggested BMI impacts lower extremity bone stress injuries; however, this was not the case in assessing the lumbar spine. BMI was not a useful predictor of spondylolysis nor associated with a longer time to return to sport.

CLINICAL RELEVANCE: Clinicians should not let BMI play a role when diagnosing spondylolysis or in the decision to return the athlete with spondylolysis back to sport.

SP0110

IMPROVING CLINICAL DIAGNOSTIC DECISION MAKING FOR YOUNG ATHLETES WITH LOW BACK PAIN

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PURPOSE/HYPOTHESIS: Half of all adolescents report low back pain, with an even higher rate in athletes. Spondylolysis, a stress fracture in the lumbar spine, is the most common identifiable cause of low back pain in adolescent athletes. Currently, patient history and special tests add little value in diagnosing spondylolysis. The best method for diagnosing spondylolysis is through advanced imaging, however, high cost and exposure to radiation are significant disadvantages. Therefore, the purpose of this study was to identify a cluster of patient characteristics to maximize diagnostic sensitivity, to help rule out acute spondylolysis in adolescent athletes with low back pain.

NUMBER OF SUBJECTS: One thousand twenty-five adolescent athletes with low back pain (mean ± SD age, 15.0 ± 1.8 years; 56% female) were reviewed.

MATERIALS/METHODS: A retrospective chart review was performed on all adolescent patients with low back pain treated by a sports medicine department from 2009 to 2016. Primary variables of interest included patient report and clinical examination findings. The outcome variable was the presence of spondylolysis. Logistic regression analysis was performed to identify variables associated with acute spondylolysis. Sensitivity and negative predictive values were calculated on the resultant cluster of variables.

RESULTS: Acute spondylolytic injuries were identified in 22% (n = 228) of the adolescent athletes presenting with low back pain. Pain with extension (P<.001), difference between active and resting pain of 3/10 or greater (P<.001), and male sex (P = .002) were significantly associated with acute spondylolysis. Absence of 2 of these variables had a sensitivity of 88%, negative predictive value of 90% (95% CI: 86%, 93%) and absence of all 3 variables had a sensitivity of 98%, negative predictive value of 91% (95% CI: 77%, 97%).

CONCLUSIONS: Due to high costs and exposure to radiation associated with current diagnosis of spondylolysis in adolescents with low back pain, improved clinical diagnostic decision making is needed. This study found a cluster of 3 patient characteristics that can assist in ruling out acute spondylolysis, potentially reducing the need for advanced imaging. Pain with extension, difference between active and resting pain, and male sex have all previously been found to be associated with acute spondylolysis, supporting the findings of this study. Due to this study's retrospective nature, prospective research is necessary to validate these findings.

CLINICAL RELEVANCE: The identified cluster of patient characteristics have potential for use in clinical diagnosis of acute spondylolysis if validated by prospective research.

SP0111

RELATIONSHIP BETWEEN Y BALANCE PERFORMANCE, SINGLE-LIMB VERTICAL JUMP DISPLACEMENT, AND SINGLE-LIMB HOP TESTS FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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PURPOSE/HYPOTHESIS: The purpose of this study was to examine the relationship between neuromuscular control, performance on a lateral hop to vertical jump test, and single limb hop distance between limbs at time of return to sport in athletes following anterior cruciate ligament reconstruction (ACL-R).

NUMBER OF SUBJECTS: A total of 83 participants (47 female) between the ages of 13 and 21 years old (mean ± SD age, 15.9 ± 1.7 years) were enrolled in the study.

MATERIALS/METHODS: Y Balance Test Lower Quarter (YBT-LQ) was completed bilaterally and composite scores were calculated for involved (INV) and uninvolved (UNV) limbs. A novel jump task (the lateral hop to vertical jump test) which requires the participant jump laterally, land on a single limb and then perform a max effort vertical jump was assessed using an 8-camera Qualisys Motion Capture System and 2 ATMI force plates. The average of 3 repetitions were used to calculate maximum vertical jump height (VJH) which was performed on both the INV and UNV limbs. Single-limb hop and triple hop for distance were also recorded bilaterally and the best of 3 repetitions were used to calculate maximum distance. Pearson product-moment correlations were used to assess for the relationship between YBT-LQ and vertical jump height. Alpha level was set at P<.05.

RESULTS: When reach distances were normalized for height, there were no significant correlations between INV VJH and INV limb YBT-LQ ANT (P = .803), PM (P = .415), or PL (P = .463) directions. Strong and moderate correlations were found between INV VJH and INV THD (r = 0.807, P<.001) and INV VJH and UNV VJH (r = 0.688, P<.001) respectively. Moderate correlations were also found between UNV VJH and UNV THD (r = 0.688, P<.001) and UNV VJH and UNV SHD (r = 0.516, P<.001).

CONCLUSIONS: The results of this study seem to indicate that YBT-LQ as an assessment of neuromuscular control does not correlate to single-leg jump height or single-leg hop distances. Jump height was associated with single hop and triple hop distances, which suggests that the vertical hop test completed in this study may be more representative of lower-limb power rather than neuromuscular control.

CLINICAL RELEVANCE: YBT-LQ and vertical jump height measure different constructs of physical performance ability. Hop tests appear to be related to power needed to perform a vertical jump. A return to sport program should include a variety of assessments to evaluate lower extremity power generation and neuromuscular control.

SP0112

HIGH KNEE VALGUS MOMENT OF FEMALE ADOLESCENTS IS POTENTIALLY MODIFIABLE

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PURPOSE/HYPOTHESIS: Knee valgus moment (VM) is known to load the anterior cruciate ligament (ACL), and VM estimated with 3-D movement analysis result in meaningful loads on the anterior cruciate ligament in-vitro. Females have a higher risk of ACL injury compared with males but studies have not shown if females have a higher VM compared with males during a cutting movement (CM). The primary aim was to analyze prospectively sex-dependent changes in VM observed within the first 100 milliseconds of a CM across puberty. A secondary aim was to assess which other parameters observed explain the VM magnitude.

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NUMBER OF SUBJECTS: One hundred thirty-six (56 male) youth and 27 (14 male) adolescents.
MATERIALS/METHODS: Athletes performed 5 repetitions per leg of a CM which was recorded using marker-based motion capture sampling at 200 Hz (youth athletes) or 400 Hz (adolescent athletes). Three mixed linear models were constructed: (1) subjects as random effects, (2) subject specific fixed effects (sex, maturity, anthropometrics, power, and strength), (3) combination of subject-specific and CM specific (joint angles, ground reaction forces) fixed effects. An iterative model selection process was implemented where variables were tested and compared using R^2 until the best available model was constructed. Sex by maturation was always included.
RESULTS: Model 1 had an R^2 of 0.33. Model 2 had an R^2 of 0.59 for the full model, and 0.20 for the fixed effects. Model 3 (knee valgus angles, hip valgus angles, hip rotation angles, vertical ground reaction force, knee flexion angles, ankle adduction angles, knee valgus posture, hip rotation posture) had an R^2 of 0.59 for the full model, and 0.46 for the fixed effects. Under model 2, youths had comparable VM (P = .08), while adolescent girls had higher knee valgus moments compared with boys (0.17 versus −0.07 Nm/kg, P<.001). Under model, youth boys had higher knee valgus moments compared with girls (0.35 versus 0.23, P<.001) while at adolescence there was no difference (0.24 versus 0.20, P = .19).
CONCLUSIONS: The most important finding of this study is that similar to jump landings when accounting only for individual differences in build, explosive ability and hip muscle strength, adolescent girls demonstrate higher knee valgus moments compared with boys. However, if movement specific factors are included (many of which can potentially be modified with training), there is no difference in VM between adolescent girls and boys.
CLINICAL RELEVANCE: VM has been linked to risk of anterior cruciate ligament injury, and female athletes have a higher risk of receiving an anterior cruciate ligament injury than males. Our results show that this increased risk of ACL injury is reflected in sex-specific changes in VM which are explained by differences in execution of the cutting maneuver. Further studies using a larger sample size are required to confirm these findings which will have implications for screening and prevention of ACL injury.

SPO113

REHABILITATION OF A TAE KWON DO ATHLETE FOLLOWING A REVERSE TOTAL SHOULDER ARTHROPLASTY

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BACKGROUND AND PURPOSE: The prevalence of the Reverse Total Shoulder Replacement (RTSA) has increased over the past couple of years. Previously utilized for older arthritic individuals with concomitant RTC tearing or pathology, these surgeries are now being employed for younger and more athletic individuals. At this time, there are no reports of return to martial arts participation following a RTSA. The purpose of this case report is to describe the postoperative management and return to Tae Kwon Do competition of a master's athlete following RTSA.
CASE DESCRIPTION: A 60-year-old martial arts athlete had an extensive history of right shoulder pain, arthritis, and biceps tendon pathology that led to the surgeon's decision to perform a RTSA. Post surgically, the patient was seen for a total of 25 visits over the course of 17 weeks. Initial treatment included manual therapy focusing on the posterior shoulder and periscapular musculature, perturbation training, scapular setting, isometrics, and transition from AAROM to AROM. Return-to-Tae Kwon Do training was performed with specific guidelines to reduce excessive loading on the prosthesis and stress on the deltoid musculature and acromion.
OUTCOMES: The Tae Kwon Do athlete had full shoulder AROM in all directions except for IR. He had 5/5 strength in his deltoid, RTC, and periscapular musculature, and had significant improvement on patient-reported outcome measures. He had improved postural awareness and mobility within his cervical and thoracic spine. He was able to fully return to Tae Kwon Do competition within 6 months following surgery.
DISCUSSION: Treating a Tae Kwon Do master's athlete following RTSA surgery involves a multimodal approach including manual interventions, neuromuscular re-education, perturbation training, periscapular and deltoid-specific strengthening, and proper reintegration into Tae Kwon Do participation.

SPO114

DOES DISCOID MORPHOLOGY AFFECT PERFORMANCE ON RETURN-TO-SPORT TESTING AFTER MENISCUS REPAIR?

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PURPOSE/HYPOTHESIS: Return to sport (RTS) after knee surgery involves the return of strength and dynamic knee stability, which can be assessed with isometric strength and functional performance testing. There is little evidence-based data to assist with RTS decision-making after meniscus repair. Furthermore, there is limited RTS data comparing patients with discoid meniscus tears to those with nondiscoid tears. The purpose of this study was to compare the performance on functional RTS tests between pediatric patients with discoid and nondiscoid meniscus tears. We hypothesized that patients with discoid morphology who underwent meniscus repair (1) would be younger, (2) would perform worse on RTS testing, and (3) would take longer to pass the RTS testing compared to those with repairs of nondiscoid meniscus tears.
NUMBER OF SUBJECTS: Thirty-two.
MATERIALS/METHODS: A retrospective review was performed of patients that underwent isolated meniscus repair by a single pediatric orthopaedic surgeon from 2010 to 2016. Thirty-two patients (14 discoid, 16 nondiscoid) were identified who underwent a postoperative RTS assessment consisting of isometric strength testing (knee extension, knee flexion, and hip abduction), the Lower Quarter Y Balance Test (YBT-LQ), and single-leg hop testing (single hop for distance, triple hop for distance, crossover triple hop for distance, and timed hop). Demographic information and RTS data were compared between groups. Recovery of muscle strength and power were defined by a limb symmetry index (LSI) of 90% or greater.
RESULTS: The mean age of the patients was 13.95 years (range, 8-19 years). Patients in the discoid group were younger than those with nondiscoid meniscus tears (12.9 versus 15.1 years, respectively; P = .05). There was a statistically significant difference in the average time from surgery to RTS testing between the discoid (269 days) and nondiscoid (184 days) groups (P = .02). For isometric strength testing, both groups had mean LSIs greater than 90% for knee extension, knee flexion, and hip abduction. There were no statistically significant differences between groups in isometric strength or performance on the YBT-LQ or any of the single-leg hop tests.
CONCLUSIONS: Pediatric patients who undergo repair of a discoid meniscus may require prolonged rehabilitation to achieve satisfactory completion of RTS testing. In our study, an additional 3 months on average were required to allow adequate recovery of muscle strength and dynamic functional stability when compared to those with a nondiscoid meniscal repair. However, upon completion of a structured physical therapy program with stringent RTS guidelines, at the time of testing, there was no significant difference in performance on any of the RTS tests between patients with discoid and nondiscoid meniscus tears.
CLINICAL RELEVANCE: The findings of this study can assist clinicians in safely returning pediatric patients back to sporting activities following meniscus repair. In addition, this study presents a novel combination of objective and functional measures to be used as RTS testing following meniscus repair.

SPO115

PATIENTS WITH PATELLAR TENDINOPATHY COMPENSATE WITH THE PLANTAR FLEXORS TO MAINTAIN JUMP PERFORMANCE

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PURPOSE/HYPOTHESIS: Patellar tendinopathy is a chronic, painful injury of the patellar tendon, most common in jumping athletes. Greater jumping ability is a risk factor for the injury. Despite impaired quadriceps function in the injured limb, symptomatic athletes still have significantly better jump performance than healthy, matched controls in bilateral jumping tasks. However, it is unknown whether side-to-side differences exist in lower extremity function, which may provide insight into how these athletes maintain greater jumping performance. Therefore, the purpose of this study was to determine if side-to-side differences exist in unilateral lower extremity functional tests in individuals with unilateral patellar tendinopathy.

NUMBER OF SUBJECTS: Eight (3 female) subjects with a diagnosis of unilateral patellar tendinopathy were recruited.

MATERIALS/METHODS: Diagnosis was confirmed using a standardized clinical exam and B-mode ultrasound imaging. Symptom severity was assessed using the Victorian Institute of Sport Assessment-patella (VISA-P) questionnaire. Participants performed the heel rise endurance test, a single-leg countermovement jump (CMJ), and a single-leg drop CMJ to evaluate lower extremity function. Paired *t* tests were used to compare repetitions and maximum height from the heel rise test and average jump height from the CMJ and drop CMJ between the symptomatic and asymptomatic limbs. Effect sizes (Cohen's *d*) were calculated for comparisons.

RESULTS: Subjects had a mean ± SD age of 26 ± 9 years, height of 69 ± 5 inches, weight of 169 ± 34 lb, symptom duration of 13 ± 19 months, and VISA-P score of 58 ± 16 points. Subjects performed significantly more heel rise repetitions on their symptomatic limb and the effect size was large (symptomatic, 28 ± 6 repetitions; asymptomatic, 25 ± 5 repetitions; $P = .045$, Cohen's $d = 0.86$). There were no significant differences in heel-rise height (13.2 ± 1.9 versus 12.9 ± 2.3 cm, $P = .72$, Cohen's $d = 0.13$), CMJ height (9.6 ± 4.8 versus 10.2 ± 4.9 cm, $P = .40$, Cohen's $d = -0.32$), or drop CMJ height (11.0 ± 5.3 versus 12.1 ± 6.0 cm, $P = .12$, Cohen's $d = -0.70$) between the symptomatic and asymptomatic limbs.

CONCLUSIONS: Individuals with unilateral patellar tendinopathy have greater performance on the symptomatic limb in the heel rise test but no differences in jump performance between limbs. This suggests that these patients may be compensating with the plantar flexors to maintain jump performance, while also decreasing load on the patellar tendon.

CLINICAL RELEVANCE: Individuals with patellar tendinopathy may be subjecting the ankle of their injured limb to greater loads. Improving plantarflexion strength and endurance may prevent further injury and help maintain jumping performance.

SPO116

EFFECTS OF RECOVERY LEG SLEEVES ON TIME LOSS FOR MAJOR LEAGUE SOCCER PLAYERS

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PURPOSE/HYPOTHESIS: Every season Major League Soccer (MLS) players are injured, resulting in time loss. Out of all MLS injuries, the most common injury sites are on the lower extremities and the most common injury types are strains, sprains, and contusions. Over half of these injuries occur from overuse without proper recovery. To enhance recovery, professional athletes have begun wearing Incrediwear recovery sleeves that contains germanium metal, but their effectiveness is unclear. It is hypothesized that germanium has a transdermal effect by creating an electromagnetic field in response to temperature changes, thereby promoting blood circulation. The purpose of this study was to investigate the effects wearing Incrediwear recovery leg sleeves on time loss for professional soccer players.

NUMBER OF SUBJECTS: For the 2015 season, n = 31; for the 2016 season, n = 28.

MATERIALS/METHODS: A retrospective review of injury reports from an MLS team between the 2015 and 2016 competitive seasons was performed. All players on this team wore Incrediwear recovery leg sleeves using the following mandatory protocol beginning in the 2016 season: (1) a minimum of 1 hour before and 1 hour after games for injured athletes, (2) on all travel days, and (3) a minimum of 1 hour posttraining if players trained at least 10% over their norm in distance, high-speed running, and/or accelerations/decelerations. After outlier removal, *t* tests were used to identify statistically significant differences ($P<.05$) in games and events missed between 2015 and 2016.

RESULTS: Two outliers from 2016 (n = 26) and 3 outliers from 2015 (n = 28) were removed from further statistical analysis. Soccer players with lower extremity injuries missed significantly less mean games (mean ± SD, 0.79 ± 1.02; $P = .005$) and mean events (mean ± SD, 3.96 ± 2.84; $P = .004$) in 2016 than 2015's games (mean ± SD, 2.41 ± 2.44) and events (mean ± SD, 10.68 ± 10.44). When including only lower extremity soft tissue injuries, players in 2016 (n = 23) also missed significantly less mean games (mean ± SD, 0.74 ± 1.01, $P = .007$) and events (mean ± SD, 3.74 ± 2.68, $P = .004$) than 2015's (n = 16) games (mean ± SD, 1.88 ± 1.45) and events (mean ± SD, 8.75 ± 7.14).

CONCLUSIONS: Following a mandatory Incrediwear recovery leg sleeve protocol may help reduce time loss for professional soccer players after lower extremity soft tissue injuries. The reduction in time loss could be due to enhanced blood circulation to facilitate recovery.

CLINICAL RELEVANCE: This is first study to investigate the effects of wearing Incrediwear recovery sleeves on time loss for athletes. While the results in the study are statistically significant, future studies should focus on other sports, age groups, and specific injuries before physical therapists can confidently recommend its use for their patients. Moreover, it would be beneficial clinically to investigate changes in patient outcomes by wearing these sleeves in nonathletic populations, such as patients with edema following traumatic injury or during postoperative rehabilitation.

SPO117

USE OF A PROGRESSIVE INTERVAL TRAINING PROGRAM IN A PATIENT WITH DECREASED EXERCISE TOLERANCE SECONDARY TO A MULTIYEAR HISTORY OF POSTCONCUSSION SYNDROME: A CASE REPORT

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BACKGROUND AND PURPOSE: Post concussion syndrome is the presence of persistent symptoms including headache, dizziness, fatigue, irritability, insomnia, concentration difficulty, or memory difficulty lasting months after a concussion takes place. PCS affects 10% to 20% of those that suffer concussions and it is estimated that 1.6 to 3.8 million concussions occur annually in the United States. There is some evidence to support graded aerobic exercise as a treatment for individuals with PCS. There is evidence to support a decrease in both brain derived neurotrophic growth factor and cerebral blood flow occurs after concussions and there is evidence to support that interval training increases these levels greater than aerobic training. Therefore the purpose of this case report was to describe the effects of a progressive interval training program on an individual with PCS.

CASE DESCRIPTION: The patient was a 19-year-old man who suffered a concussion while playing soccer 23 months prior to initial evaluation. He presented to physical therapy with headaches during physical activity followed by increased fogginess and difficulty concentrating during academic activities. Upon examination he displayed a decrease in exercise tolerance on the Buffalo Concussion Treadmill Test (heart rate of 111 bpm at symptoms threshold) and impaired gaze stabilization (symptom provocation at 1.6 Hz). The patient participated in 6 months of physical therapy, initially attending 1 time per week and decreasing to 1 time every 3 to 4 weeks until discharge. His treatment involved gradual progression gaze

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stability exercises and progression of aerobic exercise, beginning with low to moderate intensity sustained walking and progressing to moderate to high intensity interval training. Target heart rate was determined by symptom threshold on the Buffalo Concussion Treadmill Test (BCTT) and progressed based on patient's symptom report.

OUTCOMES: Following 6 months of physical therapy including patient demonstrated a significant increase in max asymptomatic heart rate (189 bpm) and improved gaze stability (2.2 Hz) without symptom provocation. He also reported a significant decrease in symptoms and an ability to return to recreational athletics including basketball and no longer experienced increase in fogginess or difficulty concentrating during cognitive activities.

DISCUSSION: The patient's improvement in max asymptomatic heart rate and reported decrease in symptoms demonstrate the potential benefit of interval training in individuals suffering from PCS. Further research needs to be done in individuals with PCS comparing the benefits of interval training with traditional aerobic training.

SP0118

COMPARISON OF SINGLE-LEG BALANCE TO ISOMETRIC ANKLE AND HIP STRENGTH

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PURPOSE/HYPOTHESIS: The purpose of this study was to investigate the correlation between a static single-leg balance task (modified Balance Error Scoring System) and isometric ankle and hip strength. We hypothesize that there is a significant, moderate to high correlation between balance and strength.

NUMBER OF SUBJECTS: Forty.

MATERIALS/METHODS: Healthy subjects were randomly assigned to 1 of 3 stations: balance, ankle strength, and hip strength. Static balance was assessed using a modified Balance Error Scoring System (mBESS), which included single-leg balance with eyes closed on stable and unstable surfaces. Isometric strength of hip extension, hip abduction, ankle eversion, and ankle inversion were assessed using standardized manual muscle testing procedures with a handheld dynamometer. A Pearson correlation coefficient (r) was utilized to evaluate the relationship between balance and strength measures. A paired t test was utilized for secondary analysis to compare dominant and nondominant limb performance.

RESULTS: Forty of 44 subjects (mean ± SD age, 23.6 ± 4.9 years) were included in data analysis. Low to negligible correlations were found between mBESS and hip extension strength ($r = -0.35$, $P<.01$) and mBESS and ankle eversion strength ($r = -0.29$, $P = .01$). No significant correlations existed between mBESS and hip abduction or ankle inversion strength. Moderate correlations were found between all hip and ankle strength measures ($r = 0.75$-0.82, $P<.05$). When comparing dominant to nondominant limbs, only minimal differences were noted in hip extension strength (mean difference, 6.6%; $P<.01$) and ankle eversion strength (mean difference, 6.4%; $P<.01$). Other measures did not reveal differences between dominant and nondominant limbs.

CONCLUSIONS: Minimal correlation was identified between mBESS performance and isometric hip and ankle strength. Comparison of dominant and nondominant limbs suggests that clinicians should expect relative symmetry in strength and balance in healthy adults. Further, asymmetries found during clinical examination should raise suspicion of specific impairments that may lead to dysfunction.

CLINICAL RELEVANCE: The lack of association between static single-leg balance and isometric hip and ankle strength reinforces the importance of conducting a thorough musculoskeletal examination for individuals with balance deficits, such as those with chronic ankle instability. Clinicians should avoid making assumptions about isometric strength in the presence of good performance on the mBESS, or vise versa.

SP0119

BLOOD FLOW RESTRICTION TRAINING: A SYSTEMATIC REVIEW OF SAFETY AND ADVERSE EVENT REPORTING

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PURPOSE/HYPOTHESIS: Introduction: Blood flow restriction (BFR) training appears to be a viable exercise option for patients participating in rehabilitation, as its effects show to elicit an increase in muscle strength, muscle hypertrophy, and muscular endurance while exercising at low loads. The aim of our systematic review is to provide an appraisal of the current research on the safety of blood flow restriction training with respect to cardiovascular risks, musculoskeletal risks, and neuromuscular risks.

