

Research Symposium**2022 IJSPT Orthopedic Summit Research Abstracts**

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The International Journal of Sports Physical Therapy is pleased to publish abstracts from the 12th Orthopaedic Summit (OSET) taking place in Boston, September 21-24, 2022. The IJSPT hosted the 2nd annual research forum and reception at OSET, sponsored by ATI Physical Therapy and Hyperice.

The abstracts presented in the following pages were selected by the OSET Research Committee and editorial staff of the International Journal of Sports Physical Therapy. After careful review, a total of 17 research abstracts were accepted and presented at OSET 2022. Awards for outstanding abstracts were presented on September 23rd.

The 2022 abstracts include contemporary orthopaedic and rehabilitation topics across various research designs. Each abstract presents only a brief summary of a research project / presentation and does not permit full assessment of the scientific rigor with which the work was conducted. While the abstracts offer only preliminary results that may require further refinement and future validation, they do serve an important role in sharing new research ideas and rehabilitation advancements. This sharing of ideas helps to encourage dialogue among researchers, clinicians, and educators that will ultimately contribute to the orthopaedic and rehabilitation body of knowledge. We strongly encourage authors to continue pursuing the publication of their research as a full manuscript.

Thank you to all submitting abstracts for consideration. We look forward to another outstanding season of submissions for OSET 2023.

*Phil Page PhD, PT, ATC*

*Chuck Thigpen PhD, PT, ATC*

OSET Research Committee Co-Chairs

**Digital versions of the posters presented at the OSET meeting can be found [here](#):**

**(1) A MUSCULOSKELETAL APPROACH FOR PRE- AND POSTNATAL REHABILITATION TO PROMOTE RETURN TO SPORT: A CASE SERIES**

Selman R, Early K, Battles B, Seidenburg M, Wendel E, Westerlund S

Benchmark Physical Therapy, Stirrups to Situps LLC

**Background:** Recent changes to exercise guidelines have expanded to include pregnant athletes. More women are transitioning into motherhood at the height of their athletic careers and there is limited guidance on appropriate musculoskeletal rehabilitation from pregnancy through return to sport. Lack of education and awareness of a standardized musculoskeletal approach in this population may lead to increased postpartum symptoms and delay of treatment, ultimately hindering athletic performance.

**Purpose:** The purpose of this case series is to assess the athletes' musculoskeletal response through a new pre- and postnatal rehabilitation protocol.

**Study Design:** Case Series

**Methods:** Six women were referred to physical therapy during pregnancy to participate in this protocol. The women completed a time and criterion based pregnancy and postpartum rehabilitation plan. Subjective and objective data was collected for each participant from the first trimester up to 16 weeks postpartum over the course of approximately 18 months.

**Results:** Pain, urinary dysfunction, and pelvic floor muscle strength were assessed at 6 weeks postpartum and at discharge. Meaningful improvement was noted in pain, urinary dysfunction, and muscle strength by the time of discharge both within participants and as compared to general population statistics.

**Conclusion:** These changes suggest that a musculoskeletal protocol monitored by a licensed and specialized physical therapist should be considered as part of the standard of care in pregnancy and postpartum due to high musculoskeletal demands in pregnancy, postpartum, and sport. Improving understanding of training in these athletes can minimize musculoskeletal and urinary symptoms while decreasing this population's exposure to scrutiny and judgement as they excel in both motherhood and sport.

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## (2) 3D-PRINTED SHORT ARM CASTS: A PILOT CASE STUDY OF RELIABILITY, VALIDITY, AND FEASIBILITY COMPARED TO CONVENTIONAL WATERPROOF FIBERGLASS CASTS

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**Background:** Short arm casting (SAC) is a common treatment of various sports injuries including wrist fractures. Currently, fiberglass and waterproof lining reflect a standard of practice for SAC; however, evolving techniques involving three-dimensional (3D) print fabrication show early promise in optimizing the mechanical properties of orthopedic immobilization techniques, and advantages such as comfort, customization, breathability, waterproofing, lifestyle, and social effects have been reported. However, limited studies have been performed to examine the reliability of 3D printed cast application and the validity and feasibility of the fitting compared to the conventional fiberglass approach.

**Purpose:** To evaluate the reliability, validity, and feasibility of 3D printed short arm casts versus conventional casts.

**Study Design:** Case Study

**Methods:** Three raters of varying experience were instructed on the application of both the conventional and 3D printed (ActivArmor) SAC. Each rater applied two conventional and two 3D printed casts to a participant's dominant wrist to evaluate reliability. Each cast was worn for 24 hours and removed the following day after data collection. Data collection included measures of clinical effectiveness, patient satisfaction, patient rated wrist evaluation, and the upper extremity functional index.

**Results:** ICCs demonstrated 'excellent' intra-rater reliability for clinical effectiveness (0.997, 0.766, 0.997) and patient satisfaction (0.789, 0.892, 0.877). ICCs demonstrated 'excellent' inter-rater reliability for both clinical effectiveness and patient satisfaction metrics (ICC: 0.857, 0.767, respectively). There were no significant differences between fiberglass and 3D printed SACs in terms of average scores of clinical effectiveness (11.50 vs. 11.17,  $P = 0.342$ ), patient satisfaction (11.50 vs. 12.50,  $P = 0.307$ ), or the patient rated wrist evaluation (10.92 vs. 10.14,  $P = 0.865$ ), respectively. The 3D printed SAC group had significantly higher wrist function compared to the fiberglass SAC group as reported in the upper extremity functional index (65.83 vs. 64.00,  $P < .001$ , respectively).

**Discussion:** This pilot case study demonstrates that 3D printed short arm casts may be a valid immobilization technique of the wrist compared to conventional waterproof fiberglass casting. Equivalence in clinical effectiveness and patient rated wrist and upper extremity function was reported between the two types of casting. Participants were slightly more satisfied with the 3D printed casts, which also proved to be more waterproof. The psychomotor skills of

both casting techniques were learned by Athletic Trainers, who were then able to reliably apply, retain, and repeat the technical work.

