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Abstract #1

Are Neuromuscular Landing Patterns Related to ACL Injury Risk? A Prospective Study

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Context: Only few prospective studies have determined biomechanical and neuromuscular risk factors for anterior cruciate ligament (ACL) injury risk. Additionally, no other prospective studies have confirmed the earlier suggested ''high risk'' biomechanical or neuromuscular parameters.

Objective: To investigate, if athletes who sustained an ACL injury during one year follow-up period, showed at baseline significantly different neuromuscular (co-)activation patterns and/or different landing kinematics and kinetics during the landing phase of drop vertical jumps (DVJ).

Design: Prospective cohort study design.

Setting: Controlled, laboratory setting.

Patients or Other Participants: Forty-six uninjured female top level athletes (21 soccer, 9 handball and 16 volleyball) with no history of ACL and posterior cruciate ligament injuries. Four sustained a non-contact ACL injury during one-year follow-up.

Intervention(s): All measures were performed on the dominant and non-dominant leg. Trajectory-level vector field statistics were used to investigate if differences in neuromuscular (co-)activation patterns (vastus medialis (VM) and lateralis (VL), hamstrings medialis (HM) and lateralis (HL)) and in knee abduction angles and external knee abduction moments were present between athletes who sustained ACL-injuries and uninjured controls.

Main Outcome Measure(s): VL, VM, HL and HM activation time curves were normalized to maximum voluntary contractions. Muscle co-activations were evaluated as a vector-field over time {VM,VL,HM,HL} with post-hoc analyses for {VM,VL}, {VL,HL}, {HM,HL} and {VM,HM}, and for the individual muscles (%MVC). Time curves of knee abduction angles and external knee abduction moments were expressed in degrees (°) and Newton-meters (Nm), respectively.

Results: The overall muscle co-activation {VM,VL,HM,HL} vector differed significantly between the ACL-injured group and the control group during the peak loading phase ($P < .001$). Significantly greater {HM,HL} and {VL,HL} co-activation amplitudes were found in the ACL-injured group during peak loading ($P < .001$). The ACL-injured group showed significantly greater HL amplitudes during these time periods ($P < .001$) (mean ± SD [%MVC]; 33.2 ± 11.2 in the control versus 57.7 ± 25.9 in ACL-injured group) while no other differences in VM, VL or HM were found. No differences were found between the ACL-injured group and the control group in knee abduction angles (mean ± SD; 6.58 ± 5.27° in control group versus 8.12 ± 5.41° in the ACL-injured group) and knee abduction moments over time (mean ± SD; 18.28 ± 16.40 Nm in control group versus 19.18 ± 17.05 Nm in the ACL-injured group).

Conclusions: This study showed that participants who go to incur an ACL injury had at baseline neuromuscular landing patterns with increased lateral and posterior neuromuscular co-activation. An increased HL activity and an increased lateral vector in combination with a rather similar VM and HM activity might lead to imbalance in the tibio-femoral contact forces predisposing athletes to greater ACL strain. Considering that no kinematic or kinetic differences were found in these individuals, neuromuscular screening should be considered as a key part of future ACL injury risk screening tools.

Abstract #2

Hip Muscle Strength Predicts Noncontact ACL Injury in Male and Female Athletes: A Prospective Study

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Context: Abnormal movement patterns at the knee, hip, and trunk have been linked with non-contact ACL injuries prospectively. These abnormal movement patters may be explained, in part, by diminished hip muscle strength.

Objective: To determine if baseline hip muscle strength predicts future non-contact ACL injury in athletes.

Design: Prospective cohort.

Setting: Athletic training facilities and various athletic fields.

Patients or Other Participants: 501 competitive athletes (138 females and 363 males) participating in various sports.

Intervention(s): Prior to the start of the sport seasons, isometric hip strength (external rotator and abductor) was measured bilaterally using a hand-held dynamometer. Postseason, logistic regression was used to determine whether baseline hip strength predicted future non-contact ACL injury. Receiver operating characteristic (ROC) curves were constructed independently for each strength measure to determine the clinical cut-off value to distinguish between a high and low risk outcome.

Main Outcome Measure(s): Preseason hip abductor and hip external rotator strength (%BW). During the sports season, ACL injury status was recorded. Injured athletes were further classified based on the mechanism of injury (non-contact vs. contact).

Results: Fifteen non-contact ACL injuries were confirmed (6 female, 9 male), for an overall annual incidence of 3.0% (2.5% for males and 4.3% for females). Baseline hip strength measures were significantly lower in injured athletes compared to non-injured athletes [hip external rotator strength: 18.8 ± 2.0 vs. 24.1 ± 5.3 %BW, $P = .003$; hip abductor strength: 35.9 ± 5.3 vs. 40.3 ± 6.3 %BW, $P < .001$]. Separate logistic regression models indicated hip strength was predictive of injury status [hip external rotator strength: OR = 0.815 (95% CI: 0.720, 0.922), $P = .001$; hip abductor strength: OR = 0.889 (95% CI: 0.831, 0.952), $P = .001$]. Clinical cutoffs to define *high risk* were established as hip external rotator strength ≤ 20.3% BW and hip abductor strength ≤ 35.4% BW. Using these cutoffs, the corresponding sensitivities were comparable for both hip external rotator and abductor strength measures [93% (95% CI: 68, 99) vs. 87% (95% CI: 60, 98)], as were specificities [59% (95% CI: 54, 64) vs. 65% (95% CI: 60, 69)]. Athletes classified as *high risk* based on their preseason hip abductor and hip external rotator strength tests had their probability of injury increase from 3.0% to 7.2% and 6.6%, respectively. Athletes classified as *low risk* on their preseason hip abductor and external rotator strength tests had their probability of injury decrease from 3.0% to 0.65% and 0.34%, respectively.

Conclusions: Measures of preseason isometric hip abductor and hip external rotator strength independently predicted future non-contact ACL injury status in competitive athletes. Our data suggest that screening procedures to assess ACL injury risk should include an assessment of isometric hip abductor and/or external rotator strength.

Abstract #3

Association of Gene Polymorphisms in COL1A1 and COL12A1 With ACL Tears: A Study in the Indian Population

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Context: Genetic polymorphisms are increasingly being identified in white populations as an intrinsic risk factor predisposing an individual to an ACL tear. This is the first study in a non-Caucasian population to look into genetic risk factors in ACL tear as well as to study the protein expression profile of these polymorphisms.