NUMBER OF SUBJECTS: This research is a systematic review, and there were 20 studies included.

MATERIALS/METHODS: Web search of PubMed, SPORTDiscus, Clinicaltrials.gov, and Web of Science were queried and articles were screened by titles, abstracts, and full content. Two reviewers independently evaluated the studies using the Cochrane risk of bias tool. When the 2 reviewers did not agree, a third reviewer resolved the disagreement. A summary of adverse events reported was also developed from the twenty studies included in the review. The events were categorized into mild, moderate, or severe.

RESULTS: Cardiovascular effects: there were no adverse events related to heart rate, blood pressure, stroke volume, cardiac output, coagulation, arterial thickness, brachial artery and popliteal artery pressure, or central blood pressure. Musculoskeletal effects: BFR elicits similar responses as conventional strength training in relation to soreness, range of motion, markers for muscle damage, oxidative stress, pH, and inflammation. BFR training shows increases in heat shock proteins, glycogen, muscle fiber recruitment, and intramuscular metabolic stress. Neuromuscular effects: nerve conduction velocity did not change after training compared to conventional training and neuromuscular activation showed no significant difference. Adverse event reporting: a total of 6 studies reported adverse events in their subjects. One study reported a severe event of rhabdomyolysis. Three studies reported muscle soreness, while 1 study reported elevated HR and another reported numbness.

CONCLUSIONS: Through this review, BFR training appears to be a modality to facilitate musculoskeletal strengthening programs. Because these studies directly investigated populations of healthy, active, young men and women, future research should consider and report safety aspects for specific patient populations. Clinicians should continue to follow currently advised precautions and contraindications when choosing to facilitate strengthening with a BFR training program. Future studies should also improve on adverse event reporting, even though the events encountered may not be severe.

CLINICAL RELEVANCE: BFR is becoming a popular modality used in sports physical therapy, and its safety should be research to ensure patient's are safe when using the modality. Patients should also know the symptoms that could possibly occur when utilizing this modality.

SP0120

QUADRICEPS STRENGTH SYMMETRY AT THE TIME OF RETURN TO SPORT: DOES IT IMPACT LANDING MECHANICS 5 YEARS LATER?

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PURPOSE/HYPOTHESIS: Altered knee mechanics persist after anterior cruciate ligament reconstruction (ACLR) and are thought to contribute to early cartilage degeneration. Previous work shows quadriceps femoris (QF) strength asymmetry at the time of return to sport (RTS) after ACLR is associated with asymmetric landing patterns at the time of RTS and at 2 years post RTS. This study tested the hypothesis that young athletes after ACLR with QF strength asymmetry at RTS clearance would demonstrate greater asymmetry during landing 5 years later compared to young athletes with symmetric QF strength at RTS.

NUMBER OF SUBJECTS: Twenty-two young athletes (77% female; mean ± SD age at 5 years post RTS, 22.5 ± 2.6 years) after primary, unilateral ACLR were tested at time of RTS and at 5 years post RTS.

MATERIALS/METHODS: At RTS, isometric QF strength was measured bilaterally on an isokinetic dynamometer and limb symmetry index (LSI) was calculated. QF LSI was used to divide the cohort into 2 groups: High QF (RTS-HQ; LSI of 90% or greater; n = 10) and Low QF (RTS-LQ; LSI less than 85%; n = 12) based on published work. At 5 years post-RTS, 3-D motion analysis data were collected during the initial landing phase of a drop vertical jump task. Variables included involved limb peak vertical ground reaction force (vGRF), knee loading rate (LR), peak total support moment (TSM), peak internal knee extension moment (IKEM) and peak knee flexion angle (KFA). LSI (percent) was calculated for each variable. Group differences in landing were compared between the RTS-HQ and RTS-LQ groups using independent samples *t* tests ($\alpha = .05$).

RESULTS: The RTS-HQ and RTS-LQ groups did not differ in landing symmetry at 5 years post RTS: vGRF LSI (101% versus 94%, respectively; $P = .37$), LR LSI (97% versus 94%, respectively; $P = .92$), TSM LSI (99% versus 93%, respectively; $P = .44$), peak IKEM LSI (99% versus 94%, respectively; $P = .82$), or peak KFA LSI (101% versus 98%, respectively; $P = .34$). Similarly, the RTS-HQ and RTS-LQ groups did not differ in landing variables on the involved limb at 5 years post RTS: vGRF (N/kg) (1.6 versus 1.4, respectively; $P = .90$), LR (N/kg/s) (17.5 versus 21.1, respectively; $P = .92$), peak IKEM (Nm/kg) (1.9 versus 1.6, respectively; $P = .63$) or peak KFA (degrees) (83° versus 80°, respectively; $P = .97$). The TSM (Nm/kg) was lower in the RTS-LQ group (4.1) compared to the RTS-HQ group (5.1) ($P = .05$).

CONCLUSIONS: Participants with QF asymmetry at RTS do not appear to demonstrate landing asymmetry 5 years later during a double-leg landing task, although additional study of the joint contributions to TSM is warranted. Further study of QF strength changes over time and the potential impact with landing mechanics during double-leg and single-leg tasks would be informative.

CLINICAL RELEVANCE: This work shows that landing asymmetries, related to RTS QF asymmetry, previously identified at RTS and 2 years post RTS do not persist at 5 years post RTS, in this preliminary analysis. Further evaluation is needed with larger sample sizes and to investigate the potential impact of early movement strategies on cartilage integrity at 5 years post RTS.

SP0121

THE RELATIONSHIP BETWEEN MAXIMUM TRUNK ROTATION FORCE, PLANK HOLD FOR TIME, AND Y BALANCE TO SELF-REPORTED FUNCTION AND PAIN IN ATHLETES WITH LUMBAR INSTABILITY: A CASE SERIES

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BACKGROUND AND PURPOSE: Lumbar instability can be a common pathology for athletes. Literature has shown that for athletes with low back pain, trunk endurance testing can provide clinicians with a measure for predicting improved patient-perceived function as well as be used for an intervention to assist in preventing low back pain in athletes. Evidence has also shown that athletes produce more power into flexion and extension than the nonathletic population. The purpose of this case series was to investigate movements within multiple planes of motion during the early phase of physical therapy for athletes with low back pain due to lumbar instability and evaluate if there's a relationship to their self-reported function and pain.

CASE DESCRIPTION: A total of 4 athletes diagnosed with lumbar instability participated in this case series. Pain was isolated to the lumbar spine at either midline or to 1 side without radicular symptoms.

OUTCOMES: Each participant completed the Modified Oswestry Disability Index, a plank hold for time, the Y Balance LQ test, maximal rotation effort using a Keiser functional trainer, and ranked their pain on the VAS at initial evaluation, 2 weeks, and 4 weeks. Participants were given a zero if they had pain during the functional tests. The greatest improvement in rotation force within a 2-week period was 90 and 84 more pounds to the right and left respectively. The same patient reported a 70% improvement at week 2 and then reported pain in his right low back at week 4, which presented as a 28-lb reduction in right rotation force. This was associated with the patients plank time in which he improved his plank time by 20.41 seconds at 2 weeks and then was unable to be scored due to pain at 4 weeks. The largest improvement in plank time was 73.47 seconds which was associated with an increase in rotation force right and left by 17 lb and 19 lb, respectively. These improvements paralleled the patients' MODI score which improved by 48 points. The average improvement in rotation force was 22 lb to the right and 23.7 lb to the left. Plank hold time increased by an average of 18.8 seconds, while Y Balance composite scores on the right and left leg improved by an average of 0.16 and 0.03 respectively. Average improvement on the MODI and VAS were 8.67 and 2.33, respectively.

DISCUSSION: There appeared to be a direct relationship between each patient's ability to produce rotational force to their self-perceived improvement and function. The outcomes of this case series suggest that rotation force production and plank hold for time are safe and viable measures early in rehabilitation for determining athletes with lumbar instability progress toward return to sport. However, more research needs to be conducted through a randomized control trial to establish reliability, validity, and prognostic factors of rotational force and a plank hold for time as outcome measurements for athletes with lumbar instability.

SP0122

PSYCHOLOGICALLY INFORMED PHYSICAL THERAPY TO ENHANCE RETURN TO SPORT AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: A CASE SERIES

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PURPOSE/HYPOTHESIS: Despite successful anterior cruciate ligament reconstruction (ACLR), up to 55% of athletes do not return to their preinjury level of sport. There is limited evidence on the efficacy of psychologically-informed physical therapy (PIPT) programs for improving ACLR outcomes, including return to sport. The purpose of this case series was to describe feasibility, acceptability, and 6-month outcomes of a PIPT program titled Cognitive-Behavioral based Physical Therapy (CBPT) for improving recovery after ACLR.

NUMBER OF SUBJECTS: Eight consecutive patients (mean age, 20.1 years; 6 female) undergoing unilateral ACLR.

MATERIALS/METHODS: Patients participated in the CBPT program beginning preoperatively and lasting up to 8 weeks after surgery. The CBPT program was based on evidence-based cognitive-behavioral principles and included deep breathing, grounding exercises, graded activity, monitoring self-talk, present-mindedness, and guided imagery. The program

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included 1 preoperative and 6 postoperative phone sessions with a physical therapist who was trained by a clinical psychologist. Feasibility and acceptability was assessed with session compliance and patient perceptions of CBPT. Patient-reported knee and psychological functioning was measured preoperatively and at 6 months. Patient-reported measures included the Knee injury and Osteoarthritis Outcome Score (KOOS) sports/recreation and quality of life (QOL) subscales, International Knee Documentation Committee (IKDC), Tampa Scale of Kinesiophobia (TSK), and Pain Catastrophizing Scale (PCS). Minimal clinically important difference (MCID) was used to determine meaningful change in functioning. Subjective Patient Outcome for Return to Sports score and satisfaction were measured at 6 months.

RESULTS: Seven of the 8 patients completed all CBPT sessions. One patient completed 4 sessions. After intervention, 6 patients felt the benefits of CBPT somewhat or far outweighed the effort required and 1 patient felt the benefit equaled the effort. Five patients felt CBPT was as important as other postoperative services for recovery, while 1 patient felt CBPT was more important. At 6 months, 7 patients exceeded MCID on the TSK, 6 on the PCS, 5 on the KOOS sports/recreation subscale, 4 on the IKDC, and 3 on the KOOS QOL subscale. At 6 months, 3 patients returned to their same sport at the same level of effort and performance as before injury. Six patients reported they were satisfied with their outcome after surgery and 1 patient was very satisfied.

CONCLUSIONS: The CBPT program is a feasible and acceptable intervention designed to address psychological functioning and promote recovery after ACLR. Future efforts are ongoing to determine the efficacy of the CBPT program on return to sport within a larger randomized trial.

CLINICAL RELEVANCE: These preliminary data suggest physical therapists can utilize telephone-based cognitive-behavioral strategies with patients after ACLR.

SP0123

ASSOCIATION OF CUMULATIVE LOAD AND ASYMMETRY WITH RUNNING INJURY IN FEMALE CROSS-COUNTRY RUNNERS

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PURPOSE/HYPOTHESIS: Studies investigating the influence of ground reaction force (GRF) characteristics on running related injury (RRI) report varying results regarding the association of these factors to injury. Discrepancies between these studies suggest that a discrete biomechanical characteristic may not be sufficient in predicting RRI. Authors have proposed that rather than investigating biomechanical characteristic alone, exposure should also be considered. The purpose of this study was to determine if average weekly load and asymmetry is higher in injured versus noninjured runners, and whether higher cumulative load and asymmetry predict injury.

NUMBER OF SUBJECTS: Twenty female collegiate cross-country runners (mean ± SD age, 19.5 ± 1 years) volunteered to participate. Runners were injury free at the time of initial testing.

MATERIALS/METHODS: Three-dimensional kinematic and kinetic data were collected during treadmill running at 2.68, 3.13, 3.58, and 4.02 m/s. By utilizing GRF and cadence data collected at each of the 4 speeds, individualized regression models were created based on each athlete's vertical instantaneous loading rate and cadence to predict these variables at any given velocity. Predicted weekly cumulative load for each limb was calculated from each athlete's prescribed training volume and intensity for a 12-week cross-country season. Pilot testing demonstrated good agreement (ICC = 0.847) between prescribed versus actual training using GPS and accelerometer data. Injuries meeting a recent consensus definition were recorded throughout the season. A 1-tailed *t* test was used to determine differences in cumulative load between injured versus noninjured limbs of injured runners. Two-tailed *t* tests were used to determine differences in cumulative load between injured limbs versus the dominant limb of noninjured runners, and to compare differences in between-limb asymmetry in injured versus noninjured runners. A logistic regression was used to evaluate the probability of injury based on cumulative load and asymmetry between limbs.

RESULTS: Twelve (60%) participants reported a RRI during the study. Cumulative load was significantly higher ($P = .031$) in the injured limb versus noninjured limb of injured runners. Cumulative load was also significantly higher ($P = .044$) in injured limbs versus the dominant limbs of noninjured runners. The difference in asymmetry between injured versus noninjured runners was not statistically significant ($P = .070$), though there was a trend toward higher asymmetry in injured runners. The logistic regression model was significant ($P = .001$) with 71% of the variance in injury incidence being explained by the independent variables.

CONCLUSIONS: The results of this study suggest that injured limbs undergo higher cumulative load than noninjured limbs. Furthermore, cumulative load and asymmetry explain 71% of variance in injury among this population.

CLINICAL RELEVANCE: Cumulative load monitoring may guide clinicians in minimizing RRI risk and guiding return to run programs. In athletes with higher VILR, training volume and intensity can be altered to reduce cumulative load.

SP0124

KINETIC ASYMMETRY IN FEMALE COLLEGIATE CROSS-COUNTRY RUNNERS WITH AND WITHOUT RUNNING-RELATED INJURY: A PROSPECTIVE STUDY

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PURPOSE/HYPOTHESIS: Running kinetic variables and asymmetry in loading has been found to be associated with running related injury in recreational runners. Limited evidence exists regarding asymmetry and injury in the competitive runner. The purpose of this study was to examine the differences in kinetic asymmetry between female collegiate runners who sustained a running related injury and those who did not during a cross-country season

NUMBER OF SUBJECTS: Twenty female collegiate cross-country runners (mean ± SD age, 19.5 ± 1 years; BMI, 20.6 ± 2.1 kg/m^2) volunteered to participate. Runners were injury free at the time of testing.

MATERIALS/METHODS: Participants were recruited from a Division I collegiate cross-country team as part of a larger study examining injury incidence and changes in biomechanics (IRB 16-X-201). A 3-D kinematic and kinetic running gait analysis was performed. Kinematic and kinetic running data were collected during treadmill running at 3.58 m/s. Three dimensional data were collected using a 10 camera motion analysis system (Vicon, Oxford, UK). Force data were collected via an instrumented treadmill (Bertec, Worthington, OH). Motion Monitor software (The Motion Monitor, Chicago, IL) was used to identify stance phase, and analyze ground reaction force data. Kinetic variables of interest were vertical impact peak (IPEAK), instantaneous (VILR), and peak vertical ground reaction force (PVGRF). Limb symmetry was analyzed using the Symmetry Index. Participants were monitored over the course of a 12-week cross-country season for incidence of running related injury. Injury was identified using a recent consensus definition. A 2-tailed Student *t* test was used to compare differences in kinetic symmetry between those who sustained a running related injury (RRI) and those who did not (CON).

RESULTS: Twelve (60%) participants reported a RRI during the study. There were no significant differences between any of the variables of interest ($P>.05$). However, there was a significant difference ($P = .04$) between the RRI and CON group in average running volume during the season.

CONCLUSIONS: Asymmetry in kinetic variables previously shown to be associated with injury in recreational runners is not associated with incidence of injury in a group of female collegiate runners. Future research

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would benefit from examining a larger population, as well as the impact of running volume in combination with kinetic asymmetry on incidence of injury.

CLINICAL RELEVANCE: While asymmetry in kinetic loading in runners tested at 1 velocity may not be associated with injury incidence, the clinician may consider the impact of asymmetrical loading has on the runner at higher training volumes and varying training intensities. A recent framework for the etiology of running-related injuries suggests that rather than investigating the biomechanical characteristic alone, exposure to the biomechanical characteristic should also be considered. Therefore, kinetic asymmetry may have a greater impact on injury at greater exposures.

SP0125

USE OF EMERGING DRONE TECHNOLOGY FOR IMPROVED QUALITATIVE ANALYSIS IN SPORTS MEDICINE: A CASE REPORT

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BACKGROUND AND PURPOSE: Many athletic human movements occur too quickly for full comprehension by the naked eye. Technologies including smartphone and drone cameras have recently emerged and may provide clinicians a practical, reasonably priced method to capture sporting activity, allowing for slowing down this movement for analysis and aiding in clinical decision making. The purpose of this case study is to pilot test the use of emerging drone technology to provide axial video capture during the rotary motion which characterizes swinging a baseball bat.

CASE DESCRIPTION: A 17-year-old baseball player, presenting with chronic left-sided low back pain, had an MRI revealing an L4 pars interarticularis stress reaction that warranted extended rest. Qualitative analysis of in-season batting via standard smartphone digital video revealed excessive rear knee flexion, excessive upper trunk rotation and lumbar extension, and likely reduced weight transfer to the lead lower extremity during the batting swing. Nearing completion of rehab, subsequent video capture utilizing a smartphone (frontal view) and a drone (axial view) added qualitative information that aided in formulation of a treatment progression to improve the athlete's movement pattern and ultimately contributed to the determination of return to play.

OUTCOMES: Postintervention axial drone video showed clinically-meaningful improvements in batting qualitative kinematic measures with simultaneous anticipated reduction in pain ratings. This method of qualitative analysis helped the athlete to confidently return to his previous level of activity without pain.

DISCUSSION: Drone video for use in qualitative motion analysis is an emerging technology particularly valuable to clinicians as a practical, sport-specific, and unique perspective method to assess high velocity rotary motions. These findings may have particular relevance for physical therapists who work with highly functioning patients, as the methods used in this case study may assist clinicians in determining progression of rehabilitation activities and/or clearing an athlete to resume previous sporting activities. Further study of axial view analysis is warranted toward delineating qualitative measures of batting that might be useful to clinicians, including bat speed, trunk rotation, and joint angles at various points in the swing, particularly when pre and post injury evaluation is warranted.

SP0126

CONCURRENT VALIDITY AND INTRARATER RELIABILITY OF VIDEO-BASED TRANSVERSE PLANE TRUNK ROTATION ANALYSIS DURING RUNNING

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PURPOSE/HYPOTHESIS: Two-dimensional (2-D) video analysis of running gait is a common and cost effective tool in managing and preventing injury in runners. While the reliability and validity of common 2-D lower extremity measures is known, the reliability and validity of transverse plane 2-D trunk rotation measures remain unknown. The purpose of this study was to determine the concurrent validity and reliability of 2-D video analysis of transverse plane trunk rotation during running.

NUMBER OF SUBJECTS: Sixteen healthy male (n = 8; mean ± SD age, 25 ± 4.8 years) and female (n = 8; mean ± SD age, 25 ± 4.5 years) collegiate or competitive recreational runners (average ± SD weekly mileage, 33 ± 18 miles per week; range, 10-60 miles per week).

MATERIALS/METHODS: Each participant ran in preferred running shoes at self-selected speed on a treadmill. Simultaneously, 3-D motion and 2-D overhead video was captured at 120 and 60 frames per second, respectively. Peak trunk rotation in the transverse plane was determined from 3-D and 2-D video captures as the angular excursion of a line connecting reflective markers positioned on the right and left acromioclavicular joints relative to the treadmill frame. For right and left trunk rotation, one 2-D and the corresponding 3-D stride per participant was used to calculate concurrent validity using the Pearson product correlation coefficient (r) with right and left rotation analyzed separately. Intrarater reliability was assessed by comparing the angle and timing of peak trunk rotation in each of 16 2-D videos on 2 separate occasions separated by 7 days. Intraclass correlation coefficients (ICC) were calculated for 2-D video frame numbers corresponding to peak trunk rotation and between 16 randomly chosen peak trunk rotation angles (1 per 2-D running video).

RESULTS: Excellent intrarater reliability was observed for the timing of peak trunk rotation (ICC = 1, $P<.001$) and for peak right trunk rotation angle (ICC = 0.997, $P<.001$) and peak left trunk rotation angle (ICC = 0.992, $P<.001$) using 2-D video capture. Trunk rotation measurements from 2-D and 3-D video capture were significantly correlated (left trunk rotation: $r = 0.963$, $P<.001$; right trunk rotation: $r = 0.992$, $P<.001$).

CONCLUSIONS: A single rater can reliably determine the timing and measurement of peak trunk rotation from 2-D video on 2 separate occasions and this measure is significantly correlated to 3-D peak trunk rotation measurement. The high ICC for the 2-D trunk rotation measure indicates that a clinician can reliably assess transverse plane trunk rotation by selecting a single right or left trunk rotation from 2-D running video.

CLINICAL RELEVANCE: Measurement of peak transverse plane trunk rotation from a 2-D video is a valid and reliable measure that may be useful in running gait analysis. Trunk rotation assessment may inform a comprehensive running gait analysis to evaluate running-related injuries and injury risk.

SP0127

USE OF 2-DIMENSIONAL SAGITTAL KINEMATIC VARIABLES TO ESTIMATE GROUND REACTION FORCE DURING RUNNING

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PURPOSE/HYPOTHESIS: Variations in vertical loading rates have been associated with overuse injuries of the lower extremity, however, they are typically collected using 3-D motion capture systems and in-ground force plates that are not easily available to most clinicians. The purpose of this study was to determine if kinetic measures commonly used to describe lower extremity loading characteristics could be estimated from step rate and specific sagittal plane kinematic variables captured using 2-dimensional motion analysis during treadmill running.

NUMBER OF SUBJECTS: Ten high school cross-country runners (4 male, 6 female; mean age, 15 years; range, 14-17 years) voluntarily consented to participate in this study.

MATERIALS/METHODS: Reflective markers were placed on each lower extremity over multiple anatomical landmarks. Participants were then asked to run on the treadmill at their preferred running speed. When the participants indicated they were in their typical running pattern, they continued to run at their preferred speed for a minimum of 5 minutes.

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After 3 minutes of running at their preferred running speed, the participant's step rate was counted and after running for 4 minutes, video and ground reaction force data were recorded for 60 seconds. All running motion data were recorded using a single high-speed camera at 240 frames per second and ground reaction force data were sampled at 1000 Hz.
RESULTS: Mean kinematic values between the left and right extremities for all 10 participants were not significantly different. Consequently, data for the left and right extremities were grouped for all further analyses. The stepwise forward regression to predict vertical ground reaction force resulted in a 5-variable model (step rate and 4 kinematic variables) with adjusted R^2 = 0.52. The stepwise forward regression to predict average loading rate also resulted in a 5 kinematic variable model with adjusted R^2 = 0.51.
CONCLUSIONS: Step rate and sagittal plane kinematic variables measured using a simplified 2-dimensional motion analysis approach with a single high-speed camera can provide the clinician with a reasonable estimate of ground reaction force kinetics during treadmill running. Clinical relevance: this study provides evidence that a clinician can use 2-dimensional video analysis to collect kinematic data that reasonably predicts ground reaction force and loading rates in runners.
CLINICAL RELEVANCE: This study provides evidence that a clinician can use 2-dimensional video analysis to collect kinematic data that reasonably predicts ground reaction force and loading rates in runners.