**Conclusion:** The most common fracture in humans before the age of 75 is a wrist fracture. Furthermore, wrist fracture is the second most common specific injury that brings a person to the emergency room, and many wrist fractures are treated with short arm casting (especially in children). As evolving techniques such as 3D printing in medicine emerge, reliability, validity, and feasibility studies are paramount to further investigations on clinical effectiveness with randomized controlled trials. This study illustrates this specifically with short arm casting techniques. This study sets the foundation for further investigations of 3D printed casting techniques for orthopedic conditions by demonstrating specific reliability, validity, and feasibility for short arm casting. Further studies should investigate similar qualities of lower extremity casts (short leg casts) and pursue randomized controlled trials involving patients requiring definitive immobilization treatment of fractures.

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## (3) SCREENING ASSESSMENT, PERCEIVED TRAINING LOAD AND INJURY INCIDENCE IN A YOUNG AND PRESELECTED VOLLEYBALL POPULATION: RESULTS FROM A 3-MONTH OBSERVATION PERIOD USING A RETROSPECTIVE DESIGN

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**Background:** The value of screening for the prediction of injury risk in team sports has been questioned. The relation between screening and injury incidence has to a lesser extent been studied in youth volleyball athletes, while the relationship between perceived training load and injury incidence is unexamined in this population.

**Purpose:** This study investigates the relationship between a group of physical screening parameters, perceived training load and observed injuries during a 12-week follow-up period. We hypothesize a higher incidence of injuries for: 1) players with inferior outcomes on physical screening parameters and/or 2) players with a higher perceived training load.

**Study Design:** Level 3: Non-randomized controlled cohort/follow-up study

**Methods:** This retrospective study analyses the information from a routine, standardized screening assessment in 46 youth elite athletes between 12-16 years. This screen-

ing included various mobility, strength and stability tests. Injuries, training participation and perceived training load using Borg scores were administered by the medical team during a 12-week follow-up period. The group with chronic overuse injuries was compared to a group without chronic overuse injuries using a Mann-Whitney U test. Effect size was reported using rank-biserial correlation ( $r_{pb}$ ).

**Results:** Sixteen athletes (34.8%) reported a chronic injury. Only the Biering-Sørensen test ( $r_{pb}=0.392$ ) and the relative strength for hip abduction of the right leg ( $r_{pb}=0.381$ ) were significantly lower for the injured group. Small to moderate effect sizes were found for all other screening parameters, but no significant differences. Both groups showed no significant difference regarding perceived training load.

**Discussion/Conclusion:** Our results confirm results in adult athletes, that screening information at group level cannot be linked with future injuries. In addition, perceived training load does not indicate injury susceptibility. Based on these results, other approaches should be explored. The use of multivariate analysis methods or personalized approaches can help in unraveling the complex, dynamic nature of injuries.

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#### (4) A SCOPING REVIEW OF REAL-TIME PERFORMANCE DATA TRACKING IN PROFESSIONAL RUGBY ATHLETES

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**Background:** Athletes and coaches are under stress to maximize performances and outcomes. Every advantage can matter in the world of athletics; technology can be one of those advantages as a tool that can be utilized by coaches, athletes, and medical professionals. The data recorded by global positioning systems (GPS) and accelerometers can provide a valid and reliable means of objectively measuring and assessing physical performance parameters in athletics.

**Purpose:** The purpose of this scoping review was to provide an overview of the existing literature on real-time data tracking technology in the performance of professional rugby athletes.

**Study Design:** Scoping Review

**Methods:** One reviewer searched SportDiscus, CINAHL, Academic Search Complete, and MEDLINE databases using PRISMA guidelines between June and November 2020. The inclusion criteria were articles evaluating professional rugby athletes that were published after 2004 in peer-reviewed journals. Data were extracted for study title, year, study design, tracker technology used, the technology company, athletic variables tracked in the study, notable findings, any changes implemented or suggested, and further research needed.

**Results:** Eleven included studies were identified as descriptive observational studies quantified and reported on performance variables during rugby matches and practices, including total distance, average speed, max speed, number of sprints, low, medium, and high accelerations, max heart rate, mean heart rate, and time in heart rate percentages. Five synthesis studies suggested these devices have different capabilities to accurately measure some movements. Four validation studies identified a lack of clear consensus on the validity of the tracking technology used in professional rugby. Five associative designed studies indicated data collected from these tracking devices can provide sports medicine teams with insight into game trends and workloads of athletes that can then be used to create more appropriate and specific training protocols. The comparative study found that teams may perform better with longer recovery periods, potentially playing a role in team schedule planning.

**Discussion/Conclusion:** The extensive number of variables available from performance tracking devices may provide an overwhelming number of options to consider in capturing, interpreting, and applying the data. GPS and accelerometer units provide valuable data that give insight into the athletes' performance, training load, and health; however various factors such as the brand of tracking device used, and proprietary outcome algorithms limit an analysis of the validity of performance tracking. These data and devices would be best used in combination with other player measurement and assessment methods to provide a comprehensive assessment of the athlete.

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#### (5) DOES BLOOD FLOW RESTRICTION CHANGE FOREARM MUSCLE ACTIVATION AMPLITUDE IN THE UPPER EXTREMITY?

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**Background:** Blood flow restriction (BFR) training involves the use of a band or inflatable cuff to partially restrict blood flow during exercise. Blood flow restriction is thought to create a metabolic environment resulting in muscle hypertrophy and strength. Several researchers have observed increases in muscle activation during and/or following BFR combined with resistance exercises; however, none have investigated acute changes in forearm musculature. Understanding the changes in forearm muscle activation after upper extremity BFR exercise may aid clinicians treating upper extremity tendinopathies such as lateral epicondylitis.

**Purpose:** The purpose of this study was to evaluate the feasibility of a study to evaluate acute changes in surface electromyography (sEMG) activation levels of forearm muscles after strengthening exercise with and without BFR.