Objective: (1) To evaluate if there are SNP's (single nucleotide polymorphisms) in *COL1A1* and *COL12A1* that result in an ACL tear phenotype. (2) To investigate any association between protein expression of *COL1A1* and *COL12A1* and the genetic polymorphisms identified in these loci.

Design: Case-control genetic association study.

Setting: Research laboratory and operation theatre.

Patients or Other Participants: Fifty patients with ACL tear taken up for arthroscopic reconstruction. Fifty-two patients with unilateral, closed fracture of upper limb served as controls (Age group: 18–45 years). Mean age of cases was 24.76 ± 6.1 years whereas that of control group was 30.25 ± 7.15 years. Females comprised 6% and 13.5% of the study and control populations respectively.

Main Outcome Measure(s): Venous blood samples collected from cases and controls whereas tissue samples collected from cases only. Lymphocytes extracted from blood. ACL remnant tissue excised during arthroscopic intervention and stored for DNA extraction. DNA isolated from both lymphocytes and tissue using commercial kits. The eluted DNA was quantified using ultraviolet spectrophotometry and run on agarose gel to verify the quality. By using RT-PCR (real time-polymerase chain reaction) amplification, *COL1A1* and *COL12A1* genes were analyzed for SNPs using specific primers. rs970547 (AluI polymorphism), rs240736 (BsrI polymorphism) of COL12A1 and rs1800012 (Sp1 binding site polymorphism) and rs1107946 of COL1A1 gene

tested. The RT-PCR amplification products were imported by sequence detection software for the detection of SNP. ELISA (enzyme-linked immune sorbant assay) analysis of ACL tissue extracted from cases was carried out and the results normalized to corresponding total protein.

Results: (1) AG, GG genotypes of rs970547 of *COL12A1* significantly under-represented in the study group (Odds ratio {OR} = 0.219; Confidence interval {CI} = 0.053–0.906; Z value = 2.096; *P* value = .036 for AG and OR = 0.214; CI = 0.05–0.914; Z = 2.082; *P* = .037 for GG). (2) No significant difference in genotype and allele distributions in rs240736 of *COL12A1* gene (*P* = .712), rs1800012 (*P* = .516) and rs1107946 (*P* = .971) of *COL1A1* gene. (3) No significant association found in the protein expression pattern in the ELISA test. Gender-specific analysis of the genotype results was not possible due to the relatively small population of female patients in both groups.

Conclusions: We found that the AG and GG genotypes of rs970547 (Alu1 polymorphism) of COL12A1 gene were significantly under-represented in ACL tear patients in the Indian population. No significant association of the rs240736 SNP of COL12A1 gene, rs1800012 and rs1107946 SNP's of COL1A1 gene.

Abstract #4

Investigation of Genes Involved in the Cell Signaling Pathway With Risk of Anterior Cruciate Ligament Ruptures

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Context: The extracellular matrix of ligaments continuously undergo remodeling, following mechanical loading, in order to maintain tissue homeostasis. Polymorphisms within genes encoding signaling molecules may result in inter-individual variation in the responses to mechanical loading, which may potentially alter risk of injury.

Objective: To determine if genetic variants within genes encoding proteins involved in the cell signaling pathway are associated with ACL injury risk.

Design: Case-control genetic association study design.

Setting: Laboratory setting.

Patients or Other Participants: A total of 232 control participants (CON) and 234 ACL rupture participants (ACL), of which 135 had a non-contact mechanism of injury and were analysed as a separate subgroup (NON) were included in this study.

Main Outcome Measure(s): All participants were genotyped for the functional *IL1B* rs16944, *IL6* rs1800795, *IL6R* rs2228145, *CASP8* rs3834129, *CASP8* rs1045485, *PTGER4* rs4495224, *TGFB2* rs7550232, *TNF* rs1800629, *TNF* rs1799964 and *TNFRSF1B* rs1061622 polymorphisms. Haplotypes were also inferred for the *CASP8* and *TNF* genes. Statistical analyses were conducted to determine any significant differences ($P < .05$) between the groups (CON vs. ACL and CON vs. NON). Due to previous findings, sex-specific interactions were also investigated.

Results: No independent significant differences were observed in the genotype and allele frequency distributions when all participants were analysed together. After stratification by sex, the *CASP8* rs3834129 del allele was found to be significantly under-represented in the male CON group (41%) compared to the male NON subgroup (51%) (*P* = .047, OR: 1.46, 95%CI: 1.01–2.12). In the female participants, the *IL1B* rs16944 genotype frequency distribution was significantly different (*P* = .042) between the female CON groups and female NON subgroup. Specifically, the TT genotype was significantly under-represented in the CON group (10%) compared to the NON subgroup (26%) (*P* = .029, OR: 3.06, 95%CI: 1.09–8.64). Haplotype analyses of the *CASP8* gene revealed the ins-G haplotype to be significantly over-represented in the CON group (55%) compared to both the ACL group (48%, *P* = .017) and the NON subgroup (48%, *P* = .031). In addition, the del-G haplotype was significantly under-represented in the CON group (33%) compared to both the ACL groups (40%, *P* = .026) and the NON (42%, *P* = .034) subgroup. Similar results were observed in the male participants after stratifying by sex (ins-G: CON (56%) vs NON (43%), *P* = .040 and del-G: CON (30%) vs ACL (44%), *P* = .029).

Conclusions: This study suggests that variants within the *CASP8* gene are associated with ACL ruptures. These novel findings provide evidence highlighting the potential biological significance of the apoptosis signaling cascade as one of the important biological pathways involved in the in the gender-specific etiology of ACL ruptures. The associations observed in this study should be explored in larger independent groups, of different ethnicities, to elucidate the biological significance of the apoptosis signaling cascade in ACL ruptures.

Abstract #5

Motor Neuron Excitability and Sex Hormones Across the Menstrual Cycle

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Context: The significant sex-disparity in sports-related knee injuries may be due to underlying differences in motor control. While the development of sex-specific movement patterns is likely multi-factorial, there is significant interest in the potential modulatory role of sex hormones. We have demonstrated that the muscle stretch reflex (MSR) changes throughout the menstrual cycle; however, further exploration is necessary to determine the origin of this change. This study examined the Hoffman Reflex (HR), electrical analogue of the MSR, across the menstrual cycle.