SP0128

KNEE INJURY RISK DURING FOOTBALL-RELATED MOVEMENT PATTERNS

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PURPOSE/HYPOTHESIS: Football is one of the most popular high school sports in the and is the sport with the leading number of injuries. Approximately 20% of high school football injuries involve the knee. Anterior cruciate ligament (ACL) injuries are common in football and these athletes are 4 times more likely to sustain ACL injuries than in other sports. The drop vertical jump (DVJ) has been used to identify athletes at high risk for ACL injury, however limited research has been done on males. The purpose of this study was to identify knee movement patterns of athletes during the DVJ and compare those to more sport specific tasks, a weighted sled push (WSP), and a jump stop unanticipated cut (JSUC).
NUMBER OF SUBJECTS: Fifty-two.
MATERIALS/METHODS: Fifty-two high school American football players are included in this study consisting of 17 linemen and 35 skill players. Each participant completed 3 trials of each task. For the DVJ, subjects dropped from a 31-cm box and performed a maximum effort vertical jump. During the WSP, participants pushed a prowler sled with 75% body mass added. Moments were calculated during the propulsion phase (initial forward momentum to toe-off) of the back plant foot. For the JSUC, each player completed 3 trials of a reaction jump stop into a cutting trial that randomly displayed an arrow to the left or right. These trials were performed on a synthetic turf surface with an embedded force platform. Kinetic and kinematic data were recorded using 3-D capture motion analysis. Peak knee abduction moments were normalized to body weight. For analysis the participants were separated into tertiles of low risk (LR, n = 17), moderate risk (MR, n = 18), and high risk (HR, n = 17) from the knee moment of the DVJ. Multiple 1-way analysis of variance tests (P<.05) were used to test for biomechanical differences between groups with post hoc Bonferroni-corrected pairwise comparisons.
RESULTS: During the DVJ, there were significant differences between the LR (0.308 ± 0.16 Nm·kg^{-1}), MR (0.294 ± 0.12 Nm·kg^{-1}) and HR (0.254 ± 0.13 Nm·kg^{-1}) groups. There were significant differences in knee abduction moment between groups for the WSP (LR, 0.46 7 ± 0.25 Nm·kg^{-1}; MR, 0.32 ± 0.25 Nm·kg^{-1}; HR, 0.22 ± 0.21 Nm·kg^{-1}; P = .024) and JSUC (LR, 0.6 ± 0.20 Nm·kg^{-1}; MR, 0.41 ± 0.19 Nm·kg^{-1}; HR, 0.41 ± 0.29 Nm·kg^{-1}; P = .028).
CONCLUSIONS: Injury risk groupings (low, moderate, and high risk) from the DVJ showed similar biomechanical differences during other sport-related tasks. These players moved with a similar pattern when completing an unanticipated cut or pushing a prowler sled, which mimics game like situation or exercises that can be utilized in a clinic post ACL injury.
CLINICAL RELEVANCE: Low quality landing patterns have been found to translate to other sport related activities. Assessment and monitoring of quality of movement can provide physical therapists with information for the progression of athletes to sport related tasks.

SP0129

HEART-RATE VARIABILITY BIOFEEDBACK TRAINING WITH AN ELITE FEMALE TRIATHLETE

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BACKGROUND AND PURPOSE: Heart-rate variability (HRV)—the time interval variation between consecutive heart beats—is a quantitative measure of autonomic nervous system (ANS) balance and a potent index of overall health, fitness and performance potential. At rest, low HRV indicates greater sympathetic drive consistent with higher stress while high HRV indicates stronger parasympathetic drive consistent with performance readiness and stress resilience. Breath-based biofeedback meditation where attention is focused on breathing while tracking HRV, is an effective tool to increase resting HRV. The purpose of this single-subject case study was to assess (1) the impact of breath-based meditation HRV biofeedback training on daily resting HRV values of an elite student-triathlete and (2) the association between HRV with 2 subjective performance indicators: workout quality and amount of postworkout energy.
CASE DESCRIPTION: One 24-year-old competitive, elite, female amateur triathlete (top 3 finisher) and doctoral physical therapy graduate student completed an 8-week A-B repeated-measures study. A: baseline 4 weeks (n = 24 days measured), then 1 week off. B: meditation training 4 weeks (n = 27 days measured). The subject recorded resting HRV upon waking daily for 2 minutes with a chest-strap monitor (Elite HRV app). The athlete completed an average of 1.5 coach-assigned workouts per day (tracked by Garmin Connect) and rated school stress, workout performance, and postworkout energy levels on a 0-to-10 scale. During B, the subject added 15 minutes of breath-based meditation training on 20 of 27 days with HRV tracking at night before going to sleep (Inner Balance app, HeartMath).
OUTCOMES: Visual analysis to identify level, trend and stability between A and B was conducted for HRV (0-100 scale), school stress (0, no stress to 10, high stress), work-out performance (0, poor to 10, excellent) and amount of post work-out energy (0, no energy to 10, high energy). With meditation, median HRV level increased (A, 75.5; B, 81) and the interquartile band narrowed (A, 67.75-80; B, 76.5-82), suggesting higher overall HRV with less variability. Additionally, the subject had more days rated at peak readiness level (A, 42%; B, 60%). Median values for subjective reports of work-out performance and post workout energy increased with mediation and the subject had twice as many days with high ratings (8-10) despite increased daily workout time between A (91 minutes per day) and B (107 minutes per day). Trend lines for all measures remained level suggesting no training effect from simply measuring HRV. Ratings of school stress did not change between A and B (median, 7; 33% high-stress days).
DISCUSSION: The results of this pre-experimental AB design single case study found that for this elite triathlete, 15 minutes of breath-based HRV-tracking biofeedback meditation was associated with an increase in overall HRV combined with increased subjective reports of workout performance and energy. Further study of the benefits of HRV biofeedback meditation and the utility of the HRV index to inform athletic performance and training is warranted.

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SP0130

PATELLOFEMORAL JOINT KINETICS IN MALES AND FEMALES DURING EXERCISES ASSOCIATED WITH RETURN TO PLAY

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PURPOSE/HYPOTHESIS: Patellofemoral joint (PFJ) symptoms are particularly common among females and individuals following anterior cruciate ligament reconstruction. Mechanical loading of the PFJ is a key consideration in the development and therapeutic management of PFJ symptoms. However, PFJ kinetics across a continuum of dynamic exercises have not been previously reported. The purpose of this study was to compare PFJ kinetics across progressively dynamic tasks commonly used to prepare athletes for return to play. We also tested for sex differences in PFJ kinetics during these tasks.

NUMBER OF SUBJECTS: Forty recreational athletes (20 female; mean ± SD age, 21.3 ± 2.0 years).

MATERIALS/METHODS: Three-dimensional lower extremity kinematics (200 Hz) and ground reaction forces (1000 Hz) were collected during 8 dynamic activities performed in a random order: walking (1.5 m/s), running (3.5 m/s), sprinting (5.5 m/s), 45° cutting (3.5 m/s), double-leg jump (75% max jump height), double-leg landing, single-leg jump (75% max jump height), and single-leg landing. Estimated quadriceps, hamstring, and gastrocnemius muscle forces during 6 stance phases of the left limb were derived from these data and input to a PFJ biomechanical model. Peak PFJ contact force and impulse were evaluated using separate 2 factor (sex by condition) ANOVAs and follow-up Sidak pairwise comparisons ($\alpha = .05$).

RESULTS: A condition effect was observed for both PFJ peak force and force impulse. PFJ peak force was 5 to 7 times greater during running and jumping tasks compared to walking ($P<.001$). PFJ peak force during cutting and jumping activities was 30% greater than running and sprinting (all, $P<.001$). PFJ impulse was 2.0 to 7.5 times greater during running and jumping activities compared to walking (all, $P<.001$). Double and single-leg jumping had the largest PFJ impulse, and were over 3 times larger than running and sprinting (all, $P<.001$). PFJ peak force and impulse among males was 18% to 51% greater than females, but only during more demanding tasks including sprinting, double-leg jumping and landing, and single-leg jumps (all, $P<.001$).

CONCLUSIONS: PFJ kinetics were markedly elevated for all dynamic activities relative to walking. Single and double-leg jumping and landing expose athletes to much larger PFJ loads than running, regardless of running speed. Although PFJ symptoms are more prevalent among women, males experience greater PFJ kinetics, particularly during jumping and landing, underscoring the interaction of PFJ kinetics with additional factors such as PFJ contact area, cartilage structural and mechanical properties, or hyperalgesia to the sex bias for PFJ symptoms.

CLINICAL RELEVANCE: Dynamic activities associated with preparation to return to play expose the PFJ to disproportionately high mechanical loads. For example, the cumulative PFJ impulse associated with 2 minutes of running is achieved by only 30 submaximal double-leg jumps in males and 40 jumps in females. Exposing patients to an appropriate mechanical load through guided prescription of therapeutic exercises prior to returning to play may benefit PFJ symptom management and prevention.

SP0131

LATERAL GASTROCNEMIUS AND SOLEUS COMPENSATION, AND MEDIAL GASTROCNEMIUS ATROPHY, AFTER ACHILLES TENDON RUPTURE

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PURPOSE/HYPOTHESIS: Alterations in running and jumping mechanics have been reported in individuals after Achilles tendon rupture. The purpose of this study was to investigate differences in ankle plantar flexor muscle structure and activity during a hopping task.

NUMBER OF SUBJECTS: Eleven individuals 1 to 3 years after Achilles tendon repair and 10 individuals with healthy Achilles tendons.

MATERIALS/METHODS: Medial (MG) and lateral gastrocnemius (LG) cross-sectional area and soleus thickness were measured using B-mode ultrasound. Structural differences between injured and uninjured sides were compared using a paired t test. Surface electromyography (EMG) was used on the MG and LG along with the soleus. EMG signals were filtered, smoothed using a root mean square, and normalized to an M-wave. The maximum rate of rise and amplitude at 100 milliseconds prior to take off and landing were compared between groups using a 1-way ANOVA.

RESULTS: Soleus thickness was significantly smaller on the injured side (injured, 0.98 ± 0.33 cm; uninjured, 1.26 ± 0.17 cm; $P = .006$). There was smaller MG cross sectional area on the injured side (injured, 14.2 ± 3.2 cm^2; uninjured, 15.9 ± 4.7 cm^2; $P = .05$; effect size, 0.42) There were no significant differences in LG cross sectional area between injured and uninjured sides (injured, 8.7 ± 1.7 cm^2; uninjured, 9.1 ± 2.1 cm^2; $P = .52$). During takeoff, the maximum rate of rise in the LG significantly increased from control to uninjured side to injured side (control, 0.21 ± 0.27 s^{-1}; uninjured, 0.43 ± 0.33 s^{-1}; injured, 0.78 ± 0.63 s^{-1}; $P = .02$). There were no other differences between groups for maximum rate of rise during takeoff or landing ($P>.05$). At 100 milliseconds prior to landing, LG and soleus amplitude of activity significantly increased from control to uninjured side to injured side (LG: control, 0.9% ± 0.5%; uninjured, 1.6% ± 0.7%; injured, 2.3% ± 1.0% of M-wave peak-to-peak amplitude; $P = .003$ and soleus: control, 0.8% ± 0.4%; uninjured, 1.5% ± 1.2%; injured, 1.9% ± 0.9% of M-wave peak-to-peak amplitude; $P = .02$). There were no differences in amplitude between groups in the MG ($P = .60$) at landing, and no differences in amplitude prior to takeoff between groups in any muscle.

CONCLUSIONS: The muscles of the triceps surae are affected differently after Achilles tendon repair. The lateral gastrocnemius appears to compensate, evidenced by alterations in EMG rate of rise and comparable cross-sectional area compared to the uninjured side. The medial gastrocnemius, however, appears to atrophy rather than compensate for the injury. Soleus is structurally affected by injury, and appears to compensate by increasing amplitude of activation.

CLINICAL RELEVANCE: It may be important to consider the different roles of the triceps surae musculature and their propensity to compensate following Achilles tendon rupture. It may be that strategies specifically targeting the medial gastrocnemius and soleus are warranted.

SP0132

USING KING-DEVICK AND MODIFIED CLINICAL TEST OF SENSORY INTERACTION IN BALANCE SCORES TO ASSESS EFFECT OF A SOCCER HEADING DRILL ON ADOLESCENT FEMALE SOCCER PLAYERS

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PURPOSE/HYPOTHESIS: Concussive and subconcussive events remain prevalent in adolescent athletes, especially female soccer players. Numerous sideline concussion screening assessments have been developed to quickly diagnose players, and guidelines have been established to limit the number of headers in players aged 11 to 13 years old. Studies have shown that heading the ball in a controlled environment does not influence concussion screening assessments. The purpose of this study was to evaluate the effect of a soccer heading drill performed during a typical practice session using 2 concussion screening metrics.

NUMBER OF SUBJECTS: Eleven.

MATERIALS/METHODS: Preseason baseline metrics were taken on eleven female, high school varsity soccer players (mean ± SD age, 16.6 ± 1.4 years) using King-Devick (K-D) and Biodex Biosway Balance Assessment (CTSIB-M). CTSIB-M scores for both sway index and impairment per-

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centage were recorded. K-D and CTSIB-M tests were repeated 3 weeks later immediately following a heading drill (HD). Number of headers and acceleration data during HD was recorded by Triax head impact monitoring system. Mean baseline test scores were statistically compared to mean posttest scores utilizing a Wilcoxon signed-ranks test.

RESULTS: Each subject had a mean average ± SD of 6 ± 2.9 headers during the drill. The mean minimum to maximum linear acceleration of each header ranged from 27.5 ± 3.4 *g* to 57.4 ± 9.9 *g*. There were no significant differences between baseline scores and posttest scores on either the K-D or CTSIB-M tests. Mean baseline K-D score was 42.9 ± 6.8 while mean posttest score was 41.6 ± 4.9. The Wilcoxon signed-ranks test for K-D scores was $z = -0.89$, $P = .37$. Both mean baseline and posttest scores for CTSIB-M sway index were 0.8 ± 0.1 with $z = -1.38$, $P = .17$. Mean baseline scores for CTSIB-M impairment percentage was 0.8 ± 2.7 while mean posttest score was 0 ± 0, with $z = -1.00$, $P = .32$.

CONCLUSIONS: These findings are consistent with the hypothesis that a single standard soccer heading drill does not affect K-D and CTSIB-M metrics.

CLINICAL RELEVANCE: This study indicates that a single session of a soccer heading drill does not affect performance on the K-D and CTSIB-M. Musculoskeletal and concussion injuries may be primed by pre-existing altered movement patterns from previous injuries, concussive events, or from forces incurred during sports participation, like a soccer heading drill. Subconcussive impacts may manifest themselves without signs of obvious deficits in postural stability, vestibulo-ocular function, or balance deficits. Therefore, continual assessment of performance for subtle signs may be the first step in concussion prevention. K-D and CTSIB-M are performance metrics which might be used to identify cumulative performance deficits over the course of an entire soccer season. Further studies with larger sample sizes and multiple heading drills remain to be performed.

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Blood Flow Restriction Resistance Exercise as a Rehabilitation Modality Following Orthopaedic Surgery: A Review of Venous Thromboembolism Risk

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Orthopaedic surgery to address lower extremity musculoskeletal injury and disease is among the most routinely performed procedures in the United States.[55] It has been estimated that 60% of the surgeries conducted by orthopaedic physicians involve the knee joint,[103] which may include meniscal repairs, ligament reconstructions, or total knee arthroplasties. Despite widespread attention on musculoskeletal injury and disease prevention, the number of total knee and hip arthroplasties is projected to grow by 673% and 174%, respectively, by 2030.[59]

Following surgery, the primary physical rehabilitation goals are to resolve the patient's pain and effectively re-establish normal joint movement, muscle mass, strength, and function.[126] Achieving these goals is crucial for successful outcomes, which may include the ability to complete activities of daily living, return to a demanding occupation or sport, reduce secondary injury risk, and mitigate the development of such health complications as osteoarthritis, osteoporosis, and chronic disease.[135]

To effectively enhance muscle size and strength, professionals recommend performing resistance exercise at an intensity greater than 70% of maximum strength under normal training conditions.[57] Yet, in the early stages of rehabilitation, the postsurgical patient is often restricted by his or her initial atrophic state, arthrogenic muscle inhibition, and a desire to protect the surgically repaired limb.[42] These patients often cannot complete resistance exercise at the preferred intensities, instead exercising at lower intensities,[126] which may lead to an incomplete restoration of muscle mass and strength that persists after rehabilitation.[96] Blood flow restriction (BFR) resistance exercise is an attractive candidate to supplement low-intensity physical rehabilitation exercises to achieve a similar degree of muscle mass and strength restoration attributed to high-intensity resistance exercise.[38,46]

During BFR, a low-intensity resistive load, such as 20% to 30% of maximum

SYNOPSIS: Restoration of skeletal muscle mass and strength is critical to successful outcomes following orthopaedic surgery. Blood flow restriction (BFR) resistance exercise has emerged as a promising means of augmenting traditional low-intensity physical rehabilitation exercise and has yielded successful outcomes in a wide range of applications. Though BFR is well tolerated and safe for most individuals, patients who have undergone orthopaedic surgery may be an exception, due to their heightened risk for venous thromboembolism (VTE). While the pathogenesis of VTE is multifactorial and specific to the individual, it is commonly described as a combination of blood stasis, endothelial injury, and alterations in the constituents of the blood leading to hypercoagulability. The collective literature suggests that, given the pathogenic mechanisms of VTE, limited use of a wide, partially occluding cuff during resistance exercise should be low risk, and the likelihood that BFR would directly cause a VTE event is remote. Alternatively, it is plausible that BFR may enhance blood flow and promote fibrinolysis. Of greater concern is the individual with pre-existing asymptomatic VTE, which could be dislodged during BFR. However, it is unknown whether the direct risk associated with BFR is greater than the risk accompanying traditional exercise alone. Presently, there are no universally agreed-upon standards indicating which postsurgical orthopaedic patients may perform BFR safely. While excluding all these patients from BFR may be overly cautious, clinicians need to thoroughly screen for VTE signs and symptoms, be cognizant of each patient's risk factors, and use proper equipment and prescription methods prior to initiating BFR. *J Orthop Sports Phys Ther 2019;49(1):17-27. Epub 12 Sep 2018. doi:10.2519/jospt.2019.8375*

KEY WORDS: *blood stasis, endothelial injury, hypercoagulability, occlusion, tourniquet*

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strength,[98] and an external inflation cuff placed around the proximal portion of the exercising limb are used in an effort to partially occlude the underlying vasculature that likely initiates muscle hypoxia and metabolic stress.[69,77,117] There are several synergistic physiological mechanisms that appear to facilitate BFR adaptations, which may include increased anabolic hormone production,[100,105,120,121] acute skeletal muscle swelling,[66,134] increased cell signaling for pathways related to muscle protein synthesis,[23,27,28,35,130] suppressed negative growth regulators,[61] decreased cell signaling for pathways resulting in muscle protein breakdown,[78] altered muscle fiber–type recruitment associated with hypoxia and fatigue,[9,17,24,52,84,124,132] and a heightened accumulation of metabolites.[28,30,105,120] Professionals using this modality have demonstrated successful outcomes in a variety of applications,[98] including rehabilitation from knee osteoarthritis,[112] osteochondral fracture,[72] inflammatory myositis,[80] muscular weakness from disuse,[13,14,37] sarcopenia,[15,54,127] anterior cruciate ligament reconstruction,[93,122] Achilles tendon rupture,[137] and nonreconstructive knee arthroscopy.[125]

Efficacy and patient safety associated with any new rehabilitation modality are necessary concerns for the health care team. Thus far, BFR is generally well tolerated and regarded as safe for most healthy, active adults.[6,11,51,71] Advancements in BFR science and technology, cuff pressure prescription techniques, and cuff designs have been pursued to enhance safety.

Some clinicians may use rudimentary techniques to achieve occlusion, such as surgical tubing or elastic straps wrapped tightly around the proximal portion of the exercising limb.[73,74,98,134] This method may or may not completely occlude all arterial and venous blood flow, and there is no way of knowing what occlusive pressure the vessels experience. Further, the relatively thin diameter of the tubing or straps may cause highly localized stresses and an ineffective transmission of pressure,[19,33,34,90] potentially causing direct damage to the soft tissues and structures underneath the application site.

The cuffs developed for BFR are wider than those traditionally used. The most frequently used cuff width is 10 to 12 cm, although cuffs greater than 15 cm may be more desirable.[19,98] Additionally, cuffs are now tapered to conform with the natural proximal-to-distal narrowing of the thigh or upper arm and are limb-circumference specific, which allows them to be fitted to various limb circumferences. Together, these advances enhance the transmission of pressure, and may appropriately mitigate complications caused by finely localized stresses from the cuff itself and reduce the pressure required to reach the same level of occlusion achieved with narrower cuffs.[19,33,34,64,65,67,68,90]

Blood flow restriction cuff pressure prescription methods have included a standard pressure for all patients, such as 180 mmHg; a pressure relative to the patient's systolic blood pressure, such as 1.2- or 1.5-fold greater than systolic blood pressure; or a pressure relative to the patient's thigh circumference.[70,98,101,114,131] A pressure specific to each individual would be the safest prescription method, because the same pressure may not necessarily occlude the same amount of blood flow for all individuals under the same conditions.

Devices and procedures specifically designed for BFR have been developed to individualize the pressure for each patient using plethysmography or Doppler ultrasound to detect blood flow.[25,61,125] At rest, cuff pressure is slowly increased until the flow of blood is no longer detected, a term frequently referred to as total limb occlusion pressure (LOP) or arterial occlusion pressure (AOP). A submaximal percentage (eg, 40%-80%) of that pressure is prescribed for the exercise session.[98,125] This pressure prescription method ensures that patients are not exercising with a pressure that is too high relative to their systolic blood pressure, and accounts for the volume and density of soft tissue underneath the cuff. Further, this method allows for appropriate progression of the pressure, similar to the way a clinician would progress resistive load, repetitions performed per set, and total number of sets performed for a resistance exercise. Despite this sensible approach to prescribing BFR cuff pressure based on the individual, this prescription method is not being used as frequently as other prescription methods.[98]

An important consideration is that systolic blood pressure will rise during exercise; thus, the pressure prescribed at rest to achieve a given submaximal degree of occlusion is most likely occluding blood flow to a lower degree when exercise is initiated. However, alterations in soft tissue volume beneath the BFR cuff may occur due to skeletal muscle contraction and relaxation, which may rapidly increase and decrease the relative pressure.[51] Blood flow restriction devices are available that quickly regulate the cuff pressure in response to these rapid changes, likely narrowing the excursion in the relative pressure from what was prescribed at rest during skeletal muscle relaxation. Nevertheless, research demonstrates that pressures lower than those previously believed to be required may cause similar muscle mass and strength increases compared to traditional resistance exercise,[17,53] which would further enhance safety and warrants continued investigation.