**Study Design:** A randomized crossover observational pilot study using a convenience sample of healthy university

students was IRB-approved and conducted at Franciscan Missionaries of Our Lady University.

**Methods:** Six subjects completed pretest measurements of maximal grip strength using a Jamar® hand dynamometer while sEMG was assessed in the wrist flexors and extensors. Subjects then performed wrist strengthening exercise with or without BFR using the TheraBand® Flexbar (the “Tyler Twist” exercise) followed by post-test measures of grip strength and sEMG immediately afterward. Subjects were randomly assigned to perform the strengthening exercise with or without BFR first followed by a 60-minute wash-out. Due to the small sample size, non-parametric statistical analysis was performed.

**Results:** Wilcoxin Signed Rank Test for matched pairs demonstrated no significant differences in the activation of flexors ( $p=.463$ ) or activation of extensors ( $p=.753$ ) between BFR and non-BFR after exercise. There were no adverse events reported.

**Discussion:** This protocol was feasible. There were several limitations of this study. As a pilot study, the statistics were underpowered to detect a true difference. The convenience sample consisted of young, healthy individuals and only 1 female, also limiting the generalizability of the results.

**Conclusion:** This pilot study demonstrated no significant difference in forearm muscle activation after strengthening exercises with or without BFR. The protocol should be performed in larger samples among upper extremity patient populations.

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## (6) DIAGNOSIS OF DEEP VEIN THROMBOSIS IN OUTPATIENTS WITH MUSCULOSKELETAL DISORDERS: A SURVEY OF ORTHOPEDIC AND SPORTS ACADEMIES

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**Background:** Venous thromboembolism can present as either a deep vein thrombosis (DVT) or dislodge and become a pulmonary embolism. Physical therapists routinely examine patients with musculoskeletal conditions that may have serious associated disorders like a DVT.

**Purpose:** The purpose of this study was to determine if there was a difference in physical therapists’ estimation of the probability of a patient having a DVT in patient vignettes as compared to the actual Modified Wells criteria prediction.

**Study Design:** Exploratory Survey

**Methods:** Following a university Institutional Review Board approval, members of the American Academy of Orthopedics (AOPT) and American Academy of Sports Physical Therapy (AASPT) were asked to complete a survey of patient vignettes. Descriptive statistics were calculated, and

Sign Tests were performed to assess differences between responses of presence of DVT (likely or unlikely), and whether the respondent would refer the patient. Nonresponse bias was assessed via Chi square or Fisher’s Exact Tests.

**Results:** Six hundred and seventy members consented and 521 completed the full survey out of 24,028 academy members. 7.2% of full survey respondents reported not considering themselves as competent to screen for DVT. However, this number may be as high as 19.8% due to 75 consent individuals exiting the survey as they declined to answer the competence to screen question. Frequency analysis revealed substantial difficulty in respondents determining whether a DVT was likely or unlikely in 4 of the 5 vignettes, as compared to the Modified Wells criteria, with only vignette 2 having 92.9% of respondents correctly answering as DVT being unlikely. In all vignettes there were statistically significant differences between determination of DVT being likely or unlikely and decision to refer, with respondents consistently choosing to refer despite providing a determination of DVT being unlikely ( $p<.001$  for vignettes 1,3-5.  $p=.038$  for vignette 2). There were no differences in any vignette based on residency or fellowship status, specialist certification, or practicing direct access. There was no evidence of response bias.

**Discussion:** It appears that members of the AOPT and AASPT have difficulty in determination of DVT presence or absence in clinical vignettes. Despite this difficulty, more respondents were likely to refer, possibly indicating their understanding that the ultimate decision to rule out presence of a DVT is beyond the scope of physical therapist practice.

**Conclusion:** Efforts to educate members should be considered to improve the understanding of DVT assessment.

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## (7) THE EFFECT OF ADDING A FOAM SURFACE CONDITION TO THE HEAD SHAKE SENSORY ORGANIZATION TEST IN HEALTH AND CONCUSSED ADULTS

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**Background:** Visual-motor disruptions occur in 65% to 90% of concussed patients that impair balance and can be measured by posturography. The Head Shake-Sensory Organization Test (HS-SOT) is a computerized postural test that increases complexity by including dynamic head motions while maintaining balance.

**Purpose:** The purpose of this study is to compare equilibrium scores while standing on stable and foam cushion surfaces between the SOT and HS-SOT in healthy adults and those concussed.

**Study Design:** Cohort study

**Methods:** Twenty-five participants completed outcome measures and 3 trials of testing. Sixteen individuals ( $21.50\pm 4.52$  years) were healthy and nine ( $20.33\pm 3.35$  years) were concussed. Participants completed the Dizziness

Handicap Inventory, Activities of Balance Confidence Scale, SOT, HS-SOT, and Foam cushion HS-SOT in one session.

**Results:** The groups did not show significant differences on gender, age, DHI, or ABC. The LMM (3 Tasks x 2 SOT conditions x 2 groups) showed that there was a significant effect of task,  $F(2, 100.584) = 55.372, p < 0.001$ , a significant effect of SOT condition,  $F(1, 98.930) = 179.653, p < 0.001$ , and a significant effect of group,  $F(1, 28.367) = 14.701, p < 0.001$ . No significant 2- or 3-way interactions were found ( $p > 0.05$ ). A post hoc analysis of task effect with Sidak adjustment showed that the average equilibrium scores (average of SOT2 and SOT5) in both groups significantly decreased with more complex tasks. Furthermore, the concussion group had significantly worse equilibrium score than the control group during HS-SOT ( $p = 0.007$ ) and Foam HS-SOT ( $p = 0.002$ ) tasks but not during the standard SOT.

**Conclusions:** The HS-SOT may assess and quantify subtle balance deficits in concussed individuals that are not losing balance during simple balance testing such as the BESS. The addition of a foam cushion could be considered to increase complexity of balance performance.