Objective: our aim was to measure motoneuron excitability across the menstrual and oral contraceptive pill cycle. Our hypothesis was that we would see an increase in motoneuron excitability during the peri-ovulatory phase in regularly menstruating women, due to the excitatory effects of the unopposed peak in estrogen concentration prior to ovulation. In addition, we hypothesized that the magnitude of change would be greater in eumenorrheic women with greater changes in hormonal concentrations than in women on oral contraceptives who have a fairly stable sex hormonal milieu.

Design: Case-control trial.

Setting: Research laboratory.

Patients or Other Participants: Thirty women ages 18–35 volunteered for this study: 10 "non-users" (emenorrheic) and 10 "users" (taking oral contraceptives).

Intervention(s): "Non-users" were tested in the follicular (lowest estrogen; days 1–3), peri-ovulatory (highest estrogen; days 12–14) and luteal phases (highest progesterone; days 20–24). "Users" were tested on corresponding days. Testing included serum hormonal analysis and HR testing (maximum H Reflex to maximum M-wave ratio [Hmax/Mmax]).

Main Outcome Measure(s): H/M ratio at three time points during the menstrual and contraceptive pill cycle. A series of 2 (Group: Users vs. NonUsers) × 3 (Time: menstrual and contraception cycle phase- Follicular, Ovulatory, and Luteal) mixed-model analyses of variance were conducted as the primary analyses.

Results: There were no significant differences between the groups with respect to age ("non-users" 23.0 ± 3.0 years, "users" 25.0 ± 3.0 years, *P* = .10) or body mass index ("non-users" 23.5 ± 3.4 kg/m^2, "users" 24.0 ± 2.7 kg/m^2, *P* = .67). The H/M Ratio was lower in the "users" compared to the "non-users" in all phases, but the ANOVA examining H/M Ratio yielded no significant interaction, $F(2, 56) = 0.671$, $P = .515$, partial $\eta^2 = 0.023$ or main effects for group $F(1, 28) = 2.748$, $P = .109$, partial $\eta^2 = 0.089$ or phase in the cycle $F(1, 28) = 0.742$, $P = .481$, partial $\eta^2 = 0.026$.

Conclusions: Basic neuromuscular control, as measured by the MSR, changes throughout the menstrual cycle. In this study, motor neuron excitability did not demonstrate a concordant change. Therefore, it is possible that the origin of hormonally-mediated changes in the MSR occurs in the connective tissue rather than the neural circuitry.

Abstract #6

Generalized Joint Hypermobility Alters Frontal Plane Knee Loading During a Drop Jump Task in Division 1 Female Athletes

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Context: Certain movement patterns during landing have been implicated as risk factors for non-contact Anterior Cruciate Ligament (ACL) injuries. Generalized Joint Hypermobility (GJH) has been defined as a form of increased joint laxity that affects individuals systemically and is thought to occur secondary to genetic differences related to collagen synthesis. Individuals with GJH have been noted to experience more frequent and more serious knee injuries. Differences in movement patterns, muscle recruitment and joint loading have been noted during gait in the population of GJH individuals, but the effect of GJH in athletes during landing is unknown.

Objective: To examine differences in knee kinematics and kinetics during a drop jump in collegiate D1 women's Lacrosse athletes with GJH.

Design: Controlled Laboratory Study.

Setting: University Biomechanics Laboratory.

Patients or Other Participants: Thirty eight athletes from the women's Lacrosse team were screened for GJH level using Beighton's signs, a clinical assessment of 9 movements to determine GJH. Seven women were identified for the experimental group with 5 or more positive Beighton's signs ("GJH" 19.4 ± 1.0 yrs, 66.0 ± 6.1 kg, 167.3 ± 3.3 cm). Seven matched controls having 0 out of 9 Beighton's signs from that same team were chosen for comparison ("CTRL" (19.9 ± 1.2 yrs, 62.1 ± 7.1 kg, 165.3 ± 7.3 cm).

Intervention(s): Participants performed 5 trials of a vertical drop jump task off of a box normalized to maximum vertical jump height while 3D kinematic data were collected via a 14 camera Vicon system (Vicon Inc. Oxford, UK) at 120 Hz. Right lower extremity kinetic data were collected at 960 Hz on an AMTI force plate (AMTI Corp. Watertown, MA). Data were tracked in Vicon, filtered using a 4th order low pass Butterworth filter with a cutoff frequency of 12 Hz, a model

built in visual 3D software (C-motion Inc, Germantown, MD), and an inverse dynamics approach was utilized for joint moment calculations.

Main Outcome Measure(s): Knee joint angle and moment in 3 planes. Variables were analyzed for between group differences with independent samples t-tests.

Results: Parametric test assumptions were met. The GJH group frontal plane knee angles were less varus during the first 20 percent of the ground contact time (GJH: –0.2 ± 4.4 deg; CTRL 4.1 ± 2.7 deg; $P = .045$). The (internal) knee adductor moments were greater in the GJH group during the first 20% of ground contact time (GJH: 9.8 ± 10.9 N-m; CTRL: –8.1 ± 4.0 N-m; $P = .004$). No other statistical differences were noted in knee moment or angle during the drop jump.

Conclusions: Participants with higher GJH exhibited a greater knee adductor moment during a drop jump task. This loading pattern has been associated with non-contact ACL injury, and may offer insight into the greater prevalence of knee injuries in this population.

Abstract #7

Quadriceps Muscle Volume is Predictive of ACL Volume

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Context: Larger ACL size is associated with an increase in failure load. While it is understood that in isolation quadriceps force production is antagonistic to the ACL and hamstrings force production is agonistic to the ACL, the relationship between thigh muscle volume and ACL volume is little understood.

Objective: To examine the relationship between quadriceps and hamstring muscle volume and ACL volume.

Design: Cross-sectional.

Setting: Controlled laboratory.

Patients or Other Participants: Eleven recreationally-active females (1.63 ± 0.07 m, 62.0 ± 8.8 kg, 22.6 ± 2.9 yrs) and ten recreationally-active males (1.80 ± 0.08 m, 82.3 ± 12.0 kg, 23.2 ± 3.4 yrs) were recruited.

Intervention(s): ACL volume and thigh muscle volume (quadriceps and hamstring) measures were obtained with T2 weighted magnetic resonance (MR) scans of the dominant knee.