The concern regarding the potential for BFR to increase the risk of venous thromboembolism (VTE), which may present as deep vein thrombosis (DVT) or pulmonary embolism (PE), remains for some clinicians,[98] especially for their postsurgical patients. This concern is valid because, while the occurrence of DVT is 3-fold that of PE,[92] PE can be fatal and is responsible for more than 150 000 deaths per year in the United States.[43] Those who survive an acute VTE event may develop severe postthrombotic syndrome and are often subject to significant, lifelong reductions in health and well-being.[111] Venous thromboembolism has been predicted to occur in approximately 1 to 2 per 1000 people in a

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given year in the general population,[107] although the risk of VTE is increased nearly 100-fold for postsurgical patients in the first 6 weeks following surgery.[118]

Venous thromboembolism risk is multifactorial for any patient, which makes predicting those who are most likely to have a VTE event very difficult.[3,31] While all people are at risk for VTE, the foremost determinants of VTE risk may be hereditary or acquired.[3,31] Hereditary risk factors are generally associated with inherited thrombophilia.[3,31] Spontaneous VTE rarely arises from hereditary factors alone, however, so it is commonly believed that an acquired factor must also be present.[3,31] Approximately 50% of patients who develop a clinically diagnosed VTE have 3 or more acquired risk factors present at the time of diagnosis, including more than 48 hours of immobility in the preceding month; hospital admission, surgery, malignancy, or infection in the past 3 months; or current hospital admission.[115] Risk for VTE appears to be magnified exponentially with additional risk factors, especially if the patient has inherited thrombophilia.[91]

While there have been many attempts to quantify VTE risk, there is no universally accepted model.[7,32] In this context, risk factors combine until a theoretical threshold is reached in which a VTE event occurs; however, the definition of this theoretical threshold is elusive and is likely different for each individual.[62] Nevertheless, most models use a point scale to define risk for broad categories of factors and stratify patients into risk groups using the sum of the points, such as the Caprini risk assessment model.[7]

To truly understand VTE risk in postsurgical orthopaedic patients performing BFR, it is imperative that the incidence rate be established. Presently, there is available in the literature only 1 large-scale study assessing the incidence of VTE in patients completing BFR.[85] Although the study demonstrated that the rate of VTE was lower than that of the general Asian-American population, a number of critical issues severely limit the strength of these findings.[85] A large number of clinical trials are presently being conducted in a variety of postsurgical populations, and, collectively, the reported incidence of any adverse events associated with BFR is extremely rare.[6,87]

However, until the incidence rate is quantitatively defined for postsurgical orthopaedic patients, professionals may, at best, theorize the effects of BFR on the physiological catalysts associated with VTE. While the coagulation (eg, formation of fibrin clots) and fibrinolytic (eg, breakdown of fibrin clots) systems are complex, a commonly accepted model describing the pathogenesis of VTE is Virchow's triad.[58] This triad, developed in the mid 19th century, suggests that VTE occurs as a result of stasis, endothelial injury, and acute or chronic alterations in the constituents of the blood leading to a hypercoagulable state.[58]

STASIS

There is no doubt that BFR causes a temporary partial restriction of blood flow; indeed, the goal of this modality is to initiate hypoxia and metabolic stress by limiting the arterial inflow of oxygenated blood and venous outflow of blood containing metabolites.[69,77,117] Most individuals associate stasis with tourniquets, such as those used in the operating room or on the battlefield to prevent significant blood loss and save a life, although the acute use of a tourniquet in the absence of other factors is not necessarily associated with VTE.[25,39,50,90]

While surgical tourniquets and BFR cuffs share many characteristics, there are several important differences in their function and application. For example, final BFR cuff inflation pressure is typically between 50 and 200 mmHg.[98] These values coincide with a submaximal LOP or AOP between 40% and 80%, which allows for some blood flow to be maintained. This is much lower than the 300 mmHg routinely used in the operating room for lower extremity surgeries that causes complete arterial and venous occlusion.[25] Further, using standard set and repetition prescriptions, the BFR cuff will be inflated for approximately 5 to 10 minutes per exercise.[98,125] Additional exercises may be performed, but the cuff is deflated between them. Maximal BFR cuff inflation time per exercise session likely does not exceed most typical tourniquet times in the operating room, and certainly does not exceed the often-cited 2-hour tourniquet time limit used in the operating room.[25,129]

Stasis may also occur as a result of immobility, for instance, following injury or trauma, during the surgery itself or acute recovery, or in extended periods of sitting (eg, plane or car travel). Movement of the blood in the distal region of the venous system is assisted by the compressive force of the muscles surrounding it (eg, muscle pump). Without muscle pump, the blood tends to pool in the areas surrounding the valve sinuses, increasing the likelihood for coagulation. This may be why extended immobility for more than 48 hours is so strongly associated with subsequent VTE events.[115]

The presence of muscle pump also highlights another difference between operating-room tourniquet and BFR cuff application. During orthopaedic surgery and short-term recovery, patients are immobile due to anesthesia, and may be bradycardic and hypotensive, increasing the likelihood of a degree of systemic stasis. During BFR, the patient is mobile, heart rate and blood pressure rise to sustain exercise, and muscle pump is occurring. This means that temporary partial blood flow is localized to the limb performing BFR, and that normal blood flow is likely resumed as soon as the cuff is deflated.

Intermittent pneumatic compression (IPC), applied with a cuff similar to that used during BFR, has been employed by physicians for centuries as a way to prevent stasis during periods of immobility and to improve blood flow. During IPC, a cuff is repeatedly inflated to a given pressure and then deflated in a cyclic fashion to provide sequential compressive stimuli

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to the underlying soft tissue and vasculature. These repetitive stimuli provide several proposed biochemical and mechanical benefits.[10] From a mechanical standpoint, IPC acts much like the compressive force of normal, rhythmic muscle contractions during locomotion. This enhances venous return, prevents stasis, and facilitates the clearance of valve sinuses when an immobile individual's own muscle pump cannot do so.[10,97] Biochemically, the rapid acceleration of blood also increases the secretion of nitric oxide from the endothelial cells, dilating the vessels and improving blood flow.[10]

One additional benefit of using a wider cuff that encompasses a larger volume of soft tissue, other than the lower required pressures, is that these mechanical and biochemical benefits may be greater than when a narrow cuff is used. While outside the scope of this paper, it is interesting to consider that other modalities, such as foam rolling or massage, may have similar effects on these tissues and the vasculature and are performed with higher frequency than BFR or IPC.

Although BFR causes a temporary localized reduction in blood flow in the exercising limb, complete occlusion is not achieved; it occurs for a relatively short time compared to traditional operating-room tourniquet use, and normal blood flow is resumed immediately following cuff deflation. While the compressive stimulus from the cuff during BFR is not repetitive as that during IPC, it is plausible that combining the effects of a single compressive force from the BFR cuff with the cyclic nature of muscle contractions during resistance exercise may enhance the ejection of the blood in the vasculature of the lower extremity after cuff deflation. To this effect, some evidence suggests that BFR facilitates a chronic enhancement in vascular function and blood flow compared to low-intensity resistance training alone.[48,99] When considering the mechanisms of stasis, and its contribution to the development of VTE, it seems that the very finite use of a wide, partially occluding cuff would likely be of small risk. Indeed, to date, BFR exercise has been performed in healthy individuals with single-limb immobility, via the unilateral lower-limb suspension model, with no adverse events.[13,37]

ENDOTHELIAL INJURY

In the context of orthopaedic surgery, physicians are not operating directly on the vasculature itself, so endothelial damage must arise from other sources. While it is well known that skeletal fractures can cause severe vasculature damage, injuries in which no skeletal fracture occurs can cause great harm as well. For example, the aberrant motion during knee joint dislocations may cause vascular damage to the popliteal artery, even though no surgery may be required to restore the musculoskeletal integrity of the joint.[83] Other musculoskeletal injuries, such as ligament ruptures, often require reconstructive surgery to restore stability to the joint. In this situation, vascular damage may occur as a result of the invasiveness of the surgical procedure and retraction in the operating room. As this can vary between physicians and the type of surgical procedure performed, this is likely the most important variable with regard to endothelial injury and BFR.

To illustrate this point, total hip and knee arthroplasty procedures are highly invasive because they require open surgical techniques, involve vigorous retraction in the operating room, and include significant insult to the joint's bone and articular cartilage surfaces. By contrast, knee ligament reconstructions are less invasive, which is likely why the incidence of VTE is lower following these procedures compared to knee and hip joint arthroplasties.[133] It is important to remember that all orthopaedic surgeries will cause some degree of vascular damage, even those performed arthroscopically.

As discussed previously, the development of new BFR science and technology, cuff pressure prescription techniques, and cuff designs safely disperses the compressive cuff pressures over a larger surface area and most likely does not cause focal stresses on the vasculature that could lead to permanent damage.[19,33,34,90] It is plausible that previous vasculature injury could be reinjured by the direct application of the BFR cuff, especially if it is in the area underneath the cuff application site and a relatively thin BFR cuff is used.[19,33,34,90] From a systemic perspective, some clinicians may be concerned that sudden, significant changes in hemodynamics could potentially reinjure the vasculature.[98,136] Transient alterations in hemodynamics such as blood pressure, heart rate, and mean arterial pressure during BFR have been investigated in numerous studies, and it has been shown that these alterations are comparable to those demonstrated during traditional resistance exercise.[22,88,102,106,109,110,120,128,136]

Ischemic-reperfusion injury is often a concern during surgical procedures that involve the extended use of narrow, high-pressure tourniquets, especially with tourniquet times exceeding 2 hours.[5,8,25,129] Although durations of ischemia exceeding 3 hours can cause severe damage, cell apoptosis can occur as a result of ischemia with shorter durations of occlusion.[5,8,129] The reperfusion of blood mobilizes the byproducts associated with the ischemic environment, causing further injury.[5,8,129] Cardiovascular disease appears to enhance these risks.[8,129] Preconditioning or exposure to short periods of ischemia and reperfusion may improve resistance to these ischemic episodes,[36] and while there is some evidence that BFR could cause an ischemic-reperfusion injury,[106] there is also evidence to suggest that BFR provides similar preconditioning, protective effects.[77,131] The specific effect likely depends on the duration of occlusion, the occlusive pressure, and the patient's experience with BFR.

If BFR is considered on a continuum of ischemic-reperfusion injury, with true ischemic-reperfusion injury being the most severe, then BFR would be on the low end of the continuum. In essence, BFR is trying to stimulate an ischemic response that heightens the accumulation

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of metabolic byproducts to drive adaptation.[28,30,105,120] Nevertheless, the controlled use of a wide, partially occluding cuff during a proper prescription of BFR likely would only increase the risk of endothelial damage slightly above the trivial risk already associated with traditional resistance exercise.

HYPERCOAGULABILITY

Under homeostatic conditions, there is a dynamic equilibrium between coagulation and fibrinolysis.[29,60] When the endothelium is damaged, a cascade is initiated that shifts this equilibrium in favor of coagulation.[29,60] This cascade involves the synergistic function of several coagulation factors and regulators.[29,60] Changes in the function or availability of these constituents may increase or decrease the intensity of the coagulation response.[29,60] While the activation of the coagulation cascade may enhance the necessary clotting tendency at the site of the endothelial damage to repair itself, it may unnecessarily cause thrombogenesis in other areas of the body, due to the systemic nature of the cascade.[29,60]

The most frequent causes of inherited thrombophilia that cause hypercoagulability include the factor V Leiden mutation and prothrombin, protein S, protein C, and antithrombin deficiencies.[20] The prevalence of these types of thrombophilia in the general population is low.[44,79] However, their existence most likely plays a significant role in whether an individual has a VTE episode, because these types of thrombophilia exponentially magnify the odds of developing VTE when combined with additional risk factors.[91]

With regard to acquired hypercoagulability, postsurgical patients are at a high risk for VTE due to the degree of endothelial damage that likely occurs as a result of initial musculoskeletal injury and reconstructive surgery.[63] Unfortunately, it is generally unknown how long after the inciting event hypercoagulability returns to baseline levels and the equilibrium between coagulation and fibrinolysis is restored. While VTE risk is highest in the first 6 weeks following surgery,[118] the exact duration of hypercoagulability is likely case and individual specific.

A number of studies have demonstrated that IPC reduces coagulation and enhances fibrinolysis.[2,10,12,16,40,41,45,49,81,82,89,108,113,116,123] In fact, several studies have investigated the use of IPC as an alternative or adjunct to prophylaxis and demonstrated successful results for a number of postsurgical orthopaedic patients, including those with total joint replacements.[26,47,95]

During IPC, the rapid stretch on the lumen from the accelerated blood and the increase in stress due to increased blood flow velocity catalyze several biochemical responses.[10] These responses are not localized, because the biochemicals enter circulation and have positive effects systemically. For example, it has been demonstrated that IPC performed on the arms effectively reduced the incidence of DVT in the legs.[56] Regular aerobic and resistance exercise catalyzes a similar shift in the equilibrium,[21] which may be due to the increase in cardiac output, blood flow velocity, and stress on the endothelium. Combining the effects of BFR cuff compression with resistance exercise may further magnify these biochemical responses.[119]

To date, studies examining the effects of BFR on markers of thrombogenesis and fibrinolysis have been isolated to nonpostsurgical patients.[11,27,75,76,86] The literature appears to indicate that BFR, when used by healthy adults and patients with cardiovascular disease, is not associated with changes in biochemical markers associated with thrombogenesis, which include the protein fibrillar, prothrombin fragments, thrombin-antithrombin complexes, D-dimer, or other fibrin degradation products.[11,27,75,76,86] It also seems that BFR stimulates an increase in the secretion and expression of tissue plasminogen activator in these populations, which is a marker of fibrinolysis.[11,27,75,76,86] Even though it is unclear whether traditional resistance exercise would have the same effect as BFR alone on markers of thrombogenesis and fibrinolysis, BFR does not appear to lead to hypercoagulability, and a proper prescription of BFR may shift the formation-breakdown equilibrium in favor of fibrinolysis.

RECOMMENDATIONS FOR PATIENTS FOLLOWING ORTHOPAEDIC SURGERY

The collective literature appears to indicate that a proper prescription of BFR poses little risk of directly causing a VTE event. Before prescribing BFR, the health care professional should assess each patient for signs and symptoms of DVT and PE. Signs and symptoms of DVT may include unexplained swelling, pain, cramping, or soreness, red or discolored skin, or a feeling of warmth in the affected limb. If left untreated, signs and symptoms of PE may develop, which include shortness of breath, chest pain or discomfort, rapid heart rate, feeling of light-headedness or dizziness, fainting, or coughing up blood. If a VTE event is suspected, then BFR should not be prescribed and the patient should seek medical attention immediately.

Perhaps a greater concern for the clinician is when a patient has asymptomatic VTE. There would then be a possibility of dislodging a thrombus in the vasculature underneath or near the cuff application site, potentially causing a PE event; however, the degree of risk associated with BFR compared to the risk associated with traditional exercise alone is unknown. This is relevant because the BFR cuff for lower extremity exercise is placed around the proximal thigh, and VTE occurs more often above the knee than below the knee.[133]

Because an asymptomatic VTE event cannot be detected without costly, time-consuming, and potentially unreliable phlebography or sonography,[18] the health care team needs to use sound judgment to determine which postsurgical orthopaedic patients may safely complete

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BFR. This determination should involve discussion among the patient, the operating physician, and the rehabilitation clinician administering BFR. Because VTE risk is highest in the first 6 weeks following surgery,[118] some health care teams may choose to wait until after this period to prescribe BFR. However, this is also a time frame when the patient may stand to benefit most from BFR.

An attempt to quantify the patient's risk for VTE should also be made. This may be done using BFR-specific risk questionnaires or general VTE risk questionnaires.[7,51] A simple screening of the patient for risk factors related to Virchow's triad may also be sufficient. Some of these conditions are discussed in the **TABLE**.

Regarding stasis, this screening may include, but is not limited to, anatomical alignment disorders, pregnancy, cardiovascular diseases, immobility, and obesity, as these conditions obstruct or alter the normal flow of blood.[3,31] For example, conditions such as Paget-Schroetter or May-Thurner syndrome may disrupt the normal flow of blood by altering the anatomical alignment of the circulatory system, causing impingement in the underlying vasculature. Because these anatomical alignment conditions are uncommon, it would be cost prohibitive to screen each individual in whom the status of these conditions is unknown. Pregnancy is associated with an increased risk for stasis due to the obstruction of venous return by the enlarged uterus compressing the surrounding vasculature in the lower abdomen. Cardiovascular diseases such as heart failure may reduce the efficiency of the heart to circulate blood, making it more likely to pool in the distal extremities, and atherosclerotic vessels may cause a pooling of blood behind the blockage. However, BFR has been prescribed to patients with cardiovascular disease without any adverse events.[75]

Perhaps most importantly, episodes of recent immobility must be considered in regard to stasis, especially because it is so closely associated with subsequent episodes of VTE.[115] Patients with extended stints of immobility, which may be related to the initial trauma, type of anesthesia, duration of surgery, or postsurgical complications such as infection or illness, as well as those with nerve damage or a degree of paralysis, may be poor candidates for BFR. Ideal candidates for BFR are those who can ambulate freely, are generally active, do not have a known temporary or permanent condition that alters the flow of blood, and can perform traditional resistance exercise safely, albeit not at the high intensities associated with traditional resistance training.

Regarding endothelial damage, the severity of the initial trauma as well as the invasiveness of the surgery must be considered.[3,31] Unfortunately, it is not possible to precisely grade the amount of endothelial damage to estimate the intensity of the coagulation response. Further, the multifactorial nature of VTE makes it difficult and somewhat subjective to determine overall VTE risk for each individual patient.[3,31] If specific musculoskeletal injuries and orthopaedic surgeries are considered on a low-to-high risk spectrum, certain health care professionals may categorize a patient as low risk, whereas others may consider the same patient high risk.

Pre-existing endothelial damage unrelated to the initial trauma or injury must also be considered. Open and unhealed soft tissue injuries or additional surgeries performed after orthopaedic surgery may continue to cause hypercoagulability, even if these wounds or surgeries are not on the limb in which BFR may be performed. Ideal candidates for BFR with regard to endothelial injury are those with less traumatic injuries and invasive orthopaedic surgeries, limited endothelial injury or vascular compromise, no open or unhealed soft tissue injuries, and an operative site that will not be directly underneath the cuff application site.

Pre-existing causes of hypercoagulability, including but not limited to thrombophilia, pregnancy or postpartum, sickle cell trait or anemia, oral contraceptive use, implanted biomedical devices, or infection, must also be considered.[3,31,91] Perhaps the most important hyperco-

TABLE Possible Contraindications for Blood Flow Restriction Resistance Exercise as Related to Venous Thromboembolism Risk for Patients Following Orthopaedic Surgery*

- Abnormal clotting times
- Acid-base imbalance/acidosis
- Age older than 40 years
- Arterial calcification
- Atherosclerotic vessels
- Cardiopulmonary conditions
- Creatine supplement use
- Diabetes
- Dialysis/central venous access
- General/local infection
- High intracranial pressure
- Hip, pelvis, or femur fracture
- History of venous thromboembolism
- Hormonal contraceptive use
- Hypertension
- Immobility for greater than 48 hours in the past month
- Immobilizing cast
- Implanted medical device
- Lymphectomies
- Obesity
- Open fracture
- Open or unhealed soft tissue injuries
- Paralysis
- Peripheral vascular disease
- Pregnancy/postpartum
- Prior revascularization
- Renal compromise
- Severe crush injuries
- Sickle cell trait/anemia
- Skin grafts
- Stroke
- Temporary nerve damage
- Thrombophilia
- Tumor/cancer
- Varicose veins
- Vascular grafting

**This list is not exhaustive, and a given health organization may consider one suggestion a precaution while another may consider it a contraindication. Possible contraindications are presented in alphabetical order.*

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agulability risk factor to screen for is a personal or family history of VTE.[4] It has been demonstrated that the risk of recurrence of VTE in the general population, regardless of cause, is approximately 5%, 18%, 25%, and 30% at 3 months, 2 years, 5 years, and 8 years, respectively.[104] The risk of recurrence is increased or decreased depending on factors related to the initial cause of the specific patient's VTE.[104] For example, while chronic factors such as cancer, thrombophilia, or thrombotic syndrome increase the risk for VTE recurrence, transient factors such as trauma, injury, or surgery have little effect on the risk of recurrence.[104] Thus, some individuals who had a prior VTE event may be permitted to perform BFR without additional risk factors present. However, the acquired risk factor of the most recent orthopaedic surgery may make these patients poor candidates for BFR.

When BFR is prescribed after a thorough review of the risks and benefits, it would likely be appropriate to familiarize the patient with BFR in a progressive manner. For example, while BFR cuff inflation pressures greater than 50% of LOP or AOP are often used,[98,125] it may be appropriate to begin with a lower pressure or no pressure at all (eg, apply the cuff but do not inflate it) to allow the patient to become comfortable. Then, progress the inflation pressure each BFR exercise session until the target pressure is reached. Similarly, inflation duration may be progressed from less than 1 minute to times more aligned with traditional BFR prescriptions.[98]

With regard to ischemic-reperfusion injury, these progressions may serve as an appropriate preconditioning measure.[36] Some BFR equipment manufacturers have incorporated protocols similar to IPC that are accomplished before starting BFR. These protocols involve progressive incremental inflation and deflation of the cuff until the final exercise pressure is reached.[1,94] This approach may be followed prior to full BFR cuff inflation during each exercise session, making BFR exercise more tolerable for the patient.

CONCLUSION

The VTE risk associated with BFR is likely similar to that of traditional high-intensity resistance exercise in healthy, active adults, yet the postsurgical patient has additional considerations. While the risk is probably small for most patients, the implications of VTE can be severe. The collective literature suggests that a proper prescription of BFR in the context of Virchow's triad would not heighten the risk of developing VTE. Nonetheless, clinicians need to thoroughly screen for VTE signs and symptoms and be cognizant of each patient's VTE risk factors before proceeding with BFR, particularly given the risk of asymptomatic DVT. Health care professionals must also make sure they have the proper training and are using the correct BFR equipment and pressure prescription techniques to ensure their patients' safety.

Unfortunately, there are no universally agreed-upon standards outlining which postsurgical orthopaedic patients may safely perform BFR. As a result, subjective decisions by health care professionals need to be made for each patient before performing BFR. These decisions are based on clinicians' level of comfort with BFR, understanding of its physiological mechanisms, and perception of its risks. As BFR is presently a novel, emerging form of rehabilitation exercise, exposure among physicians, physical therapists, and other orthopaedic and sports medicine professionals is generally low. There is no doubt that additional research is needed to quantifiably understand VTE risk when performing BFR following different types of orthopaedic surgery.

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Persistent Pain After Wrist or Hand Fracture: Development and Validation of a Prognostic Model

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BACKGROUND: Worldwide, the incidence of wrist fracture is increasing. There are currently no externally validated prognostic models to inform early decision making for these patients.

OBJECTIVES: To develop and validate a prognostic model from a comprehensive range of candidate prognostic factors that can identify patients who are at risk of developing persistent pain following wrist or hand fracture.

METHODS: We developed and validated a prognostic model using secondary data derived from a prospective cohort study (n = 715), with recruitment sites in 3 metropolitan hospitals in Sydney, Australia. The primary outcome was persistent pain 4 months following the injury. The current study used a backward stepwise regression analysis to develop the model in 2 hospitals (n = 408) and externally validate it in a third hospital (n = 307). To determine the accuracy of the model, we assessed calibration and discrimination in accordance with the PROGnosis RESearch Strategy framework.

RESULTS: Complete data were available for 95% of the cohort. Of 14 candidate variables, the final model contained 2 prognostic factors: patient age and pain intensity reported at initial presentation. The area under the receiver operating characteristic curve was 0.63 (95% confidence interval: 0.56, 0.69) in the development sample and 0.61 (95% confidence interval: 0.51, 0.70) in the validation sample. The model systematically overestimated risk (intercept, −1.13; slope, 0.73).