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## (8) THE ASSOCIATION OF JOINT POWER KINETIC VARIABLES WITH RUNNING INJURIES: A CASE CONTROL STUDY

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**Background:** There is conflicting data on which kinetic variables are important to consider with runners. Furthermore, less is understood regarding differences in these variables when controlling demographics. Our primary question is what joint power variables are different between healthy and injured runners.

**Purpose:** The purpose of this study is to identify if there are differences in joint power variables of healthy runners and injured runners.

**Study Design:** Case Control Study

**Methods:** Joint power kinetic variables from the hip, knee, and ankle were collected from 122 runners (26 healthy and 96 injured) over three years with a Bertec force plated treadmill and Qualisys 3D motion capture. The injured runners performed gait analysis in conjunction with physical therapy care, and the healthy runners independently obtained gait analysis for injury prevention and performance goals. Further variables include age, sex, height, weight, BMI, foot strike, and speed.

A two sample T-test was used to compare means of joint power between healthy and injured runners. A logistic regression was used to create a model with the binary dependent variable being injury status of the runner. All alphas were set at .05. Normality of the joint power variables were assessed with Shapiro-Wilk, Kolmogorov-Smirnov, Histograms, and Q-Q Plots.

The predictive value of the logistic regression was assessed with the likelihood ratio of the global null hypothesis. Hosmer and Lemeshow Good-of-Fit test was referenced for fit statistics. Area under the ROC curve was given preference during model building, with R-Square adjusted used to compare models and R-Square values referenced for the final model to report total variation in injury status.

**Results:** There were no significant differences in the means of the peak joint power data between the injured and healthy runners when using a two-sample t-test. However, lower hip power absorbed was found to be associated with injuries (odds ratio, .16; 95% CI .025-.88) when considering demographics using a logistic regression model including categorical age, gender, BMI categories, speed, and power absorbed from the hip, knee, and ankle and power generated from the hip and knees. Ankle power generated was omitted secondary to multicollinearity. The area under the ROC curve was .74, which is considered acceptable discrimination. The R-Square was 9%, suggesting the model is only responsible for 9% of the total variation in the injury status versus a model with no variables. The only significant predictor of the variables included was hip power absorbed ( $\alpha=.04$ ).

**Discussion/Conclusion:** When simply comparing the mean values of healthy and injured groups included in this study, there was no difference in joint power. When controlling for age, sex, BMI, foot strike, and speed with logistic regression analysis; lower hip power absorbed was found to be associated with the runners within the injured group of this study. This could be due to the hip muscles' unique role in absorbing force during early stance phase and may warrant consideration in the context of running injuries.

The findings confirmed much of the previous understandings about running injuries, as they are multimodal with a proportion of the risk being associated with biomechanics. This study further identifies hip power absorbed as being associated with the runners within the injured group, possibly warranting a closer look. These results do not suggest that improving runners' ability to absorb hip power would decrease their injury risk, it simply shows there may be an association.

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## (9) VALIDATION OF DIGITSOLE® PRO SMART INSOLES FOR TEMPORAL GAIT ANALYSIS

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**Background:** Inertial motion units (IMUs) are used to quantify biomechanical variables by capturing movement data relative to body segments. Physical therapists (PTs) are educated on performing gait analyses to identify specific patient gait deviations and devise intervention plans to improve function. While gait analysis is an important part of a physical therapist's initial examination, it may not be feasible to perform due to time and technology constraints, and the physical limitations of the patient. Smart insoles containing IMUs may be an alternative tool for PTs

to measure gait parameters and identify potential gait deviations. Despite this seemingly convenient technology, previous validity studies are limited in sample size and data collection; therefore, further validation is necessary to support the clinical use of IMU insoles.

**Purpose:** The purpose of this pilot study was to compare the temporal gait parameters collected by IMU insoles (Digitsole Pro<sup>®</sup>, France) to the gold standard Noraxon<sup>®</sup> Ultium Motion IMU (Noraxon, Scottsdale, AZ) biomechanical analysis system.

**Study Design:** Descriptive Pilot Study

**Methods:** This study was approved by the FranU IRB. Temporal gait data were collected from 10 healthy individuals (mean 25 years old) during a 2-minute bout of overground walking at their self-selected speed using the IMU insoles and biomechanical sensors. Temporal data were processed using the respective technology software. Independent t-tests using *a priori*  $p < .05$  were conducted to compare parameters simultaneously measured using the Digitsole and Noraxon IMUs.

**Results:** There was no significant difference between temporal parameters of cadence, stride, and swing duration on the right and left sides. A significant difference was observed during the specific phases of the stance portion of gait on both extremities (loading, foot flat, and propulsion phases).

**Conclusion:** In this small pilot sample, overall temporal variables were similar between the Digitsole and Noraxon IMU measurements; however, specific phases of the stance phase were not similar. Because the significant differences were consistent on each side, it is likely the timing of different phases of stance may not be calculated in the same way. Future research should include larger sample sizes, patient populations, and comparison of spatial parameters.

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## (10) KINEMATIC SEQUENCING OF THE FOOTBALL PASS USING INERTIAL MOTION ANALYSIS

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**Background:** The biomechanics of the overhead throw has been heavily researched in baseball players; however little research exists on the biomechanics of quarterback passing in football.

**Purpose:** The purpose of this pilot study was to identify the kinematic sequencing of football quarterbacks using wireless inertial motion technology.

**Study Design:** Descriptive Study

**Methods:** Eight healthy, right-handed, painfree quarterbacks (4 high school and 4 collegiate) performed 3 drop-back passes each at 3 increasing distances (9 total passes at 10, 20 and 30 yards) while wearing wireless IMUs (No-

raxon, Scottsdale AZ) as part of their pre-season assessment. Each pass was synchronized to video; kinematic data in each pass were identified and marked with 4 points of interest: foot contact, maximal external rotation (ER), ball release, and maximal internal rotation. Data were analyzed with Noraxon MyoMotion 3.18.98 using a customized kinematic sequence algorithm to provide mean angles over 9 throws of each quarterback.