Main Outcome Measure(s): The ACL was manually segmented from each sagittal image to calculate ACL volume. Cross-sectional areas of each of the individual quadriceps and hamstring muscles were manually segmented every 2.25 cm from the lateral knee joint line to the hip joint center. Quadriceps and hamstring muscle volumes were calculated from integrating the individual muscle CSA vs muscle length curves and then summing individual muscles for the resultant quadriceps and hamstring muscle volumes. Backward linear regression with ACL volume as the dependent variable and quadriceps muscle volume, hamstring muscle volume, and sex as the predictors was performed. Partial correlations examined relationships among thigh muscle measures.

Results: In females, mean ACL volume = 1370.5 ± 235.5 mm^3; mean quadriceps muscle volume = 1482.9 ± 231.6 cm^3; mean hamstring muscle volume = 593.2 ± 100.0 cm^3; mean hamstring/quadriceps volume (H/Q) ratio= 0.40 ± 0.03. In males, mean ACL volume = 1838.1 ± 473.7 mm^3; mean quadriceps muscle volume = 2585.0 ± 553.6 cm^3; mean hamstring muscle volume = 948.9 ± 214.4 cm^3; mean H/Q ratio = 0.37 ± 0.04. After controlling for sex, quadriceps muscle volume was correlated with hamstring volume ($r = 0.873$, $P = .000$), but not significantly correlated with H/Q ratio ($r = –0.100$, $P = .676$). Sex, larger quadriceps volume, and smaller H/Q ratio explained 59.3 % of the variance in larger ACL volume ($P < .05$). When sex and H/Q ratio were removed from the model, there was no significant change in the ability to predict ACL volume ($\Delta R^2 = –0.052$, $P > .05$). Resultant prediction equation: ACL volume = 0.456 (quadriceps volume) + 676.918.

Conclusions: Larger quadriceps muscle volume predicted larger ACL volume. Given the previously established positive relationship of ligament volume to failure load, current findings suggest that training programs designed to increase quadriceps volume may in part be related a higher ACL failure load. How these results relate to the expression of forces across the joint is unknown. Further research is needed to determine how quadriceps mechanically affect ACL volume and its contribution the failure load of the ligament.

Abstract #8

Associations Between Multi-Planar Knee Laxity and Self-Report Perceptions of Knee Function

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Context: Greater magnitudes of knee laxity have been consistently associated with a greater risk of ACL injury. While biomechanical studies suggest that individuals with greater knee laxity may have difficulty stabilizing their knee during functional activity, the extent to which this instability may be perceived by an individual is unknown.

Objective: To identify the extent to which multi-planar knee laxity is associated with patient-reported knee function during activities of daily living and sport.

Design: Descriptive, cross-sectional study.

Setting: University laboratory.

Patients or Other Participants: 40 active, healthy individuals recruited from a university student population with no previous history of lower extremity injury (20 males: 25.2 ± 3.6 yrs, 179.4 ± 9.1 cm, 83.2 ± 17.2 kg; 20 females: 21.7 ± 3.1 yrs, 164.4 ± 3.7 cm, 65.1 ± 11.1 kg).

Intervention(s): Multi-planar knee laxity was measured as the average displacement of the tibia relative to the femur during three consecutive cycles of –90 to 130 N posterior ($POST_{LAX}$) to anterior (ANT_{LAX}) directed loads, using the KT 2000™ knee arthrometer [ICC(SEM) = 0.89(0.6 mm)]; and during three consecutive cycles of ±10Nm varus (VAR_{LAX}) to valgus (VAL_{LAX}) rotation torques, and ±5 Nm internal (IR_{LAX}) to external (ER_{LAX}) rotation torques, using the Vermont Knee Laxity Device [ICC(SEM) = 0.79–92 (0.8–1.1 deg)].

Main Outcome Measure(s): Participants completed the Knee Outcome Survey, responding with degree to which symptoms (0 = completely to 5 = not at all) affected their activities of daily living (KOS-ADL) and sport (KOS-SAS). Scores were calculated as the percentage (%) of total points possible (70 and 55, respectively). Backwards, step-wise linear regressions determine the extent to which the 6 laxity variables predicted total KOS-ADL and KOS-SAS scores within each sex.

Results: KOS-ADL and KOS-SAS scores were 95.8 ± 6.1 (79–100) and 92.9 ± 9.7 (69–100) for females and 96.9 ± 3.4 (87–100) and 95.0 ± 4.9 (86–100) for males. Females had greater ANT_{LAX} (7.2 ± 1.9 v. 5.9 ± 1.2 mm), $POST_{LAX}$ (2.9 ± 1.0 v. 2.3 ± 0.7 mm), VAR_{LAX} (4.3 ± 0.7 v. 2.9 ± 1.1°), VAL_{LAX} (5.7 ± 1.4 v. 3.2 ± 1.4°) and IR_{LAX} (10.3 ± 3.4 v. 7.4 ± 1.9°) than males ($P < .05$) and trended towards higher ER_{LAX} laxity (12.2 ± 3.6 v. 10.3 ± 2.2°; $P = .053$). In females, greater $POST_{LAX}$, less VAL_{LAX}, and greater VAR_{LAX} predicted lower KOS-ADL scores ($KOS\text{-}ADL = 100.4 - 4.8POST_{LAX} + 3.3VAL_{LAX} - 2.2VAR_{LAX}$; $R^2 = 0.74$, $P < .001$) and greater $POST_{LAX}$ and less VAL_{LAX} predicted lower KOS-SAS scores ($KOS\text{-}SAS = 96.4 - 8.2POST_{LAX} + 3.6VAL_{LAX}$; $R^2 = 0.67$, $P < .001$). In males, greater $POST_{LAX}$ and less ER_{LAX} predicted lower KOS-SAS scores ($KOS\text{-}SAS = 96.4 - 4.7POST_{LAX} + 0.9ER_{LAX}$; $R^2 = 0.49$, $P < .001$].

Conclusions: The combination of greater $POST_{LAX}$ with less relative VAL_{LAX} (females) or ER_{LAX} (males) predicted lower KOS scores. Relationships were stronger in females who had greater and more variable multi-planar knee laxity and more variable KOS scores than males. These findings suggest a self-reported outcome measure may be a beneficial addition to pre-participation screening to identify those with perceived functional deficits associated with their knee laxity. Further validation in a larger athletic population is needed.