CONCLUSION: We developed and externally validated a prognostic model to predict persistent pain 4 months after a wrist or hand fracture. Future studies are needed to assess whether the accuracy of this model can be improved by updating and validating it in local settings.

LEVEL OF EVIDENCE: Prognosis, level 1b.
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KEY WORDS: *hand fracture, persistent pain, prognostic model, rehabilitation, wrist fracture*

Worldwide, the incidence of wrist fracture, most commonly of the distal radius,[2] is increasing.[20] For example, in Australia, the incidence of wrist fracture has been predicted to rise 81% by 2021 in persons aged 50 years or older due to the country's aging population.[45] Wrist fracture contributes a substantial economic burden to both the individual and society. In the United States, the median total cost per case is estimated to be $6951 (interquartile range, $3357-$22274).[31]

For most patients, pain following wrist fracture has either resolved or is of mild/minimal severity by 3 months after injury.[18] However, for approximately 20% of patients, pain persists beyond 3 months and can be associated with substantial disability.[18]

Early identification of patients who are at risk of poor clinical outcomes can inform clinical decision making.[38] Prognostic models can identify patients at higher risk of poor outcomes, such as persistent pain. This information can also assist health care systems to allocate appropriate resources according to patient need,[38,42] leading to stratified care, in which treatment decisions are guided by an individual's prognostic profile.[30] Stratifying care according to patient risk profile has proven to be effective in other musculoskeletal conditions, such as low back pain,[11,42] and has recently been included in clinical guidelines for the management of low back pain.[25,44] Prognostic models have

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been shown to improve primary care efficiency, improving health outcomes and reducing health care costs.[11] There is potential for similar benefits if care for common musculoskeletal conditions were stratified based on prognosis.[43]

Research has identified individual factors that are associated with poor outcomes or prognostic factors in wrist fracture, such as baseline pain,[21,40] age,[3,5,32,33] bone mineral density,[33] grip strength,[14,40] injury compensation,[7,17] education and socioeconomic status,[3,7,17,27] radiographic variables,[1,5,17] and psychological distress.[32,41,46] It is not known, however, whether these factors can be combined in a prognostic model to improve the identification of patients at risk of poor outcomes.[28]

For a prognostic model to be considered clinically useful, it must be easy to use, be able to predict outcome with acceptable accuracy, and be validated in external samples. Most importantly, use of the model should be demonstrated to improve outcomes compared to best care, for example, in a randomized trial. Although a prognostic model has been published for patients following wrist fracture,[21] it has not been externally validated, a step that is encouraged to minimize the potential of overfitting of data from the original sample.[38]

The aim of this study was to develop and externally validate a prognostic model from a comprehensive range of candidate prognostic factors to identify patients at risk of developing persistent pain following wrist/hand fracture.

METHODS

Study Design

This secondary analysis was conducted using data from participants enrolled in a prospective, inception cohort study that investigated recovery from wrist or hand (involving metacarpals) fracture.[35] We published a study protocol and statistical analysis plan on the Open Science Framework (https://osf.io/n5cb6/) prior to conducting the analysis. We did not deviate from the protocol.

The study was reported in accordance with the Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD) statement for prediction studies.[22]

Setting and Participants

Participants were recruited for the cohort study between September 2010 and February 2014 from a consecutive sample of patients participating in multidisciplinary hand units in 3 metropolitan hospitals in Sydney, Australia: Royal North Shore Hospital, Sydney Hospital, and Prince of Wales Hospital. To be eligible for that study, patients had to present with a unilateral fracture to the wrist and/or hand (distal third of the radius or ulna, carpal bone, or metacarpal bone) within the last 28 days (or had undergone surgery for an acute hand or wrist fracture within the last 28 days), have a sufficient understanding of written and spoken English, and be 18 to 75 years of age.

Potential participants were excluded if they had a fracture or a significant painful injury of the opposite upper extremity, a malignancy-related fracture, a coexisting medical condition that would significantly alter normal fracture management, were pregnant, or had an existing psychiatric or neurological condition that would prevent informed consent or study participation.

Outcome and Data Collection

The primary outcome for the current study was persistent pain associated with the fracture at 4 months following the injury.[34] We defined persistent pain as mild pain or worse (3/10 or greater on a 0-to-10 numeric rating scale [NRS] at rest or with movement).[18] Pain intensity was assessed over the telephone, an approach that yields comparable results to face-to-face interviews on pain-related outcomes.[23]

Candidate Predictor Variables

The candidate variables included in studies of the prognosis of wrist fracture are limited.[17,21,33] From our existing data set, we selected 14 candidate predictor variables suggested by previous studies to be of prognostic value in the following domains: fracture characteristics, treatment characteristics, sociodemographic characteristics, psychological characteristics, function/disability, pain, and health status.[1,3,5,7,14,17,21,27,32,33,40,41,46] A list of candidate predictor variables is provided in **TABLE 1**.

Sample Size

The sample consisted of 715 participants. We used data from patients recruited from the Sydney Hospital and the Prince of Wales Hospital (n = 408) to develop the model. Both hospitals lie within the same geographical area and corresponding health district. To externally validate the model, we used data from patients recruited from the Royal North Shore Hospital (n = 307), which lies outside the South Eastern Sydney health district. To adequately power the regression analysis, as suggested by the PROGnosis RESearch Strategy framework (PROGRESS), we ensured that there were 10 or more cases per candidate predictor variable.[10]

Missing Data

We planned a complete case analysis if less than 5% of the predictor values were missing.[36] If more than 5% of predictor values were missing, we planned to impute the missing values through a post hoc sensitivity analysis using the expectation maximization algorithm in SPSS Version 19 (IBM Corporation, Armonk, NY). Cases with missing outcome data were excluded from the analysis.

Statistical Analysis and Assessment of Predictive Accuracy

Model Development We performed a backward stepwise regression analysis to specify the model in the development sample. Backward stepwise regression begins with all candidate variables entered in the model and is the preferred option when using automated predictor selection procedures.[36] This method ensures that all correlations between predictors are

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considered in the modeling procedure.[22] The threshold for statistical significance for variable removal was set at $P<.20$.[37] Continuous variables were analyzed on a continuous scale. We assumed candidate variables as independent and that the natural log of the odds ratio and the candidate variables had a linear relationship. We assessed bivariate relationships between predictors to determine potential for collinearity. Because we did not detect collinearity among continuous predictors (**APPENDIX**, available at www.jospt.org), we did not exclude any of the variables in **TABLE 1** in our regression modeling.

The predictive probability of persistent pain following wrist/hand fracture was calculated using the logistic regression equation: P (persistent wrist pain) = $1/[1 + \exp - (a_0 + b_1x_1 + \ldots + b_jx_j)]$.

Model Performance in the Development Sample The predictive performance of the regression model in the development sample was assessed using measures of overall performance and discrimination. Overall performance was assessed using the Nagelkerke R^2.[39] Discrimination was determined by using a receiver operating characteristic curve analysis. This statistic refers to the probability of correctly allocating higher predicted risks to patients who develop persistent pain during the study period and lower predicted risks to those who do not. A value of 0.5 indicates that the model discriminates no better than chance, and a value of 1 indicates that the model discriminates perfectly.[8] Performance indices and plots were calculated using R software.[29]

Geographical External Validation We externally validated the model using data from the Royal North Shore Hospital (n = 307), located approximately 15 km from the hospitals that provided data for the development sample. Geographical external validation offers greater generalizability than standard internal validation.[15,37] Model predictions were tested in the external validation sample with the performance statistics described above.

Model calibration in the external validation sample was determined by plotting the predicted probability versus the observed probability of developing persistent wrist/hand pain. Patients were grouped by decile of risk. The calibration slope and calibration-in-the-large statistic (intercept) were calculated using calibration plots.[37]

TABLE 1 Candidate Predictors

Prognostic Factor Group/Characteristic	Measure (Question)
Fracture characteristics	
Fracture location	Distal one third radius, distal one third ulna, metacarpal, scaphoid, other carpal bone, multiple fractures, multiple fractures including distal radius
Dominant-side fracture	Yes/no
Intra-articular	Yes/no
Treatment characteristics	
Management	Conservative/surgical
Sociodemographic characteristics	
Age	Years
Sex	Male/female
Psychological characteristics	
Depression	DASS-21 (0-42)
Stress	DASS-21 (0-42)
Anxiety	DASS-21 (0-42)
Function/disability	
Upper extremity disability and symptoms	QuickDASH (0-100)
Pain	
Pain intensity at baseline	NRS (0-10)
Multisite pain	None, 1 site, 2 sites, more than 2 sites
General health/comorbidities	
Comorbid illness*	Yes/no
Other inflammatory conditions	Yes/no

Abbreviations: DASS, Depression, Anxiety and Stress Scale; NRS, numeric rating scale; QuickDASH, shortened version of the Disabilities of the Arm, Shoulder and Hand questionnaire.
**Presence of recent or chronic illness.*

RESULTS

Study Population

Of the 715 participants available in the sample, 33 (4.6%) cases were excluded due to missing outcome data, which left 682 cases for the analysis. Of the 715 available cases, missing predictor data did not exceed 5%; therefore, we performed a complete case analysis according to our protocol.

Characteristics of the development and validation samples are shown in **TABLE 2**. There were significant differences ($P\leq.05$) between samples in fracture characteristics, treatment characteristics, sociodemographic characteristics, general health/comorbidities, and the proportion of participants who developed persistent pain (**TABLE 2**). We have presented the bivariate relationships between predictor variables in the first table in the **APPENDIX**.

Model Development

The predictors and regression coefficients for the prognostic model derived from the development sample are provided in **TABLE 3**. The final model contained 2 prognostic factors for the development of persistent pain: age and baseline pain intensity score.

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Calculation of an Individual Predicted Risk

We generated individual predicted risk scores for developing persistent pain following wrist/hand fracture (ScorePP) using the logistic regression equation from the development sample: ScorePP = −2.419 + (0.145 × pain + 0.02 × age), where pain is the 0-to-10 score on the NRS and age is in years.

The predicted risk of developing persistent pain following wrist/hand fracture (ProbPP) can then be calculated using the score and the following equation: ProbPP = exp(ScorePP)/[1 + exp(ScorePP)].

Accuracy of the Model in the External Sample

TABLE 4 summarizes the predictive performance of the prognostic model in the external validation sample. Area under the receiver operating characteristic curve (AUC) was 0.63 (95% confidence interval: 0.56, 0.69) in the development sample and 0.61 (95% confidence interval: 0.51, 0.70) in the external validation sample. There was evidence of miscalibration in the external validation sample (**FIGURE**), where the model systematically overestimated risk (intercept, −1.13; slope, 0.73). Calibration appeared more accurate for low-risk patients than for moderate- and high-risk patients. The Nagelkerke R^2 value was 2.4% in the external validation sample and 4.7% in the development sample.

DISCUSSION

We have developed and externally validated a prognostic model to identify patients at risk of developing persistent pain following wrist/hand fracture. To our knowledge, none of the published prognostic models for wrist fracture have been externally validated. We used large samples to develop and externally validate the model. As suggested,[21] we included psychosocial, fracture characteristic, and management-related variables in the model.

TABLE 2 Patient Characteristics in the Development and Geographic External Validation Samples

Prognostic Factor Group/Characteristic	Development Sample (n = 384)	Geographic External Validation Sample (n = 298)	*P* Value
Fracture characteristics, n (%)			
Fracture location			
Distal radius	84 (21.9)	137 (46.1)	<.05
Distal ulna	2 (0.5)	3 (1)	.46
Metacarpal	186 (48.6)	80 (26.9)	<.05
Scaphoid	46 (12)	19 (6.4)	<.05
Other carpal bone	15 (3.9)	17 (5.7)	.27
Multiple fractures	31 (8.1)	27 (9.1)	.65
Multiple fractures including distal radius	19 (5)	14 (4.7)	.88
Dominant-side fracture	225 (58.6)	158 (53)	.14
Intra-articular fracture	96 (25)	68 (22.8)	.51
Treatment characteristics, n (%)			
Management			
Surgical	106 (27.7)	92 (30.9)	.35
Surgical but seen preoperation	29 (7.6)	11 (3.7)	<.05
Conservative	248 (64.8)	195 (65.4)	.82
Sociodemographic characteristics			
Age, y*	35.4 ± 14.7	42.5 ± 17.7	.10
Sex (female), n (%)	108 (28.1)	123 (41.3)	<.05
Psychological characteristics*			
Depression			
DASS-21 (0-42)	6.1 ± 8	7.3 ± 8.5	.87
Stress			
DASS-21 (0-42)	10.2 ± 9.2	11.7 ± 9.7	.83
Anxiety			
DASS-21 (0-42)	4.1 ± 6	4.9 ± 6.8	.99
Function/disability*			
Upper extremity disability and symptoms			
QuickDASH (0-100)	48.2 ± 16	51.5 ± 16.3	.63
Pain			
Pain intensity at baseline			
NRS (0-10)	2.7 ± 1.8	2.9 ± 1.9	.84
Multisite pain, n (%)			
No	287 (75.3)	207 (69.5)	.13
1 site	54 (14.1)	57 (19.1)	.08
2 sites	23 (6)	15 (5)	.59
>2 sites	17 (4.4)	19 (6.4)	.26
General health/comorbidities, n (%)			
Comorbid illness			
Recent or chronic disease	58 (15.1)	67 (22.5)	<.05
Other inflammatory conditions	10 (2.6)	35 (11.7)	<.05
Outcomes, n (%)			
Persistent pain	84 (21.9)	38 (12.8)	<.05

Abbreviations: DASS, Depression, Anxiety and Stress Scale; NRS, numeric rating scale; QuickDASH, shortened version of the Disabilities of the Arm, Shoulder and Hand questionnaire.
**Values are mean ± SD.*

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The final model contains 2 prognostic factors from a possible set of 14 candidate predictors, identified from previous research. The model's discriminative ability is low (AUC = 0.61) and may not meet what many would consider the benchmark for clinical relevance (AUC>0.70).[12] This study confirms that reported baseline pain intensity predicts persistent pain after wrist/hand fracture and suggests a need for a new avenue of inquiry to identify novel predictors, or combinations of predictors, that can more accurately predict persistent pain.

The major strengths of this study are its preplanned methods, the use of large, high-quality data sets, and transparent reporting. We used a priori methods, guided by the PROGRESS initiative. We logged methods and a statistical analysis plan online (https://osf.io/n5cb6/) before conducting the analysis and reported the results in accordance with the TRIPOD statement.[22,38] Preregistration of methods and analysis plans protects against undisclosed analytic flexibility (eg, selective reporting, post hoc data mining) and publication bias, in principle improving reproducibility and confidence in results.[16,24,26] We used large, high-quality, prospectively collected data sets to reduce the risk of statistical overfitting. Despite the expected differences in frequency of persistent pain between the development and the validation samples, the model still predicted outcome. To avoid overfitting, we validated our model in a data set that differed significantly in baseline characteristics, including fracture location.

TABLE 3 Predictors and Regression Coefficients for the Prognostic Model

Predictor	Regression Coefficient	Odds Ratio*
Age	0.02	1.02 (1.00, 1.04)
Baseline pain	0.15	1.16 (1.02, 1.32)
Constant	−2.42	...

**Values in parentheses are 95% confidence interval.*

TABLE 4 Summary Performance Measures in the Geographic External Validation Sample

Aspect of Predictive Performance/Measure	Prognostic Model*
Discrimination	
Area under the curve	0.61 (0.51, 0.70)
Calibration	
Intercept	−1.13
Slope	0.73
Overall performance	
R^2 (Nagelkerke)	2.4%

**Values in parentheses are 95% confidence interval.*

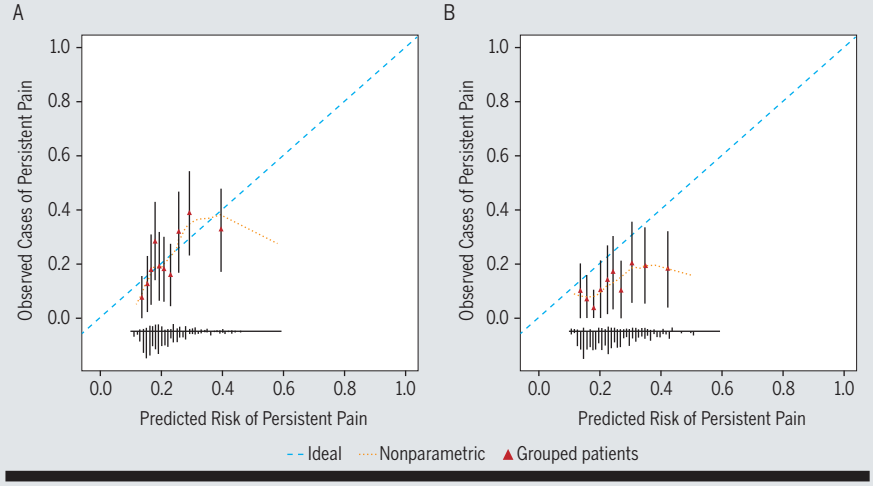

FIGURE. Calibration plots showing the (A) development (n = 384) and (B) validation (n = 298) samples. The distribution of predicted risk is shown at the bottom of each plot by 4-month outcome. The triangles indicate observed frequencies by decile of predicted risk.

The finding that baseline pain intensity and age predicted persistent pain is consistent with the previous literature investigating wrist fracture prognosis. In their multivariate model, Mehta et al[21] reported that baseline pain intensity was a significant predictor for persistent pain at 1 year after a wrist fracture. This model reported an AUC value (0.87) in the development sample. The lower AUC value in the present study could be explained, in part, by differences in the outcome measures used in the 2 studies: Mehta et al[21] used the 50-point Patient-Rated Wrist Evaluation,[19] while the current study used the 11-point NRS. Outcome measurements can affect AUC score.[4]

Future studies may benefit from using multidimensional, region-specific outcome measures, such as the Patient-Rated Wrist Evaluation,[19] rather than a generic outcome measure to better account for the complex nature of pain. Older age has been previously reported to predict functional recovery, but not to predict persistent pain, at 1 year after a wrist fracture.[3,5,7,33]

Research has identified common prognostic factors for poor outcomes for knee

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pain, low back pain, neck pain, shoulder pain, and tennis elbow.[6] Green et al[6] analyzed individual patient data from 7 randomized controlled trials and identified 4 consistent predictors of poor outcomes: baseline pain intensity and function, widespread pain, and mood problems. When we investigated these factors, only baseline levels of pain remained in our model. Commonly reported prognostic factors, such as psychological distress,[32] were not included, even though we set an inclusive threshold ($P<.20$) for variable removal from the model. It is unclear why some painful musculoskeletal conditions share prognostic factors and others do not. Further investigation of the predictive value and clinical utility of common prognostic factors in patients with wrist/hand fracture certainly appears warranted.

Because persistent pain presents as a common adverse outcome following musculoskeletal injury, there has been a move in both musculoskeletal pain[6,11] and wrist fracture[20] toward identifying at-risk patients and stratifying care according to prognostic profile. Using best-practice prognostic research methods guided by the PROGRESS framework, our final model only included 2 prognostic factors. It may be more accurate to refer to this model as a "predictive equation." We, like other researchers in the field,[21] found that when combined in a multivariate model, many previously identified predictors did not significantly predict outcomes. The identification of novel predictors, and novel combinations of previously investigated predictors, that can improve on predictive accuracy in external validation samples will be an important development in this field.

There are many factors that influence which predictors remain in a prognostic model. The prognostic factors that remain in a model can be influenced by the choice of outcome.[9] Previous studies have typically used function or disability as the primary outcome, and pain as a secondary outcome. A difference in outcome choice might therefore explain why our model did not include factors that have been identified in previous work, such as fracture characteristics.[1,3,17,33] Pain is an important patient-related outcome,[13] and, to our knowledge, only 1 study reported persistent pain as the primary outcome.

The present study has some limitations. Because this was a secondary analysis of existing data, we did not include some previously identified prognostic factors, such as education/socioeconomic status[3,7,17,27] and injury compensation.[7,17] Even though the reports of the relationship between these factors and outcome are inconsistent—for example, Chung et al[3] reported no relationship between injury compensation and wrist fracture outcomes, whereas MacDermid et al[17] reported injury compensation as the most influential predictor of pain and disability at 6 months—they should be included in updates of the model.

In the absence of prognostic information, an individual has a 20% risk for developing persistent pain following wrist fracture.[18] The current study confirms previous research findings that baseline pain intensity is a predictor of persistent pain. In a clinical setting, identifying patients at higher risk of persistent pain can assist the clinician in appropriately allocating resources and modifying treatment. Although the predictive accuracy was low, this predictive equation can quantitatively support the decision-making process, increasing confidence in the choice of treatment. Due to the potential for misclassification, caution is encouraged in using the predictive equation in isolation to guide treatment decisions.

Older patients with higher postfracture pain appear to be potential targets for preventive interventions. For example, a 60-year-old male patient with an NRS pain score of 8/10 would have a 49% predicted risk of persistent pain at 4 months. Alternatively, a 20-year-old male patient with an NRS pain score of 2/10 would have a 15% predicted risk of persistent pain at 4 months (**TABLE 5**).

CONCLUSION

We developed and validated a simple, 2-item prognostic model aimed at identifying patients at risk of developing persistent pain following wrist/hand fracture. In an external sample of patients, the performance of this model was low and may not meet benchmarks considered appropriate for clinical relevance for predicting persistent pain 4 months after wrist/hand fracture. This prognostic model confirms that patients with higher baseline pain are more likely to develop persistent pain following a wrist/hand fracture, which, in turn, could guide clinical intervention.

KEY POINTS

FINDINGS: We developed and validated a prognostic model that can predict persistent pain 4 months after wrist/hand fracture. Age and baseline pain intensity predict the risk of persistent pain.

IMPLICATIONS: This study confirms that patients reporting high baseline pain are more likely to develop persistent pain. This finding could support clinicians in identifying at-risk patients for

TABLE 5 Individual Predicted Risk Scores for Developing Persistent Pain Following Wrist Fracture

Patient Example	Age, y	Baseline Pain Score (0-10 NRS)	Predicted Risk, %
1	60	8	49
2	20	8	30
3	60	2	28
4	20	2	15

Abbreviation: NRS, numeric rating scale.

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preventative rehabilitation interventions. Stratifying care to at-risk patients has the potential to improve health care outcomes and reduce costs.

CAUTION: Further research is required to evaluate the benefit of stratified care in wrist/hand fracture. To improve predictive accuracy and clinical usefulness, this model should be updated with other predictors and validated in local settings.