**Results:** Kinematic sequencing of the extremities revealed shoulder abduction and ER peaked respectively at 112° and 134° during acceleration, and decreased during follow-through. Elbow flexion ranged from 100° to 17°, decreasing after the cocking phase. Knee flexion remained relatively consistent, ranging from 29° to 46°. The trunk remained relatively upright, generally leaning away from the throwing arm by 2° to 9°; however, quarterbacks experienced an average of 23° of lumbar extension at maximal shoulder ER. The trunk initiated rotation with an average of 40° to the right at foot contact, which reversed during the acceleration phase to a maximum of 21° to the left. The pelvis followed a similar sequence, although the rotation of the pelvis toward the target began earlier in the cocking phase and generally faced the target for the remainder of the throw (2-6° of left rotation). This sequence was seen in the hip-shoulder separation, which remained about 20°, initially favoring right trunk rotation in cocking phase, but quickly reversed to 20° favoring left trunk rotation in the follow-through. Minimal hip-shoulder separation (11°) occurred at ball release.

**Conclusion:** This pilot study provided kinematic sequencing similar to previous video analysis studies and added insight into the hip-shoulder kinematic sequencing in football quarterbacks.

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## (11) DEEP GLUTEAL PAIN: WHEN MIXED NOCICEPTIVE AND NEUROPATHIC PAIN DRIVERS MASQUERADE AS PROXIMAL HAMSTRING STRAIN

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**Introduction:** Deep gluteal pain (DGP) is a common occurrence in outpatient physical therapy settings. Etiologies may include ischiofemoral impingement, piriformis syndrome, hamstring tendinopathy, hamstring syndrome, and lumbosacral radiculopathy. This case study uses the Pain and Disability Drivers Model (PDDM) to differentially diagnose and inform intervention.

**Case Description:** A 32-year-old female diagnosed with right hamstring strain, was referred to outpatient physical therapy. PMH included obesity with a BMI of 30, anxiety, depression, partial thyroidectomy. Her Global Health was

54%. PHQ-2 score was 0/6 and GAD-7 score was 1/21. No prior pertinent imaging was available.

**Outcome:** During the initial virtual examination, the patient stated her low back pain started four weeks prior with no known cause. The back pain had since resolved but she was now reporting pain localized to the right buttock, exacerbated by rolling in bed or transitioning from a seated to supine position. Symptoms were alleviated with standing or walking. Pain radiated down the posterior thigh terminating proximal to the knee. Initial NPRS reflected a pain score ranging from 1/10 to 8/10. She was taking 600 mg ibuprofen BID with minimal effect. Initial LEFS score was 69/80 (86%). Observation showed bilateral genu recurvatum and pes planus with a FPI-6 score of +4. Lumbar flexion was limited to 70% secondary to hamstring tightness. Lumbar extension was full and painless while return to standing elicited gluteal pain. Right lateral lumbar flexion generated mild discomfort in the right hamstring. Seated rotation caused mild discomfort in lumbosacral region. Quadruped position, backward and forward rocking elicited pain in the hamstring region. Hip ROM was WNL and painless. Mild weakness in the hamstrings was noted during supine bridging. Active SLR without a belt was 60 degrees on the R, limited by concordant pain, and 90 deg on the L. Physical exam revealed absent right ankle jerk reflex. Positive confirmatory tests: *Seated Slump, Single Limb Chair Bridge, Puranen–Orava, Long-Stride Walking*. Negative special test: *Seated Piriformis Stretch Test*. The differential diagnoses of hamstring tendinopathy and hamstring syndrome were considered. A plan of care was established to address impairments. HEP included eccentric hamstring strengthening and seated sciatic nerve glide.

**Discussion:** Initial PT treatment focused on hamstring tendinopathy, however due to limited improvement with conservative therapy, a request to the treating physiatrist was made for dedicated imaging after 4 visits. MRI results revealed a L5-S1 disc extrusion, a labral tear, mild tendinopathy in the gluteus medius and proximal hamstring muscles. A bony lesion of unknown clinical significance was identified in the posterior acetabulum, later characterized by an orthopedic oncologist as an enchondroma without cortical erosion, periosteal reaction, or soft tissue involvement. The patient was prescribed 100 mg Gabapentin at bedtime and topical lidocaine patches were recommended. She received a steroid injection into the right gluteus medius and hamstring muscles while continuing her physical therapy for a total of 19 visits over eight months. Final NPRS was 0/10, LEFS was 95%, and HOOS score was 100%.

**Conclusion:** Using PDDM, we constructed a radar plot to determine the primary drivers of pain and disability. Asymmetrical areflexia supported a neuropathic etiology while pain elicited with applied pressure supported a nociceptive determinant. Cognitive, emotional, and social factors played a minimal role in this patient's presentation; therefore, disability drivers were not investigated further.

**Clinical impression:** Red flag symptoms are divided into different classes. While some findings require immediate medical attention, others allow examination and ini-

tiation of care while dedicated physical therapy is continued. This case study demonstrates the importance of an interdisciplinary approach with effective communication and informed investigation. It underscores the importance of astute clinical reasoning as precautionary intervention measures are implemented.

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## (12) EVALUATION OF QUARTERBACK THROWING MECHANICS: A SCOPING REVIEW

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**Background:** The biomechanics of a football quarterback's full-body throwing motion are understudied in comparison to baseball pitching mechanics. Although less common, quarterbacks can suffer from similar stress injuries as baseball pitchers. Understanding the throwing mechanics of quarterbacks may help guide prevention, performance, and rehabilitation programs.

**Purpose:** The purpose of this scoping review was to identify studies that analyzed and quantified the biomechanics (kinematics, kinetics, and electromyography (EMG)) of the throwing motion in football quarterbacks.