Abstract #9

The Influence of Neurocognitive Performance on Trunk Stability Varies With Sex

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Context: Neurocognitive performance may affect lower extremity injury risk by influencing neuromuscular performance. The mechanisms by which this influence occurs may vary between groups, such as between male and female athletes; however, there is little data available that addresses this question, particularly during tasks that have been shown to predict ACL injury risk.

Objective: To determine if the relationship between trunk stability and neurocognitive performance varies by gender.

Design: Descriptive cohort study design.

Setting: Controlled, laboratory setting.

Patients or Other Participants: Thirty seven (17M, 20F) healthy collegiate aged recreational athlete participants (20.9 ± 1.6 yrs, 1.72 ± 0.09 m, 69.3 ± 9.7 kg) with no history of injury to the lower extremities preventing sports participation within the past 3 months, or any concussion within the previous year.

Intervention(s): The subjects underwent neurocognitive assessment using the Concussion Resolution Index. This computer-based test creates three indices, including Simple Reaction Time (SRT; comprised of tests of reaction time with only one decision option), Complex Reaction Time (CRT; composed of tests of involving memory and speed of pattern recognition), and Processing Speed (PS; composed of tests of visual scanning and processing). The subjects also completed a pelvis-constrained unanticipated sudden-release trunk stability task in flexion (FLX), lateral flexion (LFLX), and extension (EXT) as per Zazulak et. al. (AJSM 2007). Comparisons between gender were made using Mann-Whitney U tests with alpha set at $P = .05$. Correlations were assessed with Spearman's rho.

Main Outcome Measure(s): Angular displacement in FLX, LFLX, and EXT (degrees) and Concussion Resolution Index SRT, CRT, and PS (percentile rank).

Results: No differences were observed for neurocognitive performance in SRT (50.4 ± 19.5 vs 44.2 ± 28.5, $P = .50$), CRT (59.4 ± 25.5 vs 57.2 ± 30.0, $P = .87$), or PS (71.7 ± 18.7 vs 57.2 ± 30.0, $P = .31$) for male vs female subjects,

nor in the trunk stability measures of FLX (5.8 ± 2.2° vs 7.8 ± 3.7°, $P = .28$), LFLX (4.3 ± 1.8° vs 5.0 ± 3.0°, $P = .66$), and EXT (5.2 ± 2.6° vs 5.3 ± 3.0°, $P = .98$). Significant correlations existed between FLX and SRT (–0.50, $P = .041$) and PS (–0.55, $P = .022$) as well as EXT and SRT (–0.59, $P = .014$), CRT (–0.58, $P = .016$), and PS (–0.69, $P = .002$) for males. For females, FLX, LFLX, and EXT were respectively correlated with SRT (–0.50, $P = .025$; –0.58, $P = .007$; –0.56, $P = .011$) and CRT (–0.64, $P = .002$; –0.76, $P < .001$; –0.81, $P < .001$) but not PS (–0.22, $P = .361$; –0.089, $P = .709$; –0.206, $P = .385$).

Conclusions: While the finding of no gender-based differences in trunk stability is in contrast to that of Zazulak et. al. (AJSM 2007), it is notable that male trunk stability was moderately to strongly correlated with PS whereas females lacked such a relationship. This could indicate a difference in sensory processing during the task where males have a greater reliance on visual input to quickly stabilize the trunk. Understanding these differences could assist with pre-season injury risk stratification and prevention measures.

Abstract #10

Sex Differences in Landing Biomechanics and Postural Stability of Adolescent Athletes: A Systematic Review

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Context: The adolescent "growth spurt" results in rapid growth of the skeletal system. It has been theorized that absence of a concomitant increase in sensorimotor and neuromuscular control in female athletes may predispose them to an increased risk of lower limb joint injuries.

Objective: To determine if differences in landing biomechanics and postural stability exists between male and female adolescent athletes; with a further objective of determining at what age such differences (*if apparent*) begin to manifest.

Data Sources: Relevant research papers were identified by searching the following databases in June 2014: Pubmed, Cinahl, SportsDiscus, Embase, Web of Science, and PEDro. The following keywords were used: ("neuromuscular control" OR neuromuscular OR biomechanics) AND ("lower limb" OR "lower extremity" OR leg OR hip OR knee OR ankle) AND ("jump landing" OR jump OR jumping OR land OR landing OR "postural balance" OR posture OR "postural stability" OR balance) AND (puberty OR "growth and development" OR "sexual maturation" OR adolescence OR "sexual development" OR "tanner stages").

Study Selection: Studies were required to be written in English; report on biomechanical and/or neuromuscular analyses; include landing or postural control tasks; include healthy, adolescent/pubertal subjects (Tanner staging/age range 10–16); be cross-sectional or longitudinal (cross-sectional studies were required to report on >1 age-sex group). Initially duplicates were removed, leaving 752 articles to be screened. After screening by title, abstract and full-text 15 articles were selected for inclusion in the current review.

Data Extraction: Data extraction was completed independently by two of the investigators with participant sample size and characteristics, the task performed and results documented. Results comprised of group means, accompanying measures of dispersion (standard deviation/ 95% confidence interval) and *P* values when available. Study quality was evaluated based on an adapted version of the STROBE guidelines for rating observational studies. Studies that scored ≥7/10 were considered high quality.

Data Synthesis: The overall quality of studies evaluated was low, with only 3 studies considered to be of high quality. Thirteen out of fifteen reported on landing tasks. Eight of these reported on measures of valgus or medial knee motion. Data were pooled for 5 studies (based on data availability) using the standardised mean difference (SMD) summary statistic. Females exhibited increased knee-joint valgus compared to males in the late maturation sub-group (SMD = 6.60; 95%CI 2.83 to 10.37; ES:11.51). As non-significant results were not reported, data were not available for pooling in the pre/early pubertal categories. There is no consensus on sex differences in postural stability performance.

Conclusions: Although it appears that females are characterized by increased knee valgus during landing with increasing age across adolescence there is a paucity of longitudinal studies to validate this observation. More high quality longitudinal studies on this topic are required.