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APPENDIX

Correlation	Fracture Site	Dominant-Side Injury	Intra-articular	Management	Age	Sex	DASS-21 Depression Total Score	DASS-21 Stress Total Score	DASS-21 Anxiety Total Score	Quick-DASH Total Score	Pain NRS	Multisite Pain Classification	Recent or Chronic Illness	Other Inflammatory Condition
Fracture site														
Pearson correlation	1	0.06	−0.102*	0.061	−0.126*	0.141†	−0.026	−0.031	−0.009	−0.037	−0.074	−0.004	0.045	0.033
P value (2 tailed)		.245	.047	.234	.013	.006	.615	.551	.867	.472	.146	.936	.384	.52
Dominant-side injury														
Pearson correlation	0.06	1	−0.029	−0.073	−0.222†	0.1	0.045	0.069	0.045	0.07	−0.008	0.106*	−0.049	0.07
P value (2 tailed)	.245		.567	.157	<.001	.052	.376	.18	.378	.172	.869	.039	.343	.174
Intra-articular														
Pearson correlation	−0.102*	−0.029	1	0.334†	0.096	−0.067	−0.054	−0.019	−0.024	0.122*	0.122*	0.051	−0.045	0.094
P value (2 tailed)	.047	.567		<.001	.061	.191	.294	.707	.646	.016	.017	.319	.385	.068
n	383	383	384	383	382	384	384	383	383	384	384	384	380	380
Management														
Pearson correlation	0.061	−0.073	0.334†	1	0.091	0.058	0.002	−0.036	0.01	0.072	0.012	0.013	0.152†	0.07
P value (2 tailed)	.234	.157	<.001		.077	.261	.97	.481	.849	.16	.812	.794	.003	.171
Age														
Pearson correlation	−0.126*	−0.222†	0.096	0.091	1	−0.407†	0.114*	0.150†	0.144†	0.275†	0.142†	−0.036	−0.012	0.116*
P value (2 tailed)	.013	<.001	.061	.077		<.001	.026	.003	.005	<.001	.005	.48	.824	.024
Sex														
Pearson correlation	0.141†	0.1	−0.067	0.058	−0.407†	1	−0.069	−0.087	−0.076	−0.203†	−0.116*	0.141†	0.05	−0.082
P value (2 tailed)	.006	.052	.191	.261	<.001		.179	.087	.136	<.001	.023	.006	.336	.109
DASS-21 depression total score (0-42)														
Pearson correlation	−0.026	0.045	−0.054	0.002	0.114*	−0.069	1	0.760†	0.697†	0.259†	0.222†	0.016	−0.005	−0.031
P value (2 tailed)	.615	.376	.294	.97	.026	.179		<.001	<.001	<.001	<.001	.751	.921	.543
DASS-21 stress total score (0-42)														
Pearson correlation	−0.031	0.069	−0.019	−0.036	0.150†	−0.087	0.760†	1	0.701†	0.287†	0.302†	−0.016	0.033	0.014
P value (2 tailed)	.551	.18	.707	.481	.003	.087	<.001		<.001	<.001	<.001	.75	.522	.786
DASS-21 anxiety total score (0-42)														
Pearson correlation	−0.009	0.045	−0.024	0.01	0.144†	−0.076	0.697†	0.701†	1	0.255†	0.316†	−0.007	0.017	−0.027
P value (2 tailed)	.867	.378	.646	.849	.005	.136	<.001	<.001		<.001	<.001	.899	.737	.607
QuickDASH total score (0-100)														
Pearson correlation	−0.037	0.07	0.122*	0.072	0.275†	−0.203†	0.259†	0.287†	0.255†	1	0.394†	−0.018	0.052	0.082
P value (2 tailed)	.472	.172	.016	.16	<.001	<.001	<.001	<.001	<.001		<.001	.731	.316	.112
Pain NRS (0-10)														
Pearson correlation	−0.074	−0.008	0.122*	0.012	0.142†	−0.116*	0.222†	0.302†	0.316†	0.394†	1	−0.014	0.025	0.055
P value (2 tailed)	.146	.869	.017	.812	.005	.023	<.001	<.001	<.001	<.001		.785	.625	.284
Multisite pain classification														
Pearson correlation	−0.004	0.106*	0.051	0.013	−0.036	0.141†	0.016	−0.016	−0.007	−0.018	−0.014	1	0.036	0.083
P value (2 tailed)	.936	.039	.319	.794	.48	.006	.751	.75	.899	.731	.785		.478	.104

Table continues on page A2.

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APPENDIX

Correlation	Fracture Site	Dominant-Side Injury	Intra-articular	Management	Age	Sex	DASS-21 Depression Total Score	DASS-21 Stress Total Score	DASS-21 Anxiety Total Score	Quick-DASH Total Score	Pain NRS	Multisite Pain Classification	Recent or Chronic Illness	Other Inflammatory Condition
Recent or chronic illness														
Pearson correlation	0.045	−0.049	−0.045	0.152†	−0.012	0.05	−0.005	0.033	0.017	0.052	0.025	0.036	1	−0.024
P value (2 tailed)	.384	.343	.385	.003	.824	.336	.921	.522	.737	.316	.625	.478		.64
Other inflammatory condition														
Pearson correlation	0.033	0.07	0.094	0.07	0.116*	−0.082	−0.031	0.014	−0.027	0.082	0.055	0.083	−0.024	1
P value (2 tailed)	.52	.174	.068	.171	.024	.109	.543	.786	.607	.112	.284	.104	.64	

Abbreviations: DASS, Depression, Anxiety and Stress Scale; NRS, numeric rating scale; QuickDASH, shortened version of the Disabilities of the Arm, Shoulder and Hand questionnaire.
**Correlation is significant at the .05 level (2 tailed).*
†Correlation is significant at the .01 level (2 tailed).

Bivariate Relationships Between Predictor Variables and Outcome in TABLE 2

	B	SE	Wald	*df*	*P* Value	Exp(B)
Fracture site	0.010	0.072	0.018	1	.894	1.010
Dominant-side injury	0.244	0.277	0.773	1	.379	1.276
Intra-articular	0.215	0.311	0.478	1	.489	1.240
Management	0.060	0.224	0.071	1	.790	1.061
Age	0.018	0.010	3.062	1	.080	1.018
Sex	−0.266	0.305	0.762	1	.383	0.766
DASS-21 depression total score (0-42)	−0.012	0.026	0.213	1	.645	0.988
DASS-21 stress total score (0-42)	0.003	0.023	0.016	1	.899	1.003
DASS-21 anxiety total score (0-42)	0.022	0.031	0.486	1	.486	1.022
QuickDASH total score (0-100)	0.004	0.009	0.209	1	.648	1.004
Pain NRS (0-10)	0.111	0.075	2.185	1	.139	1.117
Multisite pain classification	−0.080	0.168	0.228	1	.633	0.923
Recent or chronic illness	−0.463	0.400	1.337	1	.248	0.630
Other inflammatory condition	−0.009	0.735	0	1	.991	0.991
Constant	−2.253	0.891	6.391	1	.011	0.105

Abbreviations: DASS, Depression, Anxiety and Stress Scale; NRS, numeric rating scale; QuickDASH, shortened version of the Disabilities of the Arm, Shoulder and Hand questionnaire; SE, standard error.

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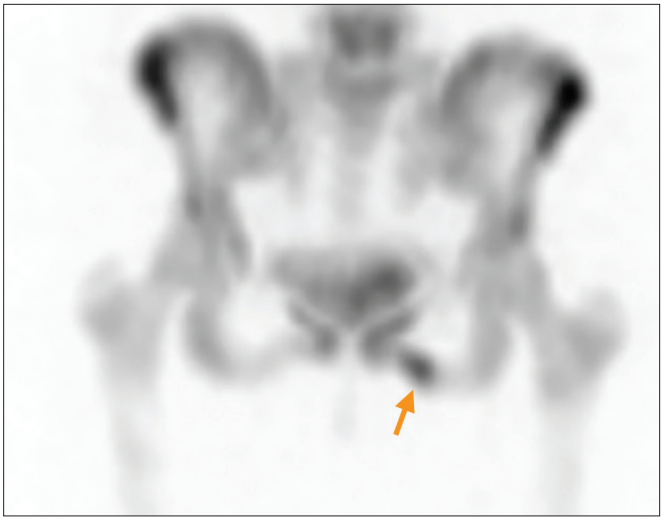

FIGURE 1. Bone scan of the pelvis, showing focal uptake (arrow) at the left inferior pubic ramus near the symphysis, consistent with stress fracture.

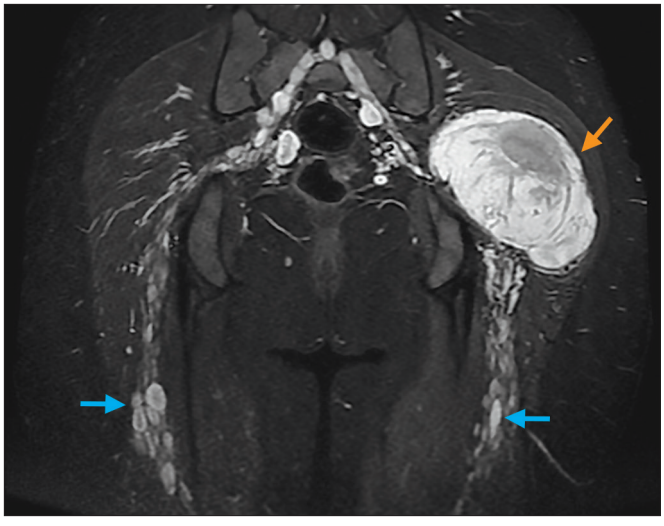

FIGURE 2. Coronal, T2-weighted, fat-saturated magnetic resonance image of the pelvis, showing a large neurofibroma (peripheral nerve-sheath tumor) within the left buttock (orange arrow) and plexiform neurofibromas along both sciatic nerves (blue arrows).

Plexiform Neurofibromatosis in a Woman With a Pubic Ramus Stress Fracture

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A 22-year-old woman in Army Basic Combat Training was evaluated in a physical therapy clinic for insidious-onset groin pain (numeric pain rating of 6/10 in resting and 9/10 with weight bearing) for 2 weeks. The referring primary care physician assistant ordered initial radiographs, which were noncontributory, followed by a bone scan, in accordance with health system policies, that indicated a left inferior pubic ramus stress fracture (**FIGURE 1**). She was prescribed a 30-day convalescent leave.

Upon return, she reported 2/10 resting pain and presented with a persistent antalgic gait and full bilateral active and passive hip range of motion, with end-range pain in all directions. The left gluteus maximus and medius were painful and weak (4–/5). Hip pain was reproduced with the scour and flexion, abduction, external rotation (FABER) tests. Palpation over the left posterolateral buttock elicited 9/10 pain, along with the presence of a firm soft tissue mass. Due to the palpable mass and severe pain, magnetic resonance imaging was ordered by the physical therapist and showed plexiform neurofibromas, with a left buttock mass (**FIGURE 2**) and left inferior pubic ramus stress fracture (**FIGURES 3** through **5**, available at www.jospt.org).

The patient was referred to an orthopaedic oncologist and underwent an open surgical biopsy, which ruled out malignant peripheral nerve-sheath tumor (neurofibrosarcoma). Plexiform neurofibromas diagnostic of neurofibromatosis type 1 characteristically manifest at birth but can continue to grow, developing in about 30% to 50% of individuals.[2] This patient was not aware of any family history of neurofibromatosis type 1. The patient was managed with excision of the buttock tumor and analgesic medications.[1] Despite extensive rehabilitation, the patient was discharged from the Army 1 year after surgery due to inability to perform occupational requirements. This case illustrates the potential for multiple pathologies to coexist and how advanced imaging information contributed to getting a definitive diagnosis.

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A Pragmatic Approach to the Implementation of Osteoarthritis Guidelines Has Fewer Potential Barriers Than Recommended Implementation Frameworks

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Randomized controlled trials, systematic reviews, and meta-analyses form the basis of international treatment guidelines, whose main purpose is to ensure that individuals living with a health care condition receive effective and suitable treatment. Treatment guidelines should form the foundation for planning, evaluation, quality improvement,[4] and allocation of health care resources. There is, however, often a gap between what we know and what we do.[3]

Translating evidence-based treatment recommendations and guidelines into feasible delivery in routine care is an essential objective to improve quality of care.[5] Nevertheless, guidelines are underused, and many physical therapists and other professionals continue to offer low-value care modalities, providing the patients with treatment options of little to no benefit.[15] In contrast to low-value interventions (eg, superficial heat, passive motion machines, and knee arthroscopy), evidence-based treatment guidelines for osteoarthritis (OA) recommend information, exercise, and weight control.[8] Recommended treatments are increasingly based and reliant on the patient's own participation, effort, responsibility, and self-management. Effective treatment also requires willingness from stakeholders to change their practice to deliver the best available care. The selection of effective implementation strategies and reduction of known barriers when implementing new guidelines are crucial to changing the frustration, uncertainty, and often negative attitudes that some health care providers have with regard to new treatment approaches. Furthermore, it is important not only to reduce/remove barriers to the implementation process, but also to focus on facilitators that may change the patients' and stakeholders' attitudes. This is especially important in the treatment of patients with OA, where lifestyle changes, including increased physical activity level and control of body weight, form the basis for long-term success.

In 2015, Gagliardi et al[4] published a systematic review with the purpose of examining published, peer-reviewed research on guidelines to describe strategies and identify trends in use. They found

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that education for professionals and/or patients and printed material were the most commonly employed strategies for translating guidelines into practice. They also found that few studies selected strategies based on theory, assessing barriers, or any other rationale, and that most studies employed multiple approaches and strategies. Little is known about the adoption and adherence rates of the suggested implementation models.[4]

Implementation of Nonpharmacological Treatment for OA in Clinical Practice Is Suboptimal

As for evidence-based knowledge and guidelines in general, implementation of international guidelines for nonpharmacological treatment of people with OA has, until recently, been inadequate.[6] To change existing practice and to enhance quality of care and patient outcomes, capability, necessary skills, and motivation to change are crucial.[9] The limited use of evidence-based guidelines in clinical practice may be due to a number of barriers.

- Insufficient knowledge of current evidence[2]
- Clinicians and patients may find it hard to break old habits and abandon existing low-value treatment[15]
- A substantial increase in the number of published frameworks and checklists for guideline implementation can make the implementation strategy too comprehensive and complicated to employ[7]

A consequence is that clinicians and researchers may find the published frameworks and associated tools too comprehensive, with barriers seemingly impossible to overcome due to lack of both human and economic resources.

A Pragmatic Approach to Implementation of Nonpharmacological Treatment

When planning implementation of guidelines, the choices of implementation approaches are influenced by different factors, such as human resources, the health care providers' attitudes to change, time available, and financial resources. To achieve a successful and effective application, simple and pragmatic implementation models may be more feasible and attractive for clinicians, patients, and a variety of other stakeholders.[5] For optimal benefit, the pragmatic implementation model should contain (1) information and feasibility testing, (2) educational courses for clinicians, (3) written and electronic material for patients and clinicians, and (4) an electronic registry system for documentation.

This simple model is supported by examples from Good Life with osteoArthritis in Denmark (GLA:D, www.glaid.dk/english.html)[13] and Active with osteoArthritis (ActiveA, www.aktivmedartrose.no) in Norway, which are 2 not-for-profit implementation programs initiated to enhance the quality of nonsurgical treatment for patients with knee or hip OA in primary care. The GLA:D program was initiated in January 2013, building on a similar initiative in Sweden,[14] while ActiveA was initiated in November 2015, building on the Swedish and Danish programs. The following is a brief discussion of the pragmatic approach to implementation, with examples from the 2 programs.

Information About the Program to Patients, Clinicians, and Other Stakeholders and Feasibility Testing It is important to inform, involve, and engage all relevant stakeholders early in the process. Stakeholders can be identified using the 7Ps Framework to Identify Stakeholders in Patient-Centered Outcomes Research and Comparative Effectiveness Research[1] and should preferably include patients, multiprofessional health care providers, health care administrators, and politicians. In GLA:D, this was achieved through an interdisciplinary stakeholder meeting introducing GLA:D and by forming an interdisciplinary, intersectorial steering group and reference group responsible for the implementation. In ActiveA, it was achieved by informing and cooperating with strategic stakeholders concerning priority of the program and economic funding.

After developing the treatment program based on available evidence, a feasibility study should be conducted to evaluate the feasibility of the program and adapt the content to increase the chances of successful implementation. The treatment program and the results from the feasibility study can then be communicated at strategic conferences (eg, orthopaedic and general practitioner conferences) and in peer-reviewed and other nonscientific publications, thereby promoting the program (if found feasible; see an example from GLA:D in the *Danish Medical Journal*).[12] Communicating the results and information on the treatment program through leaflets and flyers and attracting attention in national and local media are also an important part of the first level of the proposed implementation model. Experience from GLA:D and ActiveA suggests that the involvement of patients who have undergone the program is crucial to get the message out in the media and the population with OA.

Finally, the visibility of the program will be increased by developing a social media profile and an interactive website with information about the content of the program, where live results and videos from the program are made available for patients. Examples can be found at www.glaid.dk and at www.aktivmedartrose.no.

A 1- to 2-Day Educational Course for Clinicians Developing and introducing a course for clinicians that presents the evidence in a format that is easy to understand and apply in daily clinical practice is a crucial part of the implementation model. In GLA:D (2 days) and ActiveA (1 day), the certification courses are aimed at giving clinicians (primarily physical therapists) the knowledge, skills, and competence to offer and evaluate the treatment program at their local clinic, municipality, or hospital. This includes updated knowledge about OA and the importance of national registries for outcome collection, introduction to the current clinical guidelines, the treatment program, the implementation model, the electronic applications available, and the electronic database.

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Written and Electronic Material for Patients and Clinicians In continuation of level 2 of the implementation model, a "toolbox" with everything needed to start the treatment program needs to be available. To ensure that the content can be continuously updated to reflect the evidence and the needs among clinicians and patients, this toolbox should preferably be electronic, for example, a webpage that all certified clinicians have access to. Based on the experience from GLA:D and ActiveA, the electronic toolbox should contain (1) a continuously updated description of the evidence and how to offer the treatment program to patients, including manuals and videos; (2) brochures to advertise for the treatment program directed towards patients and clinicians; (3) materials for patients, presenting the evidence in a language and design easy to understand, and PowerPoint presentations for patient education, with a manual describing what to say for each slide (if the treatment program contains patient education); (4) an exercise therapy program with different levels of progression of dose for each exercise; and (5) a communication platform for support from the implementation team and the other units offering the program.

Electronic Registry System for Documentation To implement and adjust the treatment program, evaluation is crucial. The development of an online registry—adhering to national standards on data protection, with valid and reliable outcomes, and selected in close cooperation with professional experts and patients—is therefore recommended. To ensure feasibility of the evaluation, it is important to restrict the outcomes to what is needed and to reduce the number of outcomes that need to be collected by the clinicians, that is, including recommended patient-reported outcomes. In GLA:D and ActiveA, data from patients and clinicians are registered online before, immediately after, and 12 months after starting the treatment program (only patients). Furthermore, ActiveA includes a 24-month follow-up (only patients). By making individual summary reports for each patient available, communication between the patient and the therapist can be enhanced. Live results from the online registry and the annual reports with data from the clinicians' own unit should be available for use as quality assurance and local advertisement to further improve the implementation.

Is a Pragmatic Approach to Implementation Better Than the Existing Comprehensive Models?

To the authors' knowledge, no direct comparisons between different models of implementation exist. However, based on the implementation of GLA:D and ActiveA, a pragmatic approach seems to be a feasible option that could reduce the number of barriers to implementation.

The GLA:D program was initiated in Denmark in January 2013 as a bottom-up approach offering evidence-based courses to clinicians. Over the first 5 years, more than 1100 clinicians, mostly physical therapists, have been certified. More than 30 000 individuals with OA have participated in GLA:D in 1 of more than 400 GLA:D units nationwide, with some units having included more than 500 patients and others few or none (https://www.glaid.dk/clinic2.html). Following participation in GLA:D training, pain intensity is on average decreased by 25% (corresponding to a mean improvement of 12.4 mm; 95% confidence interval: 11.8, 13.1 mm on a 0-to-100-mm scale), sick leave is reduced (risk reduction, 14.5%), and 1 of 3 individuals has stopped taking acetaminophen, nonsteroidal anti-inflammatory drugs, and opioids for joint pain. The improvements are largely maintained after 12 months.[13] Response rates on the follow-up questionnaires are 79% following the program and 68% at 12 months. In contrast to these results, without intervention, while symptoms of some patients with OA improve over time, most patients either stay the same or deteriorate, suggesting that the effects from GLA:D are not just the result of the natural history of the disease.[10] The GLA:D program is currently being implemented in Canada (http://gladcanada.ca/), Australia (https://gladaustralia.com.au/), and China, with more countries to come.[11] In addition, a GLA:D back program has been developed, passed the feasibility testing stage, and rolled out in Denmark in 2018 (http://gladryg.sdu.dk/).

ActiveA was launched in January 2016. Currently, more than 800 Norwegian physical therapists have participated in the educational seminars and have been certified. After 2 years, 3500 patients have given their written consent to submit data to the electronic registry; however, the patients are allowed to take part in the program irrespective of their willingness to be included in the electronic registry. The response rates on the follow-up questionnaires are 83% and 48% after 3 and 12 months, respectively. At 3-month follow-up, the registry data analyses show that pain was reduced by a mean ± SD of 6.6 ± 2.0 mm ($P<.001$) on a 0-to-100-mm scale, an average decrease of 13%. After the first year, 65% of the patients report their physical function to be improved.

These national pragmatic implementation models have proven applicability in a range of countries and have facilitated improved quality of care. For any health conditions, especially musculoskeletal disorders, for which international evidence-based treatment guidelines exist, there is reason to believe that the suggested pragmatic implementation models can be successfully applied, thereby providing a potentially more feasible alternative compared to the comprehensive implementation models usually recommended in the literature.

Key Points

- A pragmatic approach to the implementation of clinical guidelines is feasible and facilitates improved quality of care for management of OA.
- Experience from Scandinavia suggests that 4 components are essential for successful implementation:
  - Widespread and multifaceted distribution of information about the

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program to patients, clinicians, and stakeholders
  - A certification course for clinicians including evidence-based knowledge about OA and treatment options, introducing the specific treatment program, the implementation model, and the importance of outcome documentation
  - Predesigned material (in print and continuously updated versions on the website) for both the patients and clinicians, including everything needed to start the treatment program locally in their own clinic/municipality
  - An electronic registry to monitor and evaluate outcomes
- The pragmatic bottom-up approach to implementation is limited by its dependency on a smaller group of engaged and enthusiastic researchers and clinicians, thereby making it vulnerable to changes in the management group.

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Exploratory Study of 6-Month Pain Trajectories in Individuals With Predominant Patellofemoral Osteoarthritis: A Cohort Study

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BACKGROUND: Knowledge of patellofemoral osteoarthritis (OA) pain trajectories is vital to helping clinicians and patients make shared disease-specific decisions regarding treatment options and coping strategies.

OBJECTIVES: To describe the pain trajectories of people living with patellofemoral OA who present to a chronic care management program, and to explore baseline characteristics associated with different trajectories.

METHODS: In this prospective longitudinal cohort study, 88 participants who presented to a chronic care management program reported their worst pain over the previous week at baseline and at 6, 12, 18, and 26 weeks using a 10-cm visual analog scale. Trajectories (classes) were identified using latent class growth analysis. Demographics, pain, physical performance, strength, quality of life, mental health, and lower limb/foot structural measures obtained at baseline were assessed for association with trajectory class membership.

RESULTS: Individuals in class 1 (28%) exhibited high, persistent pain from baseline (7.8 ± 1.7 cm), which continued over time (P = .52). Class 2 (57%) displayed moderate baseline pain (4.8 ± 1.8 cm), which also remained persistent (P = .97). Individuals in class 3 (15%) showed low, improving pain (baseline pain, 2.6 ± 1.2 cm) over time (P = .017). At baseline, poor Knee injury and Osteoarthritis Outcome Score (KOOS) scores, local and proximal sensitivity to pressure, and lower knee extensor strength were associated with increased odds of following the high-pain trajectory (range [95% confidence interval], 1.03 [1.00, 1.07] to 16.24 [2.53, 104.34]).