**Study Design:** Scoping Review

**Methods:** A systematic literature search was performed in May of 2022 in the following databases: CINAHL, Medline, and SPORTDiscus. Boolean searches and terms included: "quarterback," "throwing," "football," and "biomechanics." The article inclusion criteria were studies that measured kinematics, kinetics, and/or EMG of football throwing mechanics. Exclusion criteria were (1) abstracts without full text; (2) literature reviews or Level 5 studies; (3) studies that did not include football quarterbacks. The selection and data extraction processes were performed by a single researcher following the PRISMA-ScR guidelines.

**Results/Discussion:** Six studies were included (four Level 3 observational studies<sup>3-6</sup> and two Level 4 case studies<sup>1,2</sup>). A total of 94 quarterbacks were analyzed within all selected studies; there were 23 high school, 36 college, 20 aspiring professionals, and 15 recreational male quarterbacks. The age range of the subjects was 15 to 32.<sup>4,6</sup> Most cited biomechanical research on football throwing was from 3 studies completed between 1995 and 2002.<sup>3-5</sup> Maximum angular velocity of elbow extension was reported to be between 1,280°/s and 1,760°/s while internal rotation was reported to be between 2,990°/s and 4,950°/s.<sup>1,5</sup> Researchers<sup>2-6</sup> have described between 3 to 6 phases to quantify the throwing motion amongst quarterbacks. One researcher analyzed ground reaction forces (GRFs) through the lower extremities during various drop-back steps ranging from 1024N to 1510N.<sup>1</sup> All studies collected data using high-speed cameras and data acquisition systems (60 to 1000 Hz) both inside labs and outdoors using various drop-back steps<sup>1</sup> and a range of throwing distances (4 to 30 yards), while one study completed two throws for max distance.<sup>6</sup>

**Conclusion:** This review suggests that technological advances in biomechanical data collection and the progression of coaching and training necessitate an updated evaluation of quarterback biomechanics during throwing across multiple age groups, drop-back steps, receiver patterns and throwing distances. New technology such as wireless EMG and inertial motion units may provide updated biomechanical data in more realistic environments for football quarterbacks.

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### (13) INCORPORATING BOTH MODIFIABLE AND NON-MODIFIABLE FACTORS IMPROVE PROFESSIONAL BASEBALL PITCH INJURY NET BENEFIT COMPARED TO CURRENT BEST EVIDENCE-BASED PRACTICE.

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**Background:** The best available evidence to guide pitching injury reduction has focused on evaluating each specific physical factor in isolation. Clinical prediction models have demonstrated the ability to account for the multi-factorial nature of injuries that can aid in clinical decision making. Clinical accuracy is an important step in developing improved clinical examination; however, these current analytical methods do not assess the true impact of clinical decisions on patient/team health outcomes. Net benefit can assess clinical impact of clinical decisions. Net benefit methodology can be used to assess an action by calculating the potential value and harm of the action on the same scale, allowing for a direct comparison. While calculating the net benefit of one particular injury threshold is important, within sport, injuries vary between different teams,

competition levels, and individual pitchers. As a result, the net benefit of a prediction model must be analyzed over a range of thresholds through decision curves, allowing to evaluate the clinical decision impact at the organizational level.

**Purpose:** To determine if a clinical prediction model improves clinical decisions compared to current best evidence-based practice in minor league (MiLB) pitchers.

**Design:** Prospective cohort in MiLB

**Methods:** A 10-year prospective injury risk study was conducted with MiLB pitchers. Pitchers were evaluated during preseason and pitches and arm injuries were documented prospectively. Preseason measures included shoulder internal, external, and horizontal adduction range of motion and humeral torsion using validated methods. Body mass index, arm injury history, professional experience, and arm dominance were also assessed. Pitches and arm injuries were documented throughout the season. *A priori* it was determined that 400 pitchers were needed to develop a multivariable prediction model. A logistic regression incorporating non-linear transformations was developed and internal validation was performed with elastic net and 10-fold cross-validation. Clinical decision analysis curves, which calculate net benefit, were performed with an *a priori* risk threshold of 15-30% based on published baseball injury rates and stakeholder involvement. Net benefit is calculated by (sensitivity - (1 - specificity)) \* sample injury rate. Net benefit is interpreted on an additive scale, such that one point increase in net benefit is equivocal to properly identifying one more patient with the outcome without falsely misidentifying other patients that will not have the outcome as sustaining the outcome. The clinical net benefit was determined by comparing clinical decision curves between groups that treat all as high risk ("treat all"), all are at low risk ("treat none"), and 'risk profile' (TROM > 10° difference and HA < 0°).

**Results:** 407 MiLB pitchers (Age: 23.2 (2.4); BMI: 25.1 (2.3); Right-Handed: 83%; 141 arm injuries) participated. Arm injury incidence was 0.27 arm injuries per 1000 pitches. The prediction model demonstrated greater net benefit. At 20% risk, 'treat all' demonstrated 0.06, TROM 0.13, HA -0.01, and prediction model net benefit was 0.21. At 25% risk, 'treat all' demonstrated -0.25, TROM 0.04, HA 0.00, and prediction model net benefit was 0.07.

**Conclusions:** The multivariable prediction model demonstrated greater clinical net benefit compared to 'treat all' and ROM risk profiling for pitchers between 15-30% arm injury risk. Out of 100 pitchers, at 25% arm injury risk, the prediction model would improve injury identification by 3 pitchers compared to TROM risk profiling, and compared to 'treat all' that would intervene on all 100. While only modifiable factors can be intervened upon, these findings suggest including both modifiable and non-modifiable factors can improve injury risk assessment and clinical resource allocation compared to current evidence which assesses each risk factor in isolation.