Abstract #11

The Relationship Between Hamstring and Leg Musculo-Articular Stiffness

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Context: Hamstring (K_{HAM}) and leg (K_{LEG}) musculo-articular stiffness are two measures of lower-extremity stiffness commonly reported in the literature. Greater K_{HAM} has been associated with greater knee functional stability in ACL-deficient individuals, and measures indicative of reduced ACL loading in healthy individuals during controlled perturbations and dynamic landing tasks. Thus, K_{HAM} may be an important variable to consider from injury prevention and rehabilitation perspectives. However, the assessment methods for K_{HAM} are time consuming and require considerable familiarization, making it difficult to implement as a mass clinical screening tool. In contrast, K_{LEG} can be assessed quickly with minimal familiarization. Although K_{HAM} and K_{LEG} are assessed using fundamentally different procedures (e.g. open vs. closed kinetic chain), they are based on the same underlying construct, suggesting they may be related. However, the extent to which the more efficient measure of K_{LEG} is predictive of K_{HAM} has not been examined.

Objective: To determine the extent to which K_{LEG} predicts K_{HAM}.

Design: Cross-sectional.

Setting: Controlled, laboratory setting.

Patients or Other Participants: Fifteen (6M, 9F) healthy physically-active individuals (21.5 ± 2.5 yrs, 1.71 ± 0.1 m, 69.27 ± 11.0 kg).

Intervention(s): Because bilateral asymmetries have not been observed for K_{HAM} and K_{LEG} in healthy individuals, these measures were performed on the left leg only. K_{HAM} was assessed via the free-oscillation technique, whereby the leg is modeled as a single-degree-of-freedom mass-spring system and the damping effect that the hamstring muscles impose on oscillatory flexion/extension of the knee joint is quantified following a brief perturbation. K_{LEG} was assessed via single-leg barefoot hopping on a force platform at a frequency of 2.2 Hz. The averages of 5 K_{HAM} trials, and 3 K_{LEG} trials, were used for analysis. A multiple linear regression analysis examined the extent to which K_{LEG} predicted K_{HAM}, after controlling for sex. Measurement reliability and precision (ICC ± SEM) for K_{HAM} and K_{LEG} were 0.76 ± 1.3 N/m/kg and 0.94 ± 1.0 kN/m/kg, respectively.

Main Outcome Measure(s): K_{HAM} and K_{LEG} values were normalized to body mass to account for the influence of body size.

Results: Normalized K_{HAM} and K_{LEG} descriptive statistics (M ± SD) were 13.84 ± 1.83 N/m/kg and 0.37 ± 0.04 kN/m/kg, respectively. After controlling for sex ($R^2 = 0.07$, $P = .34$), K_{LEG} explained 37.5% of the variance in K_{HAM} (R^2 change = 0.375, $P = .02$), with the full model explaining 44.5% of the variance ($K_{HAM} = -0.21(Sex) + 30.95(K_{LEG}) + 2.75$, $P = .03$).

Conclusions: K_{LEG} was a strong predictor of K_{HAM}, suggesting it has the potential to serve as a clinically accessible measure of lower-extremity stiffness when evaluating large samples with limited time. However, 56% of the variance in K_{HAM} remained unexplained, which may in part be associated with the reported measurement error in K_{HAM}. Further work is needed to examine the extent of this relationship after addressing methodological factors that may introduce measurement error (thus unexplained variance) in K_{HAM}.

Abstract #12

The Influence of Lower Extremity Lean Mass and Strength on Thigh Muscle Activation During Landing

Montgomery MM, Caro MI: California State University, Northridge

Context: Larger quadriceps and smaller hamstring activation amplitudes have been associated with anterior cruciate ligament (ACL) loading and resultant risk of injury; however, the factors underlying these activation patterns are not well understood. Lower extremity lean mass (LELM) and strength relative to body mass have been shown to influence landing biomechanics in females. Strength has also been shown to influence muscle activation strategies in females during drop jump (DJ) landings. However, it is unknown how LELM influences the muscle activation strategy used to control landing.

Objective: To determine the extent to which LELM and MVIC strength determine thigh muscle pre- and post-activation during DJ.

Design: Descriptive Cohort.

Setting: Controlled Laboratory.

Patients or Other Participants: 33 female (1.64 ± 0.1 m, 61.3 ± 7.4 kg, 22.6 ± 2.8 yrs) and 33 male (1.74 ± 0.1 m, 76.2 ± 10.7 kg, 22.6 ± 2.6 yrs) recreationally-active athletes.

Intervention(s): LELM and MVIC torques of the knee extensors (KEXT) and flexors (KFLEX) were measured via dual-energy x-ray absorptiometry and isokinetic dynamometry, respectively. Peak activation amplitudes of the quadriceps (Quad) and hamstrings (Ham) were measured during a 45cm DJ via surface electromyography.

Main Outcome Measure(s): LELM and peak MVIC torques were normalized to body mass. Peak pre- (PRE) and post-landing (POST) muscle activation amplitudes (150 ms prior to and after foot contact (vGRF > 10N), respectively) were normalized to peak activation amplitudes achieved during MVIC (%MVIC). Separate, sex-stratified linear regressions were performed for PRE and POST Quad and Ham activation with 3 predictors: LELM, KEXT, and KFLEX.

Results: Males possessed more LELM than females (28.2 ± 2.0 vs. 24.7 ± 4.1 %BW; $P < .01$) and produced larger KFLEX (1.7 ± 0.3 vs. 1.5 ± 0.2 Nm/kg; $P < .01$) but not KEXT (2.9 ± 0.5 vs. 2.8 ± 0.6 Nm/kg; $P = .52$) torques. There were no sex differences for QuadPRE (20.6 ± 15.4 vs. 26.0 ± 20.9 %MVIC; $P = .24$) or HamPRE (17.0 ± 7.9 vs. 22.8 ± 17.2 %MVIC; $P = .08$). Males demonstrated higher HamPOST (54.4 ± 22.1 vs. 31.8 ± 22.1 %MVIC; $P = .03$), but not QuadPOST (115.7 ± 44.3 vs. 141.6 ± 62.4 %MVIC; $P = .06$). None of the prediction models for PRE or POST Quad or Ham activation in females (R^2 range: 0.00–0.09; $P = .93$–.42) or males (R^2 range: –0.003–0.11; $P = .58$–.11) were significant.

Conclusions: LELM and MVIC torques did not predict thigh muscle activation amplitudes. Females in this study possessed less LELM, but produced equivalent KEXT to males, which may explain differences from

previous work showing relationships between MVIC torques and muscle activation in females, who were relatively weaker than males. In this study, LELM was related to QuadPRE in males, who did not demonstrate the magnitude of KEXT typically observed. This suggests that LELM may be a more important determinant of muscle activation strategies when relative muscle strength is low. Future work should seek to identify the threshold of strength above which LELM ceases to be a determinant of the neuromechanical strategies associated with ACL injury risk. This work was funded by the Far West Athletic Trainers' Association.