CONCLUSION: Distinct pain trajectories appear to exist in people with patellofemoral OA presenting to a chronic care management program. Baseline variables may be useful for identifying individuals at risk of poorer prognosis. Larger studies are needed to confirm the efficacy of this finding.

LEVEL OF EVIDENCE: Prognosis, level 2b. *J Orthop Sports Phys Ther 2019;49(1):5-16. Epub 12 Sep 2018. doi:10.2519/jospt.2019.8354*

KEY WORDS: *arthritis, disease course, kneecap, prediction, prognosis*

Evidence from systematic reviews has demonstrated that the course of knee pain and impaired physical function associated with osteoarthritis (OA) varies greatly through time and differs between individuals.[14] This variability forms part of the rationale for the call to tailor treatments to the individual.[12] To date, being female, severe bilateral knee pain, a high body mass index, more than 3 comorbidities, and exhibiting coping strategies of "worrying" or "resting" have been identified as baseline predictors of poor knee OA–related pain and physical function trajectories and outcomes.[21,28,48] These predictors were identified from studies that focused on individuals with medial tibiofemoral OA[28] or that have included individuals with knee and hip OA.[21,48]

By contrast, disease trajectories in people with predominant patellofemoral OA have received scant attention, despite evidence that radiographic patellofemoral OA has greater prevalence than isolated tibiofemoral OA.[18] Structural patellofemoral OA has demonstrated a stronger correlation with knee pain than tibiofemoral involvement.[18] This correlation, coupled with the unique mechanics of the patellofemoral joint,[19,24] suggests that individuals with patellofemoral OA may experience distinct pain trajectories and, similar to their counterparts with tibiofemoral OA,[5,10] may display the distinctive, clinically measurable baseline characteristics associated with those trajectories.

Information regarding pain trajectories is important to help educate people

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living with OA about their likely clinical course.[4] Further, such knowledge can assist patients and multidisciplinary health care teams in setting realistic expectations about symptom progression and making consistent, high-quality decisions about treatment options.[23,43] For clinicians, this information may help to target interventions and to rationalize health services to those who may benefit most. For patients, poor or inaccurate knowledge of the OA process is detrimental. Those with less awareness about their condition and its likely progression tend to experience more pain.[4] By contrast, those who are better informed tend to cope better with their OA and experience less depression.[4] While most patients with OA believe that information about their disease course is useful,[26] a survey of individuals attending an orthopaedic surgical clinic found that only 20% reported that they had received enough education about their prognosis.[23]

This exploratory study aimed to identify and describe potential prognostic pain trajectories in people with patellofemoral OA who participated in chronic care management programs. The researchers also explored whether baseline characteristics are associated with distinct pain trajectories for such individuals, using a longitudinal cohort study design.

METHODS

Participants were consecutively recruited over a 10-month period from April 2014 to January 2015. All individuals enrolled in the Osteoarthritis Chronic Care Program (OACCP)[21] at a tertiary teaching hospital in Sydney, Australia were considered for inclusion.

The OACCP is a 12-month program for people with hip and knee OA that focuses on improving self-management skills as well as providing timely access to a multidisciplinary health team. This multidisciplinary team includes physical therapists, rheumatologists, dietitians, social workers, occupational therapists, and orthotists. All participants in the OACCP undergo a baseline assessment and are provided with an individualized care plan, which may involve management strategies from any or all members of the health care team.

Participants are then reviewed at 6, 12, 26, and 52 weeks to support their self-management process. Any treatments offered are designed to be implemented by the patient and focus on international guideline-based care, namely exercise and weight loss with gait aids or braces prescribed if required.[34] Inclusion criteria for the OACCP are medically diagnosed hip or knee OA, consistent with the American College of Rheumatology classification criteria,[2] and 30/100 or greater pain in the signal joint on most days of the previous month. The face validity of physician-diagnosed OA has been previously demonstrated.[32]

Inclusion within the current study required participants to have patellofemoral OA, which was defined as both structural joint disease and clinical symptoms. Structural changes of the patellofemoral compartment were defined as any of the following: presence of marginal osteophytes (X-ray and/or magnetic resonance imaging), joint-space narrowing (X-ray), and loss of articular cartilage integrity (magnetic resonance imaging).[33,42] These were identified by assessing the X-rays or magnetic resonance imaging ordered by the participant's general practitioner or referring physician prior to enrollment in the OACCP. Kellgren-Lawrence or whole-organ magnetic resonance imaging score grading was not performed, because the severity of radiographic changes is of limited value in predicting OA symptom persistence or progression.[29,45]

Clinical symptoms of patellofemoral OA were interpreted as the patient self-reporting his or her most severe pain arising from the anterior knee during activities that load the patellofemoral joint, namely, stair climbing, squatting, and rising from sitting.[22,30,42] Participants who met 1 criterion (eg, imaging changes) but not the other (eg, no pain during patellofemoral loading) were excluded. Participants who exhibited OA-related changes in the tibiofemoral compartments in addition to their patellofemoral compartment were included; however, their clinical symptoms needed to be most severe during patellofemoral joint–loaded activities.

Individuals with bilateral knee symptoms were also included, but as part of their participation in the OACCP, they were asked to select the signal knee. For purposes of this study, the signal knee was examined using the researchers' selection criteria. The New South Wales Population and Health Services Ethics Committee approved use of patient data for research purposes (2012/08/413) with an opt-out approach. All participants in the current study were informed of this at enrollment and were free to decline or withdraw from participation in the research without affecting their inclusion in the OACCP.

Outcome Variable

Worst pain over the previous week was measured on a 10-cm visual analog scale (VAS) ranging from 0 as "no pain" to 10 as "worst pain imaginable." Participants were asked to rate their pain at baseline and at follow-up assessments of 6, 12, 18, and 26 weeks.

Baseline Variables

Baseline variables were categorized as demographics and physical performance, pain, strength, and structural measures. Sex, age, body mass index, and unilateral or bilateral knee symptoms were the demographic variables. As part of the normal clinical care pathway, the timed up-and-go test and 6-minute walk test were both assessed as submaximal physical performance measures similar to the abilities required for daily activities.[1,7,15] The Knee injury and Osteoarthritis Outcome Score (KOOS) and the 21-item version of the Depression, Anxiety and Stress Scale (DASS-21) are multidimensional measures of pain and function and of mental health and quality of life, respectively. These were also collected as part of

the clinical care pathway. Each subscale of the KOOS is measured out of 100, with higher scores indicating lower impairment. The DASS-21 assesses 3 domains, each measured out of 21, with higher scores indicating greater impairment.

Pain was quantified using several approaches by a trained assessor (J.P.E.). Pain location was mapped using a knee pain map and recorded as local, regional, or diffuse.[46] Local and proximal pressure pain thresholds (PPTs) were obtained from 4 peripatellar sites on the participant's signal knee, as well as over the muscle belly of the ipsilateral extensor carpi radialis longus (ECRL).[3] Participants were instructed to indicate when the pressure applied perpendicularly to each site with a handheld algometer (Wagner Instruments, Greenwich, CT) became painful. Each site was tested 3 times, in random order, with 15 seconds between tests. The average pressure was recorded in Newtons for a combined "local" PPT, while the average PPT of the ECRL was considered the "proximal" PPT.

Maximal voluntary isometric strength of the hip abductors, hip external rotators, and knee extensors was obtained using a standardized protocol[40] and a handheld dynamometer (Commander PowerTrack II; JTECH Medical, Midvale, UT) by a trained assessor (J.P.E.). Measures were recorded in Newtons and converted into torque normalized by body weight (Newton meters per kilogram).

Structural measures of foot mobility and tibial inclination were measured by a trained assessor (J.P.E.). Weight-bearing and non–weight-bearing measures of midfoot width and arch height were obtained using a foot assessment platform.[35] Midfoot and arch height mobility were calculated using differences between weight-bearing and non–weight-bearing measures, and foot mobility magnitude was calculated from these variables using Pythagoras' theorem.[35] Tibial inclination was measured using a standardized protocol and a custom-made caliper with a gravity inclinometer attached.[25] The angle of the tibia with respect to vertical (180°) was measured, with angles less than 180° indicating varus inclination of the tibia. This angle was estimated via a simple linear regression relating the mechanical axis of the lower limb to the angle of inclination: mechanical axis = (1.153 × angle of inclination) – 28.716.[25]

Statistical Analysis

Worst pain over the previous week was used to identify distinct pain trajectories using Mplus Version 7.4 (Muthén & Muthén, Los Angeles, CA) software. This analysis assumed the presence of distinct classes that are defined by the trajectory of worst pain over the previous week across 5 time points (baseline and weeks 6, 12, 18, and 26). The analysis proceeded through a series of steps. First, as latent class growth–curve analysis assumes the dependent variable to be normally distributed,[6] the worst-pain VAS was examined for skewness, kurtosis, and with the Kolmogorov-Smirnov test ($P = .2$), indicating plausibly normally distributed data.

The next step was to detect the presence of latent classes, or subtypes, of individuals, the trajectories of which varied significantly from an underlying overall estimate. This was achieved by fitting a latent class growth analysis of the worst-pain VAS to the data and identifying the number of classes and trajectory patterns that best explained variations in the data. Goodness of fit for each model was assessed using the bootstrap likelihood ratio test (BLRT), the Bayesian information criterion (BIC), and the Akaike information criterion (AIC).

A pragmatic approach was adopted to determine the optimal number of classes based on goodness of fit as well as entropy, high posterior probability of class membership, and imposing a minimum class size of 5% of participants.[16] High entropy is indicated by scores closer to 1.0, suggesting that trajectory classes are distinct and do not overlap. An iterative approach was adopted, beginning with a 1-class solution and raising the number of classes using improvements in the model as criteria for continuing. Once the appropriate number of classes had been identified, each individual's posterior probability of membership in each latent class was estimated and participants were assigned to the class corresponding to their maximum posterior probability.

Finally, logistic regression models were fitted to predict the odds of each independent baseline variable for each class (RStudio Version 1.0.136; RStudio, Inc, Boston, MA). Each logistic model was inspected for evidence of poor fit using Pearson's deviance score and for violations of model assumptions, including potential outliers and influential cases. Due to the small sample size, no multivariate modeling was conducted.

RESULTS

Over the 10-month period, 88 participants were recruited, of whom 56 were female and 44 had isolated patellofemoral OA. Over the 6-month follow-up, 22 participants withdrew from both the study and the OACCP (**FIGURE 1**). There were no significant differences in broad demographics between participants. Significantly more patients dropped out of the study who had combined patellofemoral and tibiofemoral OA than did those who had isolated patellofemoral OA ($P = .005$). Individuals who dropped out also had slightly, but statistically significantly, weaker knee extensor strength (−2 Nm/kg; 95% confidence interval [CI]: −4.1, −0.001; $P = .04$) (**TABLE 1**). Latent class growth–curve analysis allows for missing data; thus, all 88 individuals were retained in the final analysis, despite this loss to follow-up.

Latent Class Growth Analysis

Goodness-of-fit criteria indicated that a multiclass model was found to be superior to a single-class solution (−2 log-likelihood [LL] difference, 111.14; BLRT, $P<.001$; AIC difference, 103.14). Both 2- and 3-class solutions were plausible; however, there was no improvement in model fit between a 3- and 4-class solution. A 4-class solution also resulted in

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less than 5% of the sample being included in a single class. The BLRT, AIC, and BIC model fit criteria all indicated that the 3-class solution was a significantly better fit over the 2-class solution (−2 LL difference, 56.87; BLRT, $P<.001$; AIC difference, 48.9; BIC difference, 51.6). The lowest posterior probability for group membership was comparable between solutions: 0.63 for the 3-class solution and 0.66 for the 2-class solution. Entropy was marginally better for a 2-class solution (0.89) than the 3-class solution (0.8). Acknowledging the better model fit criteria, a 3-class solution was preferred for further evaluation.

Class 1 (n = 25, 28%) was labeled the "high, persistent pain" group, with members characterized by high pain at baseline (7.8 ± 1.7 cm) (**FIGURE 2**) that continued to remain high over time (overall mean, 7.4 ± 1.3 cm) (**FIGURE 3**). A repeated-measures analysis of variance (ANOVA) examining change in the VAS over time was not significant ($P = .52$).

Class 2 (n = 50, 57%) was labeled the "moderate, persistent pain" group, with members characterized by moderate pain at baseline (4.8 ± 1.8 cm) (**FIGURE 2**) that remained stable over time (overall mean, 4.8 ± 1.9 cm; repeated-measures ANOVA, $P = .97$) (**FIGURE 3**).

Class 3 (n = 13, 15%) was labeled the "low pain, improving" group, with members characterized by low pain at baseline (2.6 ± 1.2 cm) (**FIGURE 2**). Repeated-measures ANOVA indicated that this group's pain improved significantly over time ($P = .017$). Specifically, pain improved significantly over the first 6 weeks (mean change from baseline, 0.9 cm; 95% CI: 0.05, 1.8 cm; $P = .04$), then remained persistently low for the remainder of the follow-up period (mean value for weeks 6 to 26, 1.2 ± 0.9 cm) (**FIGURES 2** and **3**).

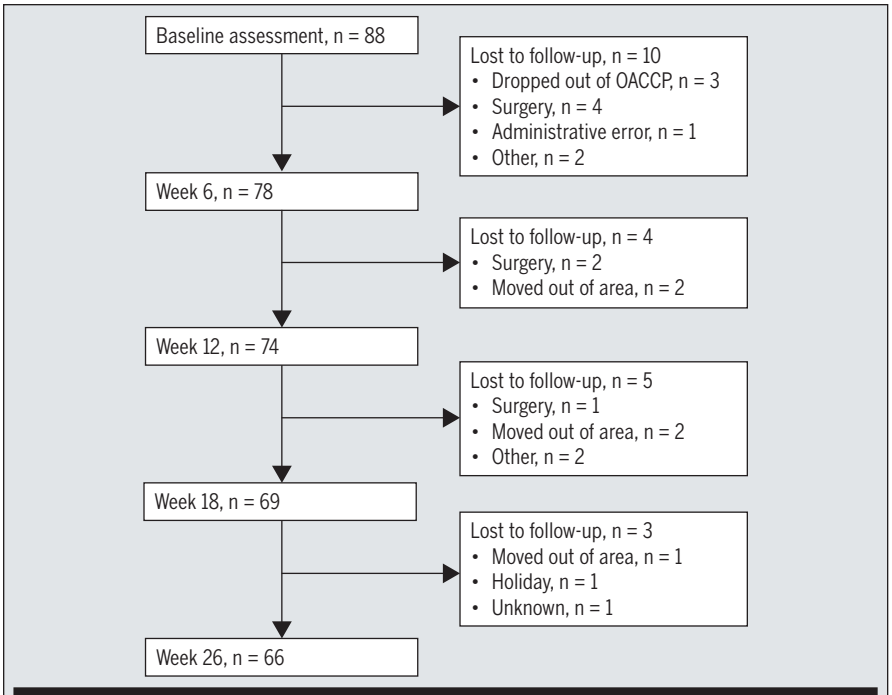

FIGURE 1. Flow chart displaying participant progression and demographics through the study. Abbreviation: OACCP, Osteoarthritis Chronic Care Program.

Baseline Variable Exploration

Multinomial logistic regression was fit setting class 1 as the referent. Models fitted for hip abductor and external rotator strength demonstrated poor goodness of fit ($P = .017$ and $P = .006$), possibly due to the small range of strength within a small sample size, and were subsequently excluded from the analysis. Remaining analyses indicated that compared with the high, persistent pain group, individuals in the moderate, persistent pain group exhibited greater odds of reporting higher KOOS subscale scores for pain (1.05; 95% CI: 1.01, 1.09), activities of daily living (1.04; 95% CI: 1.01, 1.07), and quality of life (1.03; 95% CI: 1.00, 1.07). They also exhibited higher odds of greater knee extensor strength (4.79 Nm/kg; 95% CI: 1.06, 21.61 Nm/kg). Similarly, individuals

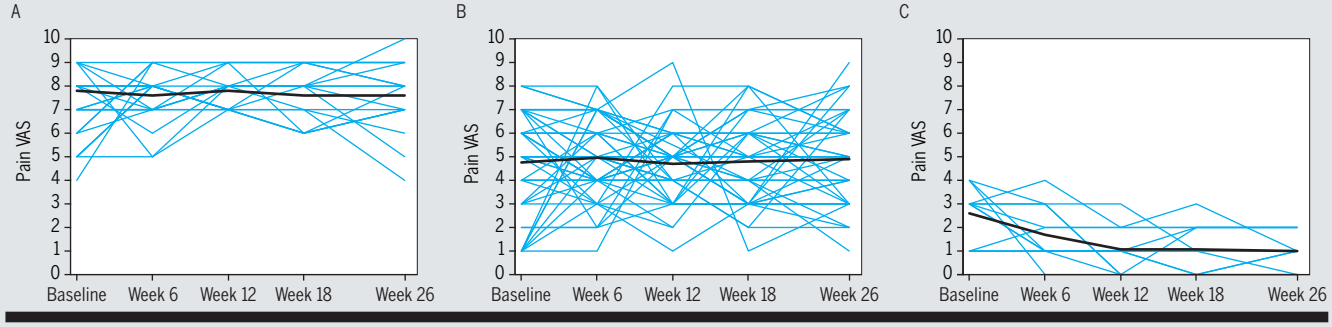

FIGURE 2. Trajectories of pain response for the (A) high, persistent pain (class 1), (B) moderate, persistent pain (class 2), and (C) low pain, improving (class 3) groups. Black lines indicate mean pain VAS trajectories over time. Blue lines are trajectories for all members of the class. Abbreviation: VAS, visual analog scale.

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in the low pain, improving group exhibited lower odds of high timed up-and-go test times (0.79 seconds; 95% CI: 0.63, 1.0 seconds)—indicating better physical performance—as well as greater odds of reporting higher scores across all KOOS subscales, higher local (1.07 N; 95% CI: 1.02, 1.12 N) and proximal (1.06 N; 95% CI: 1.00, 1.13 N) PPTs, and greater knee extensor strength (16.24 Nm/kg; 95% CI: 2.53, 104.34 Nm/kg) (**TABLE 2**). The CIs around knee extensor strength comparisons were wide, indicating that, despite the statistical significance, the size of the sample made the comparisons statistically questionable.

Sensitivity analyses of all significant univariate associations limited to individuals with isolated patellofemoral OA (n = 44) found that all KOOS variables retained significant odds ratios for the low, improving pain group, as did the PPTs and knee extensor strength. Similarly, KOOS pain, activities-of-daily-living, and quality-of-life subscales remained significantly higher in the moderate, persistent pain group compared with the high, persistent pain group. While not significant, the association between class membership and knee extensor strength for the moderate, persistent pain group remained in the same direction as for the primary analysis (**TABLE 3**), whereas the timed up-and-go test for the low, improving pain group was no longer found to be significantly different. The CIs for knee extensor strength comparisons were wider still than for the primary comparison, reflecting the even smaller sample size.

DISCUSSION

People with predominant patellofemoral OA exhibit distinct pain trajectories. Albeit with a small sample, the authors identified 3 distinct trajectory patterns. Two groups demonstrated persistent pain throughout the 26-week follow-up, with the severity of pain being the critical difference between groups. A smaller, third group comprised individuals with low pain at enrollment who experienced a significant improvement over 26 weeks. While this improvement did not reach the threshold for clinically important change,[47] this outcome may be partly attributable to the floor effect in the VAS. The exploratory component of the study also identified

TABLE 1 Baseline Demographics and Independent Variables Between People Who Completed 26 Weeks of the Osteoarthritis Chronic Care Program and Those Who Did Not*

Variable	Complete (n = 66)	Dropout (n = 22)	*P* Value
Sex, n			.082
Female	39	17	
Male	27	5	
Age, y	64.3 ± 9.1	68.4 ± 1.9	.070
Height, m	1.67 ± 0.1	1.64 ± 0.1	.231
Weight, kg	83.11 ± 17.81	83.36 ± 15.55	.951
BMI, kg/m^2	29.9 ± 5.7	30.15 ± 4.9	.860
Side with OA, n			.972
Unilateral	38	12	
Bilateral	28	10	
Compartment with OA, n			.005
Patellofemoral	38	6	
Patellofemoral and tibiofemoral	28	16	
Physical performance			
Timed up-and-go, s	8.1 ± 2.4	8.1 ± 1.9	.966
6-minute walk test, m	477.2 ± 104.0	450.8 ± 94.5	.308
Patient-reported outcomes			
KOOS pain	55.3 ± 17.0	53.6 ± 17.1	.691
KOOS symptoms	51.5 ± 20.4	49.4 ± 18.8	.687
KOOS ADL	59.4 ± 18.5	53.9 ± 20.6	.255
KOOS sport/recreation	25.2 ± 23.2	18.6 ± 15.1	.228
KOOS QoL	32.4 ± 19.8	29.0 ± 18.1	.490
DASS-21 depression	7.7 ± 9.5	8.2 ± 10.4	.844
DASS-21 anxiety	5.2 ± 6.9	5.1 ± 6.3	.962
DASS-21 stress	9.8 ± 9.2	8.5 ± 10.3	.596
PPT, N			
Local	31.5 ± 18.4	31.9 ± 17.1	.922
ECRL	23.3 ± 14.8	20.3 ± 10.9	.382
Isometric strength, Nm/kg			
Hip abductors	0.75 ± 0.20	0.66 ± 0.2	.144
Hip external rotators	0.40 ± 0.15	0.34 ± 0.1	.074
Knee extensors	1.02 ± 0.44	0.81 ± 0.3	.040
Structural			
Midfoot width difference, mm	10.9 ± 4.3	9.7 ± 4.2	.246
Arch height difference, mm	15.2 ± 5.9	15.3 ± 5.2	.967
Foot mobility magnitude, mm	19.4 ± 6.1	18.7 ± 4.6	.749
Mechanical axis, deg	181.6 ± 4.2	180.2 ± 3.9	.322

Abbreviations: ADL, activities of daily living; BMI, body mass index; DASS, Depression, Anxiety and Stress Scale; ECRL, extensor carpi radialis longus; KOOS, Knee injury and Osteoarthritis Outcome Score; OA, osteoarthritis; PPT, pressure pain threshold; QoL, quality of life.
**Values are mean ± SD unless otherwise indicated.*

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that clinically measurable baseline characteristics may be associated with the different trajectories. Specifically, these data suggest that poor KOOS subscale scores and weaker knee extensors are associated with increased odds of experiencing higher pain-severity trajectories. Further, lower local and proximal PPTs and worse physical performance were associated with greater odds of high, persistent pain compared with low and improving pain.

This study is the first to demonstrate that different pain trajectories occur in people with patellofemoral OA. While this research was exploratory in nature, multiple studies have used the same analytical approach to determine pain and functional trajectories in individuals with tibiofemoral OA.[5,10,28,39,48] Between 3 and 6 pain trajectories have been established by these studies, based on the Western Ontario and McMaster Universities Osteoarthritis Index pain subscale and numeric rating scales. Regardless of the number of trajectories, a severe pain group—one that shows minimal improvement over time—has been consistently identified.[5,10,39]

An important difference between these prior findings and those of the current study is that this severe pain group was larger. In studies of individuals with predominant tibiofemoral OA, the high pain group was the smallest,[5,10,28,39,48] typically consisting of less than 10% of the total sample.[5,10,39] This difference in group proportions may reflect the unique burden of patellofemoral OA. This hypothesis is supported by Nicholls et al,[39] whose "severe, nonimproving group" contained the highest proportion of individuals with combined patellofemoral and tibiofemoral OA. A recent 1-year prospective study reported that individuals with combined patellofemoral and tibiofemoral OA exhibited significantly worse clinical symptoms than those with isolated tibiofemoral OA.[31] Not only is there evidence to show that individuals with patellofemoral OA are likely to experience more pain than their counterparts with tibiofemoral OA, but also that their disease trajectories tend to be poorer under current management practices.