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## (14) COMPARISON OF ADOLESCENT PITCHING ARM INJURIES OUTCOMES BETWEEN GROWTH PLATE AND SOFT TISSUE INJURIES

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**Background:** Non operative management led by supervised rehabilitation is the first line treatment advocated for adolescent arm injuries. However, there is very little evidence to guide a treatment approach including patient reported outcome (PRO) measures at the time of return to sport. While many patients are given region specific PRO, they not overly sport-specific and have demonstrated a ceiling effect in athletic populations. Sport specific scales such as the Functional Arm Scale for Throwers (FAST) is specific, but lengthy. In other populations the Single Assessment of Numeric Evaluation (SANE) has shown acceptable measurement properties, however it has not been evaluated in the throwing athlete.

**Design:** Retrospective cohort

**Purpose:** To compare region specific PROs, FAST and SANE scores at time of RTS for non-operative baseball pitchers following arm injury.

**Design and Setting:** Retrospective review of non-operative adolescent baseball players at time of RTS from a large outpatient orthopedic physical therapy clinic.

**Participants:** Adolescent baseball pitchers (15.0 + 1.9yo; 36 R handers; 175 ± 11.3 cm, 69 ± 14.3 kg), who completed non operative rehabilitation for either soft tissue (ST) or growth plate (GP) injuries were included for analysis.

**Methods:** Pitchers completed a region-specific PRO, either Quick Dash (DASH) for elbow or Pennsylvania Shoulder Scale (PENN) for shoulder injuries at the beginning and end of care. Additionally, at the time of RTS pitchers completed the FAST and SANE at the time of return to sport. A one-way ANOVA comparing age, visits, and outcome measures between injury types and body regions was performed ( $\alpha \leq 0.05$ ). Pearson correlation coefficients were also assessed between region specific PRO, FAST and SANE scores at time of RTS.

**Results:** When comparing the 29 ST to the 11 GP injuries, pitchers with ST injuries tended to be older (15.3 ± 4 v 14.2 ± 5 years;  $P=0.10$ ), taller (177 ± 11 v 169 ± 14 cm  $P=0.07$ ), and heavier (72 ± 9 v 62 ± 10 kg  $P=0.05$ ) than patients with a GP injury. Average visits 17.8 ± 7.9, PENN = 97% ± 10, DASH = 96% ± 14, SANE = 94 ± 8 and FAST 9% ± 9 scores were not different between groups ( $P > 0.05$ ). There was a moderate correlation between FAST and SANE scores (-0.53), but not region-specific PROs (0.20).

**Conclusion:** Adolescent pitchers who complete rehabilitation and return to sport require around 18 visits over 8-12 weeks to achieve normalized patient outcome measures. Interestingly, adolescents with GP injuries have greater disability at onset and experience lower region PROs at time of RTS even though their sport specific PRO and SANE are normalized. The SANE appears to provide a simple, reason-

able approximation of pitcher function at the time of RTS in adolescent pitchers and is not influenced by arm injury location or type.

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## (15) ORGANIZATIONAL RISK PROFILING AND EDUCATION ASSOCIATED WITH REDUCTION IN PROFESSIONAL PITCHING ARM INJURIES: A NATURAL EXPERIMENT

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**Background:** Baseball has a high injury incidence, and these injuries continue to increase. The greatest injury incidence is to the shoulder and elbow, with pitchers having a higher injury incidence and prevalence than position players. One method to assess injury risk is through risk profiling. Risk profiling is defined as the ability to screen individuals and subsequently identify individuals at high risk for the outcome (i.e., injury). Within baseball, risk profiling has been performed, with shoulder range of motion used as the risk profile gold standard. However, despite the integration of injury risk profiling, education, and individualized interventions for high injury risk athletes, it is currently unclear how these strategies affect injuries in professional baseball pitchers.

**Purpose:** To evaluate the influence of risk profiling and education on arm injury incidence in minor league (MiLB) pitchers and to stratify by injury severity.

**Study Design:** Prospective natural experiment in MiLB.

**Methods:** A prospective natural experiment study was conducted from 2013-2019 on MiLB pitchers. Shoulder external (ER) and internal (IR), total range of motion (TROM), horizontal adduction (HA), and humeral torsion (HT) were

measured in preseason and prospectively followed throughout the season for pitch count, pitching appearances, and injuries. Organizational risk profiling and education was implemented in 2015 based on preseason assessments. Shoulder IR ROM risk was defined as  $\leq -15$  degrees, shoulder ER ROM risk was defined as  $\geq 15$  degrees, shoulder TROM risk was defined as  $\leq -10$  degrees, and dominant shoulder HA risk as  $< 0$  degrees.  $\chi^2$  were performed to investigate potential differences between shoulder ROM risk categories between the 2013-2014 (Pre) and 2015-2019 (Post) seasons. Interrupted time series analyses with quasi-poisson distributions were performed to assess the effect organizational risk profiling and education on arm injury in MiLB pitchers and repeated for 7 and 28 day injury severity. Sensitivity analyses were performed separately for elbow and shoulder injury, time to injury, and combined trunk and lower extremity injury.

**Results:** 297 pitchers (Age: 23.0 (2.2) years, Left Handed = 21%) were included (Pre: 119, Post: 178). Pitchers in the 2013-2014 seasons demonstrated less preseason shoulder injury risk for IR ( $P= 0.003$ ) and ER ( $P= 0.007$ ), while the 2015-2019 seasons demonstrated less HA risk ( $P= 0.04$ ). There were no differences between seasons for TROM risk ( $P=0.76$ ). There was a significant adjusted time loss arm injury reduction for the 2015-2019 seasons (0.68 (95% CI: 0.47, 0.99)). Similar relationships were observed for 7 days (0.62 (95% CI: 0.42, 0.93)), but not for 28 days (0.71 (95% CI: 0.47, 1.06)). There was a significant decrease in elbow injuries for the 2015-2019 seasons (0.53 (95% CI: 0.30, 0.95),  $p = 0.034$ ). There was no reduction in shoulder injuries for the 2015-2019 seasons (0.89 (95% CI: 0.53, 1.56),  $p = 0.690$ ). There was no relationship between arm injuries time occurrence within the baseball season (1.07 (95% CI: 0.74, 1.56),  $p = 0.723$ ). There was no reduction in combined trunk and lower extremity injuries for the 2015-2019 seasons (1.55 (95% CI: 0.79, 3.01),  $p = 0.204$ ).