Abstract #13

Sex Differences in Landing Kinematics: A Longitudinal Analysis of Adolescent Athletes

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Context: It has been purported that the increased prevalence and incidence of non-contact anterior cruciate ligament injuries observed in adolescent female athletes may be attributable to aberrant lower limb landing kinematics. Previous studies have suggested that the observed sex differences in lower limb landing kinematics may develop as a result of sex specific neuromuscular adaptations to growth and maturation during adolescence. Presently, longitudinal analyses of lower limb landing kinematics in an adolescent cohort are lacking.

Objective: To undertake a longitudinal investigation of lower limb landing kinematics of male and female adolescent athletes.

Design: Cohort study.

Setting: Secondary school gymnasium.

Patients or Other Participants: Forty five (20 male and 25 female) first year secondary school adolescent athletes (age = 13.02 ± 0.35 years; height = 1.61 ± 0.06 m; body mass = 48.67 ± 7.67 kg) with no current or previous history of lower limb joint injury participated.

Intervention(s): Testing was undertaken at baseline (T1) and repeated at 6 (T2), 12 (T3) and 18 (T4) months. Participants performed 3 drop vertical jump from a 31cm box. Frontal and sagittal plane knee joint angles were recorded by video cameras. The average measurement of the 3 jumps was used for analysis at each time-point.

Main Outcome Measure(s): Pre-initial contact (pre-IC) knee flexion, peak knee flexion and frontal plane knee valgus displacement were the dependant variables. The categorical independent variables were sex (male *vs* female) and time (T1*vs* T2 *vs* T3 *vs* T4). A mixed between–within subjects MANOVA was used to assess the impact of sex on lower limb landing kinematics across the four time-points.

Results: There was a significant sex*time interaction ($P = .04$). There was a significant interaction effect for pre-IC knee flexion ($P = .004$) and max flexion ($P = .027$). Males tended to increase pre-IC knee flexion (T1 = 20.51° ± 1.44°, T2 = 26.16° ± 1.66°, T3 = 28.12° ± 1.44°, T4 = 23.44° ± 1.60°) and max flexion (T1 = 78.34° ± 2.34°, T2 = 84.27° ± 3.27°, T3 = 87.13° ± 2.15°, T4 = 83.54° ± 2.20°) with age. Females did not increase pre-IC flexion with age (T1 = 16.0 ± 1.29, T2 = 17.89° ± 1.48°, T3 = 15.61° ± 1.29°, T4 = 15.48° ± 1.43°) or max flexion (T1 = 73.84° ± 2.09°, T2 = 70.47° ± 2.92°, T3 = 72.41° ± 1.92°, T4 = 72.63° ± 1.97°). There was no significant sex*time interaction for frontal plane knee valgus displacement ($P = .081$), although there was a main effect for sex ($P < .001$) with females displaying significantly greater valgus displacement than males (3.14° ± 1.42° versus –5.55° ± 1.51°).

Conclusions: Males exhibited a significant increase in both pre-IC and max knee flexion from baseline (T1), which was not observed in females. This may have implications for the design and implementation of injury prevention programmes.

Abstract #14

The Comparison of Selected Kinematics Between Anterior Cruciate Ligament Injured and Noninjured Trials of a Javelin Thrower Athlete

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Context: This study compared selected kinematics between ACL injured and non-injured trials of a javelin thrower athlete by video analyses to have insights of ACL injury mechanisms and risk factors.

Objective: The purpose of this study was to compare selected kinematics between ACL injured and non-injured trials of a female javelin thrower.

Design: This study was a case-control study on an elite female Javelin thrower.

Setting: This study was conducted on filed where two video camcorders recorded the procedure of the ACL injury and the thrower's 2-dimensional motion was digitized in each video view.

Patients or Other Participants: An elite female javelin thrower.

Intervention(s): The elite female javelin thrower completed the first three trials and sustained a non-contact ACL injury in the fourth trial of javelin throwing during a recent track and field meet. The injury occurred within the views of two video camcorders calibrated for quantitative analysis. The thrower's 2-dimensional motion was digitized in each video view. The 3-dimensional motion was calculated using a Direct Linear Transformation procedure. The thrower's center of mass velocities, knee joint angles, and knee joint angular velocities were calculated during the landing phase of the injury trial and three non-injury trials and compared.

Results: The subject had greater horizontal center of mass velocities and lower vertical center of mass velocities after the first 20% of the javelin delivery phase in the injury trial compared to the non-injury trials (4.53 vs 4.43 ± 0.12 m/s, and –0.24 vs –0.18 ± 0.03 m/s). The subject had smaller knee flexion angles and knee flexion velocities (9.28 vs 11.28 ± 2.16 deg, 1.12 vs 2.57 ± 1.34 rad/s), but similar knee valgus angles and internal rotation angles (–7.19 vs –9.76 ± 2.11 deg, 2.84 vs 2.76 ± 1.04 deg) at the beginning of the delivery phase in the injury trial compared to the non-injury trials. The video images showed an obvious tibia anterior translation at the 30% of the delivery phase in the injury trial.

Conclusions: This ACL injury was likely caused by an excessive ACL loading due to a small knee flexion angle and a hard landing.

Abstract #15

The Effect of Sagittal-Plane Mechanics on ACL Strain During Jump Landing

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Context: The underlying biomechanics leading to non-contact ACL injuries are not clear, in part due to limited experimental studies relating kinetic/kinematic parameters to ACL strain during dynamic activities.

Objective: To investigate the relationships between underlying sagittal plane mechanics and ACL strain during jump landing.

Design: Controlled laboratory study.

Setting: Research Laboratory.

Patients or Other Participants: Seven healthy recreational athletes (two male, five female; 24.3 ± 3.3 years and 66 ± 8.4 kg).

Intervention(s): Motion capture was performed on subjects performing a single leg jump-landing. Whole-body kinematics and ground reaction forces were collected. Scaled rigid body musculoskeletal models were created for each participant using Opensim. These models were driven using the motion capture data. The lower limb muscle force profiles for the jump landing were extracted for each participant. Five cadaver knee specimens were instrumented with DVRT to measure ACL strain and mounted on a dynamic knee simulator system. Muscle forces and sagittal plane kinematics were then applied on the cadaver specimens, dynamically, recreating the jump landing activity. Strain in the ACL was measured for each simulation.