In the literature, there is increasing evidence that the existence of distinct pain trajectory classes reflects substantially different clinical subgroups of people with knee OA, and that these groups may require distinct management strategies or therapeutic regimes. By exploring potential relationships between baseline characteristics and pain trajectory class membership, the findings of this study support the hypothesis that such subgroups may also pertain to people with predominant patellofemoral OA.

Interestingly, there are similarities between the baseline characteristics associated with poor prognosis for people with patellofemoral OA and those with tibiofemoral OA. Specifically, individuals in severe pain groups exhibit greater local joint tenderness than do those in the lower pain groups.[5] Although PPT has not been routinely examined, Arendt-Nielsen and colleagues[3] report significant negative correlations between worst-pain VAS scores and aggregate local knee PPT, as well as ECRL PPT. The authors concluded that this is evidence of local primary hyperalgesia and a sign of central sensitization, which may be a mechanism for underlying pain in knee OA and a subsequent target for treatment.

Further, a meta-analysis has recently demonstrated that baseline knee extensor strength deficits significantly increased the risk of Western Ontario and McMaster Universities Osteoarthritis Index pain score decline in follow-ups ranging from 1.5 to 8 years.[13] A potential pathomechanical pathway explaining this relationship in people with patellofemoral OA may involve knee extensor weakness contributing to excessive lateral displacement of the patella. If this phenomenon is not addressed, structural damage of the patellofemoral joint may result.[11,22,44]

Caution is advised when interpreting these results in the context of the current

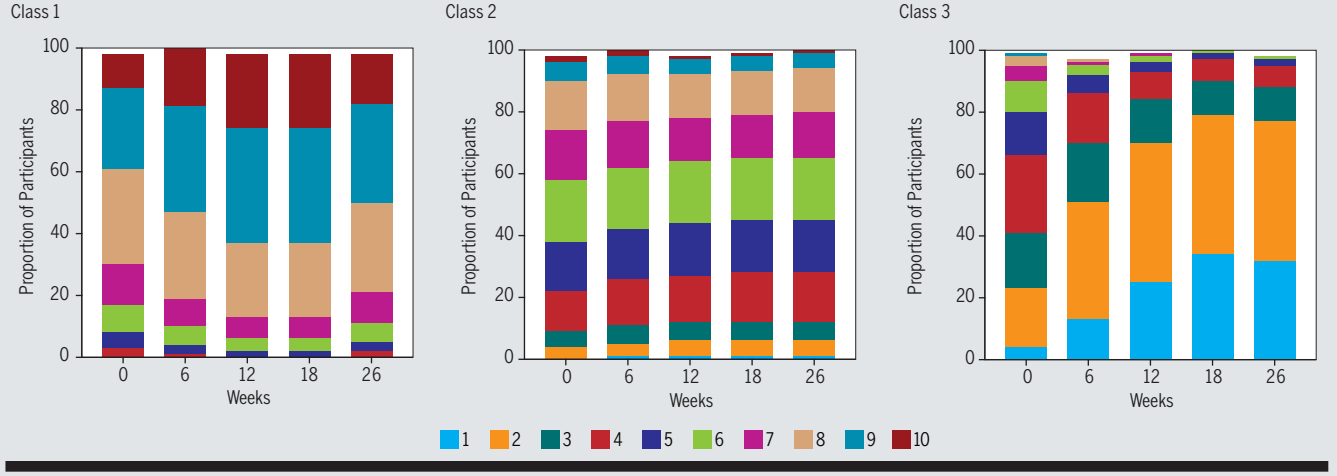

FIGURE 3. Predicted proportion of participants reporting pain of each severity over time, divided by their trajectory class. Different colors represent the different pain visual analog scale scores.

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study. This study's small sample size affected the width of the 95% CIs for the odds ratio for knee extensor strength measures, making the point estimate of effect less reliable than hoped. However, the mean knee extensor strength values observed in the participants in the current study are highly comparable to baseline measures from individuals participating in the Osteoarthritis Initiative data set.[37] Thus, while it is difficult to draw strong conclusions from these data, the validity evident from the larger external data set and the logical theoretical model for how weaker knee extensors may contribute to the pain experience of an individual with patellofemoral OA suggest that the effect the researchers observed has merit.

The authors acknowledge several limitations of this study. The sample consisted of individuals enrolled in a

TABLE 2 Mean Values and Unadjusted Odds Ratios of Baseline Variables and Trajectory Group Membership*

Variable	Class 1† (n = 25)	Class 2‡ (n = 50)	Class 3§ (n = 13)	Unadjusted Odds Ratio‖	*P* Value
Sex (male, reference)					
Class 2 versus class 1				2.90 (0.94, 8.96)	.065
Class 3 versus class 1				3.40 (0.79, 14.85)	.100
Age, y	64.6 ± 9.4	65.3 ± 9.3	65.1 ± 8.3		
Class 2 versus class 1				1.00 (0.95, 1.06)	.746
Class 3 versus class 1				1.00 (0.93, 1.08)	.878
BMI, kg/m^2	30.3 ± 6.8	29.9 ± 4.9	29.4 ± 5.1		
Class 2 versus class 1				0.99 (0.91, 1.08)	.806
Class 3 versus class 1				0.97 (0.85, 1.10)	.650
Bilateral OA (unilateral, reference)					
Class 2 versus class 1				1.90 (0.65, 5.25)	.240
Class 3 versus class 1				0.20 (0.02, 1.97)	.174
Physical performance					
Timed up-and-go, s	9.1 ± 2.9	7.7 ± 1.9	7.4 ± 2.0		
Class 2 versus class 1				0.69 (0.48, 1.00)	.053
Class 3 versus class 1				0.79 (0.63, 1.00)	.050
6-minute walk test, m	437.9 ± 105.0	475.8 ± 98.0	506.3 ± 102.0		
Class 2 versus class 1				1.00 (0.99, 1.01)	.142
Class 3 versus class 1				1.01 (1.00, 1.01)	.055
Patient-reported outcomes					
KOOS pain	43.9 ± 13.8	54.5 ± 14.7	73.7 ± 13.6		
Class 2 versus class 1				1.05 (1.01, 1.09)	.011
Class 3 versus class 1				1.17 (1.09, 1.26)	<.001
KOOS symptoms	41.6 ± 17.5	51.1 ± 20.5	65.3 ± 11.9		
Class 2 versus class 1				1.03 (0.99, 1.06)	.061
Class 3 versus class 1				1.07 (1.03, 1.12)	.002
KOOS ADL	46.52 ± 16.9	58.9 ± 17.9	74.1 ± 14.9		
Class 2 versus class 1				1.04 (1.01, 1.07)	.016
Class 3 versus class 1				1.11 (1.05, 1.18)	<.001
KOOS QoL	21.6 ± 12.6	32.5 ± 19.6	44.4 ± 21.2		
Class 2 versus class 1				1.03 (1.00, 1.07)	.029
Class 3 versus class 1				1.07 (1.03, 1.12)	.002
KOOS sport/recreation	15.0 ± 13.2	21.1 ± 16.1	45.8 ± 33.6		
Class 2 versus class 1				1.02 (0.99, 1.06)	.181
Class 3 versus class 1				1.07 (1.03, 1.12)	.001
DASS-21 depression	7.3 ± 9.6	8.8 ± 10.4	5.1 ± 6.0		
Class 2 versus class 1				1.02 (0.96, 1.07)	.570
Class 3 versus class 1				0.97 (0.88, 1.06)	.460

Table continues on page 12.

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TABLE 2 Mean Values and Unadjusted Odds Ratios of Baseline Variables and Trajectory Group Membership* (continued)

Variable	Class 1† (n = 25)	Class 2‡ (n = 50)	Class 3§ (n = 13)	Unadjusted Odds Ratio‖	*P* Value
DASS-21 anxiety	5.2 ± 7.1	6.0 ± 7.2	1.85 ± 2.9		
Class 2 versus class 1				0.85 (0.69, 1.03)	.102
Class 3 versus class 1				1.02 (0.94, 1.10)	.654
DASS-21 stress	9.9 ± 10.4	10.0 ± 9.2	6.9 ± 9.1		
Class 2 versus class 1				1.00 (0.95, 1.06)	.969
Class 3 versus class 1				0.96 (0.88, 1.05)	.356
Pain					
Local PPT, N	25.2 ± 14.5	31.4 ± 15.8	44.7 ± 20.8		
Class 2 versus class 1				1.03 (0.99, 1.06)	.103
Class 3 versus class 1				1.07 (1.02, 1.12)	.003
ECRL PPT, N	19.0 ± 8.4	22.3 ± 11.9	30.3 ± 24.2		
Class 2 versus class 1				1.03 (0.98, 1.09)	.109
Class 3 versus class 1				1.06 (1.00, 1.13)	.043
Pain mapping, n¶	11/10/4	17/19/14	6/7/0		
Class 2 versus class 1				1.49 (0.77, 2.89)	.234
Class 3 versus class 1				0.69 (0.56, 1.84)	.454
Strength					
Knee extension, Nm/kg	0.8 ± 0.3	0.9 ± 0.4	1.2 ± 0.4		
Class 2 versus class 1				4.79 (1.06, 21.61)	.041
Class 3 versus class 1				16.24 (2.53, 104.34)	.003
Structural					
Arch height difference, mm	14.5 ± 5.9	15.4 ± 6.0	16.4 ± 3.9		
Class 2 versus class 1				1.06 (0.94, 1.19)	.322
Class 3 versus class 1				1.03 (0.94, 1.12)	.521
Midfoot width difference, mm	9.8 ± 5.4	11.2 ± 3.5	10.0 ± 4.8		
Class 2 versus class 1				1.08 (0.96, 1.21)	.198
Class 3 versus class 1				1.01 (0.86, 1.19)	.876
Foot mobility magnitude, mm	18.0 ± 6.6	19.5 ± 5.6	19.5 ± 5.1		
Class 2 versus class 1				1.04 (0.96, 1.14)	.321
Class 3 versus class 1				1.05 (0.93, 1.18)	.448
Mechanical axis, deg	−27.9 ± 4.8	−27.4 ± 4.6	−28.4 ± 5.5		
Class 2 versus class 1				1.03 (0.93, 1.14)	.616
Class 3 versus class 1				0.98 (0.86, 1.13)	.984

Abbreviations: ADL, activities of daily living; BMI, body mass index; DASS, Depression, Anxiety and Stress Scale; ECRL, extensor carpi radialis longus; KOOS, Knee injury and Osteoarthritis Outcome Score; OA, osteoarthritis; PPT, pressure pain threshold; QoL, quality of life.
**Values are mean ± SD unless otherwise indicated.*
†High, persistent pain (reference group). Sex: 20 female, 5 male; side with OA: 18 unilateral, 7 bilateral.
‡Moderate, persistent pain. Sex: 29 female, 21 male; side with OA: 29 unilateral, 21 bilateral.
§Low pain, improving. Sex: 7 female, 6 male; side with OA: 12 unilateral, 1 bilateral.
‖Values in parentheses are 95% confidence interval.
¶Local/regional/diffuse, treated as an ordinal scale because no member of class 3 reported diffuse pain, resulting in a failure of the Hessian matrix to converge. Fisher exact test: 5.79, df = 4, P = .207.

chronic care program within a tertiary health care setting. This program draws individuals from the community, many of whom relocate, have other life events that make participation in programs difficult, or have been placed on the public joint replacement wait list. Current National Institute for Health and Care Excellence guidelines recommend that referral for joint surgery occur prior to the individual experiencing functional limitation and severe pain.[36] Adoption of these guidelines means that individuals on the joint replacement wait list are unlikely to represent those with the most severe clinical symptoms or structural disease.

The similarities in baseline function and pain outcomes between individuals

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TABLE 3 Sensitivity Analysis Mean Values and Unadjusted Odds Ratios of Baseline Variables and Trajectory Group Membership for Individuals With Isolated Patellofemoral Osteoarthritis*

Variable	Class 1† (n = 10)	Class 2‡ (n = 26)	Class 3§ (n = 8)	Unadjusted Odds Ratio‖	*P* Value
Physical performance					
Timed up-and-go, s	9.6 ± 4.0	7.8 ± 2.2	7.9 ± 2.2		
Class 2 versus class 1				0.79 (0.59, 1.05)	.104
Class 3 versus class 1				0.80 (0.55, 1.17)	.245
Patient-reported outcomes					
KOOS pain	40.6 ± 16.8	60.4 ± 14.6	70.4 ± 14.4		
Class 2 versus class 1				1.08 (1.02, 1.15)	.012
Class 3 versus class 1				1.14 (1.05, 1.25)	.003
KOOS symptoms	42.9 ± 22.3	56.0 ± 21.4	62.6 ± 12.7		
Class 2 versus class 1				1.03 (0.99, 1.08)	.123
Class 3 versus class 1				1.05 (1.00, 1.11)	.066
KOOS ADL	41.2 ± 20.0	63.1 ± 16.7	72.6 ± 16.9		
Class 2 versus class 1				1.06 (1.01, 1.12)	.016
Class 3 versus class 1				1.11 (1.03, 1.19)	.006
KOOS QoL	17.0 ± 11.0	35.6 ± 20.4	44.4 ± 19.1		
Class 2 versus class 1				1.06 (1.01, 1.12)	.027
Class 3 versus class 1				1.09 (1.02, 1.16)	.013
KOOS sport/recreation	8.7 ± 9.5	22.2 ± 17.6	34.4 ± 29.8		
Class 2 versus class 1				1.06 (0.99, 1.13)	.095
Class 3 versus class 1				1.09 (1.01, 1.17)	.025
Pain					
Local PPT, N	24.1 ± 13.8	29.6 ± 13.5	45.0 ± 13.6		
Class 2 versus class 1				1.03 (0.97, 1.10)	.267
Class 3 versus class 1				1.10 (1.01, 1.18)	.026
ECRL PPT, N	17.9 ± 6.8	21.5 ± 9.1	35.1 ± 9.9		
Class 2 versus class 1				1.07 (0.96, 1.20)	.208
Class 3 versus class 1				1.13 (1.00, 1.28)	.050
Strength					
Knee extension, Nm/kg	0.7 ± 0.3	1.0 ± 0.5	1.3 ± 0.6		
Class 2 versus class 1				6.58 (0.70, 61.60)	.099
Class 3 versus class 1				17.44 (1.31, 230.26)	.030

Abbreviations: ADL, activities of daily living; ECRL, extensor carpi radialis longus; KOOS, Knee injury and Osteoarthritis Outcome Score; PPT, pressure pain threshold; QoL, quality of life.
**Values are mean ± SD unless otherwise indicated. Data are not presented as sample size.*
†High, persistent pain (reference group).
‡Moderate, persistent pain.
§Low pain, improving.
‖Values in parentheses are 95% confidence interval.

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who were lost to follow-up and those who remained in the study support this and partially explain why the researchers experienced higher-than-expected dropouts, resulting in a lower final sample size. This participant loss may have impacted the capacity of this analysis to identify the precise number of classes through latent class growth analysis (2 versus 3 classes) and prohibited multivariate modeling that may have informed how baseline characteristics interact.

Further, the authors only followed individuals for 26 weeks. While this reflects the typical duration of self-management chronic care programs,[38] OA has a long disease course, and it is likely that individuals' pain fluctuates throughout that time.

The current study included individuals with both patellofemoral and tibiofemoral OA. Combined patellofemoral and tibiofemoral OA is the most common structural diagnosis of knee OA.[18] In addition, the presence of patellofemoral OA

increases the risk of incident tibiofemoral OA, and the presence of tibiofemoral OA increases the risk of structural progression of patellofemoral OA.[17] Although underpowered, sensitivity analyses demonstrated that the findings of the current study changed little when only those individuals with isolated patellofemoral OA were considered.

Interestingly, one measure that was no longer significant within the sensitivity analysis was the timed up-and-go test. This test is one of the core physical performance measures advocated by the Osteoarthritis Research Society International, as it encompasses transitions between more than 1 activity (sit-to-stand, walking, and turning).[15] It is also one of the few performance measures specifically advocated for people with patellofemoral OA.[27] The joint reaction force acting on the patellofemoral compartment when rising from a chair can exceed 15 times body weight, almost double that acting on the tibiofemoral compartment.[20] This may explain why times for the isolated patellofemoral OA group were relatively slower than when the entire group was considered.

By including individuals with both patellofemoral and tibiofemoral OA, the authors believe that the current study reflects the wider knee OA community and, therefore, is of broad interest. This is one of the benefits of being embedded in a current clinical care pathway, which is a strength of this study design. All individuals were engaged in multidisciplinary chronic care management, meaning that these results may be translated to patients undergoing current guideline-based care.[9] Similar to other studies in real-life settings, this study was not designed to test specific hypotheses regarding treatment effects and did not control for treatments. This fact is important to note, as the researchers are not suggesting that individuals in the high, persistent pain group should be excluded from participation in chronic care programs.

This study identified distinct pain trajectories and explored associations between baseline characteristics and trajectory class membership, and its findings support useful hypotheses regarding specific baseline characteristics that may be targeted with management strategies. Importantly, these findings indicate that the pain experience of people with knee OA is influenced by factors that are personal, as well as local to the joint. Therefore, it may be that treatment strategies beyond those in current international guideline-based chronic care programs, such as pain management and coping programs, and more patient-practitioner contact may be required for some people.

Recent evidence has demonstrated that pain coping skills training targeting central sensitization symptoms in people with lower-limb OA improved pain for up to 12 months following program completion.[8,41] How such programs may interact with current chronic care management practices and may change the trajectory of people identified as being at risk for high, persistent pain are unknown. These questions could be examined in future randomized controlled trials.

CONCLUSION

Consistent with current evidence pertaining to prognostic factors of pain and physical function in people with knee OA, those with patellofemoral OA may have distinct pain trajectories. These trajectories appear to be associated with baseline clinical characteristics, particularly poorer scores on KOOS subscales, lower PPTs both locally and at a proximal site, as well as possibly weaker knee extensors. Distinguishing these trajectories and modifiable baseline characteristics may have implications for treatment. However, this study's findings must be validated prior to implementation in clinical practice. Further, clinical trials comparing treatments targeting these prognostic characteristics have the potential to improve and personalize the management of people with patellofemoral OA. ◉

KEY POINTS

FINDINGS: People with patellofemoral osteoarthritis exhibit unique pain trajectories, even when self-managing their condition. Poor patient-reported outcomes, lower pressure pain thresholds, and weaker knee extensors are associated with greater odds of trajectories characterized by high, persistent pain.

IMPLICATIONS: Potential pain trajectories may identify individuals who are in greater need of clinician contact and a treatment approach that focuses on the whole person, rather than solely on the affected joint.

CAUTION: The findings of this study require external validation prior to implementation.

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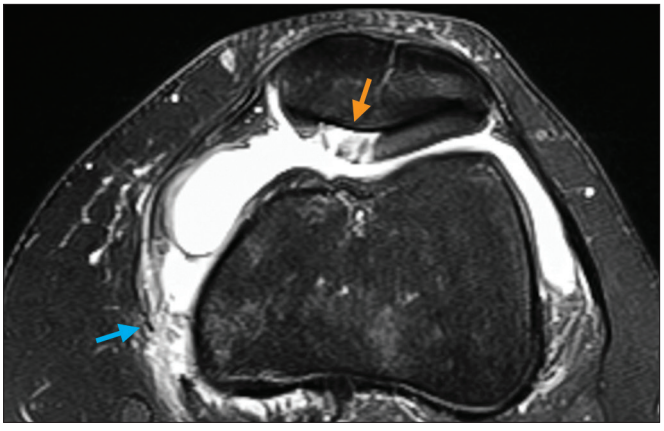

FIGURE 1. Axial, T2-weighted magnetic resonance image of the patellofemoral joint demonstrating a full-thickness patellar chondral defect (orange arrow). Also visualized is a free end of the medial patellofemoral ligament (blue arrow) that detached from the medial femoral epicondyle.

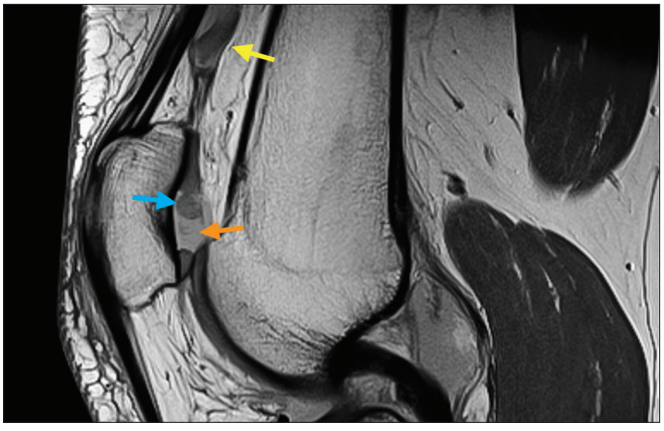

FIGURE 2. Sagittal, T1-weighted magnetic resonance image of the tibiofemoral and patellofemoral joints. The site of the patellar articular cartilage defect is well visualized (orange arrow), with adjacent loose chondral fragment (blue arrow) within the patellar lesion and a large chondral fragment in the suprapatellar pouch (yellow arrow).

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Intra-articular Chondral Fragment After Acute Patellar Dislocation

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An 18-year-old woman, who was a US Military Academy Cadet, presented to a direct-access physical therapy clinic 3 days after sustaining a lateral patellar dislocation that self-reduced with extension of the knee. Examination demonstrated an active range of motion from 0° to 100°, with marked apprehension on lateral patellar glide, diffuse medial tenderness, and effusion. Palpation of the medial patellofemoral joint revealed a small, firm mass that became mobile under direct pressure. Suspecting a loose body, the physical therapist ordered radiographs, which did not demonstrate any associated fractures.

As this patient was scheduled for mandatory Army field training within 6 weeks, rapid disposition was required to determine her potential to participate in obstacle courses and foot marches up to 12.9 km. The patient was referred to an orthopaedic surgeon, who ordered magnetic resonance imaging to assess for intra-articular pathology.[1] Magnetic resonance imaging demonstrated a full-thickness defect in the patellar cartilage at the medial facet (**FIGURE 1**), with a loose fragment in the suprapatellar pouch (**FIGURE 2**).

The patient underwent arthroscopy with excision of the loose bodies 1 week after her injury. After 5 weeks of postoperative rehabilitation, she successfully completed her required training wearing a patellar stabilization brace. The patient returned at postoperative week 11, following completion of Army field training, to discuss any need for further care. She reported full functional performance since postoperative week 8 and declined further rehabilitation visits.

In this case of acute patellar dislocation with unremarkable radiographs, clinical examination suggested a high index of suspicion for a loose body, prompting referral for definitive care. Early utilization of advanced imaging was instrumental in facilitating this patient's ability to complete required training and remain on track to graduate with her class. ◉ *J Orthop Sports Phys Ther 2019;49(1):36. doi:10.2519/jospt.2019.7599*

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