**Conclusion:** Organizational risk profiling and education appear to reduce professional pitching overall and 7 day arm injury risk by 33%-38% but not for 28 day injury risk due to the wide confidence intervals. These findings suggest that while injury risk increased over time, organizational risk profiling mitigated the expected increase in arm injury rates. Risk profiling and education can be used as a clinical screening and intervention tool to help decrease arm injuries in professional baseball populations.

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## (16) FORWARD FLEXION CAN RELIABLY BE MEASURED WITH A FRONT-FACING CAMERA USED FOR AT-HOME PHYSICAL THERAPY

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**Background:** Accurate assessment of shoulder range of motion (ROM) is important for both initial evaluation and evaluating the rehabilitation progress. Recently, digital

platforms have been developed which assess ROM with the use of a front-facing camera available on smart phones. Such tools allow ROM to be objectively assessed and monitored remotely but require validation.

**Purpose:** The purpose of this study was to compare forward flexion (FF) measured with a digital health platform (PT Genie, Orlando, Fl) to in-office measurements with a hand-held laser-powered digital goniometer (Halo Medical Devices, Australia)

**Study Design:** Prospective Evaluation.

**Method:** Consecutive patients were evaluated in a single shoulder specialist's practice. All participants completed 3 consecutive FF efforts measured first with a digital goniometer, followed by 3 consecutive FF efforts measured with the front-facing camera of a mobile device. All digital goniometer measurements were recorded by the same examiner. All measurements using the front-facing camera were obtained with an iPhone 11 running iOS 15.4.1, and the PT Genie platform. The mean from the 3 measurements was calculated and the mean differences between the two measurement options were then compared using the simple Student t-test. Analysis was completed using SPSS version 17 (SPSS Inc., Chicago).

**Results:** Thirty-two patients, including 16 males and 16 females, aged  $58.5 \pm 17.4$  years (range 24-80) participated in the study. For both the digital goniometer and front-facing camera groups there were no significant differences within the 3 measurements. Mean FF measured with the digital goniometer was  $120.1^\circ \pm 24.7^\circ$  (range  $71.7^\circ - 164.7^\circ$ ) compared to  $123.5^\circ \pm 26.0^\circ$  (range  $74.7^\circ - 173.0^\circ$ ) with the front-facing camera, for a difference of  $3.4^\circ$  between groups ( $p < 0.001$ ).

**Discussion/Conclusion:** The findings from our study suggest that measurement of shoulder Forward Flexion is comparable between a handheld digital goniometer and a digital application front-facing camera. While small differences were seen between the methods, the differences are not likely clinically relevant, and more importantly the findings were internally consistent. These preliminary findings help in establishing the use of such an application for remote physical therapy. Further study is needed to assess other planes of range of motion and obtain data in a larger cohort.

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## (17) AT-HOME PHYSICAL THERAPY WITH A REMOTE MONITORING DIGITAL HEALTH PLATFORM LEADS TO SIMILAR PATIENT REPORTED OUTCOMES COMPARED TO TRADITIONAL IN-OFFICE PHYSICAL THERAPY FOLLOWING SHOULDER SURGERY

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**Background:** Physical therapy (PT) following shoulder surgery has traditionally occurred via in-office supervised visits. Recently digital health tools with remote patient monitoring (RPM) have emerged as an option to enhance the ability to both monitor and encourage engagement of home PT. The appeal of such tools has been accelerated by the impact of COVID-19 on the healthcare system.

**Purpose:** The primary purpose of this study was to compare patient-reported outcomes (PROs) following shoulder surgery of patients who completed at-home PT with a digital rehab application to patients who completed in-office supervised PT. The secondary purpose was to assess engagement among patients who used digital PT.

**Study Design:** Retrospective Review.

**Methods:** A retrospective matched comparative evaluation was performed of patients who underwent arthroscopic shoulder surgery or shoulder arthroplasty at a single institution between April 2020 and May 2021. Patients who underwent home-based physical therapy with a digital remote monitoring platform (PT Genie; Orland, FL) were identified and age and procedure matched (arthroscopy or arthroplasty) to a cohort of patients that underwent in-office physical therapy. The digital platform provided remote monitoring capabilities with measurement of range of motion. PROs measured preoperatively and at 1 year post-operative included visual analogue scale pain score (VAS), American Shoulder Elbow Surgeons Score (ASES), and Single Assessment Numeric Evaluation (SANE). Engagement measured as the number of sessions recorded was analyzed

in the digital PT based on 6 age groups ( $\leq 40$ , 41-50, 51-60, 61-70, 71-80 and 81+). Statistical analysis using the student t-test to compare means was performed using SPSS version 17 (SPSS Inc., Chicago).

**Results:** A total of 862 patients were identified, included 396 arthroscopic surgeries (198 in each PT group) and 466 in the arthroplasty group (233 patients in each PT group). The groups were similar at baseline other than a higher pre-operative ASES score in the digital PT arthroplasty group. The ASES score for the PTG-arthroplasty group was 44.5 and for the non-PTG group it was 39.0 ( $p=0.002$ ). There was no significant difference in any PROs between the two groups at 1 year follow up. The highest engagement in digital PT group was observed in the arthroplasty group and over the age of 50.

**Discussion/Conclusion:** In conclusion, there appears to be no difference in PROs following shoulder surgery whether physical therapy is performed in-office or at home via a digital platform with remote patient monitoring capabilities. Interestingly, engagement with digital PT was highest in older patients, suggesting that the technology is not a large barrier. Although further study is needed to confirm these findings, benefits of digital PT with remote monitoring may include: 1) Decreased cost for the health-care system, 2) Decreased travel time for the patient, and 3) Scheduling efficiency and improved access to the PT for the patient.

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