Main Outcome Measure(s): Bivariate correlation and multivariate regression analyses were performed with ACL strain as a dependent variable, sagittal plane kinematic and kinetic parameters as independent variables, and knee as a categorical variable.

Results: Average peak ACL strain was 11.3 ± 9.9%. Peak ACL strain was correlated with increasing GRF ($P < .001$), increasing body weight ($P < .001$), decreasing hip flexion angles at maximum GRF ($P = .003$) and increasing hip extension moments ($P = .043$) among others. The multivariate linear regression revealed two highly significant ($P < .001$) empirical models with high R-square values (94 and 95%) that could be used to correlate the measured sagittal plane parameters to ACL strain. The models suggest that the knee categorical variable that represents the intrinsic factors account for most of the variance in maximum ACL strain (87%). One model suggested that hip and trunk flexion angles at maximum GRF (23° ± 7° for hip and 15.6° ± 9.2° trunk) influence the peak ACL strain. The second model suggested that maximum knee (54° ± 9°) and hip flexion angles (32° ± 10°) and these angles at maximum GRF (37° ± 7.5° for knee and 23° ± 7° for hip) determine the peak ACL strain.

Conclusions: Our results suggest that landing softly, by increasing hip and trunk flexion angles, could reduce ACL strain. An athlete may have little control over the intrinsic factors contributing to ACL strain, but altering their landing strategy would reduce the chance of injury. The empirical relationship developed between joint angles, energy absorption and ACL strain in this study could be used to estimate the relative ACL strain between jumps, to develop training programs and to assess the effectiveness of such training on ACL strain. Further research is needed to determine the individual intrinsic factors that determine the ACL strain.

Abstract #16

Vector-Field Statistical Analysis Reveals Important Insight into Knee Joint Moments During Sidestepping

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Context: Researchers often quantify the net moments about a joint to estimate the load placed on biological tissues. In the context of ACL injury risk,

peak moments are frequently reported to summarise joint loads during dynamic tasks e.g. drop vertical jumping or sidestepping. The subjective selection of single discrete peak values (0D scalars) is unlikely to adequately represent the complexity of three-dimensional joint loading (1D vectors) which changes in magnitude and direction during a dynamic task and which can be objectively analysed using Statistical Parametric Mapping (SPM).

Objective: The objective of this study was to compare 0D versus 1D analysis techniques for net knee joint moments evaluation during unplanned and planned sidestepping.

Design: A cross-sectional study.

Setting: Research laboratory.

Patients or Other Participants: Two groups of active sports people.

Intervention(s): Two independent datasets were used in an independent groups design. The first dataset consisted of 34 male Australian rules football players who performed three unanticipated 45° sidesteps. The second dataset were 20 male recreational soccer players who performed anticipated sidestepping. Three-dimensional motion and force data were recorded for each dataset, and an established biomechanical model with joint constraints was used to estimate time varying net knee joint moments.

Main Outcome Measure(s): Two different analysis approaches were undertaken (0D scalar analysis vs. 1D vector analysis). For the 0D scalar analysis, the peak knee abduction moments during the weight acceptance phase were extracted and statistically compared between groups using an independent t-test ($\alpha = 0.05$). For the 1D vector analysis, time-varying knee joint moment vector-fields (M_{XYZ}) were statistically compared throughout the entire stance phase using the Hotelling's T^2 test, which is the vector-field equivalent of the independent t-test ($\alpha = 0.05$). Post-hoc analyses were conducted using SPM independent t-tests over the entire stance phase.

Results: The 0D scalar analysis found no significant differences between the peak knee abduction moments in the unanticipated (0.8 $Nm \cdot kg^{-1}$, sd = 0.5) versus anticipated (0.68 $Nm \cdot kg^{-1}$, sd = 0.5) dataset ($P = .367$). In contrast, the 1D vector analysis identified significant differences throughout early (0–30%) and late (80–95%) stance. Post-hoc analysis showed the unanticipated group had significantly greater flexion and abduction moments in early stance, and the anticipated group had significantly greater internal rotation moment in late stance.

Conclusions: The focus on peak abduction moments with 0D scalar analysis fails to account for the complexity of the three-dimensional knee moment vector, which when analysed appropriately can provide greater insight into loading patterns associated with ACL injury risk.

Abstract #17

Anterior Cruciate Ligament Injury Risk During Soccer Match-Play: Does Half Time Re-Warm Up Affect Muscular or Biomechanical Markers?

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Context: Epidemiological observations of higher injury incidence during the later stages of soccer match-play have been attributed to match related exertion. Furthermore, a passive half-time interval has been suggested to impose an increased risk of injuries during the early stages of the second half.

Objective: To investigate temporal changes in the markers of anterior cruciate ligament (ACL) injury risk related to knee and hip mechanics and isokinetic muscle strength imbalance during a soccer match simulation, and the effect a half-time re-warm up has to reverse increased risk in the second half of play.

Design: Single-group repeated measures.

Setting: Controlled, laboratory environment.

Patients or Other Participants: A convenience sample of 14 male recreational soccer players (age 26 ± 4 years, height 1.8 ± 0.1 m, body mass 80 ± 12 kg), with no previous ACL injury and free from other injury within the previous 6 months.

Intervention(s): Participants completed a 90-min multi-directional over-ground match-play simulation. During the half-time period players either remained seated (passive, CON), or performed an intermittent agility exercise during the last 5-min of half-time (re-warm up, RWU). Kinematics and kinetics of the support leg during unanticipated 45° side cutting were recorded as part of the simulated match-play, providing multiple trials over the 45 minutes which were grouped for 15-min blocks. Participants also performed five maximal dominant-limb isokinetic contractions at 120 $°.s^{-1}$ for concentric quadriceps (Q_{con}) and eccentric hamstrings (H_{ecc}) prior to exercise (t_0), at the beginning and end of half-time (t_{45} and t_{60}), and post-exercise (t_{105}).

Main Outcome Measure(s): Peak knee abduction moments during weight acceptance, knee and hip extension angles at initial contact, Q_{con} peak torques, H_{ecc} peak torques and functional H_{ecc}:Q_{con} ratio.

Results: Significant reductions in H_{ecc} (CON: t_0:189 ± 56 Nm; t_{45}:166 ± 48 Nm; t_{60}: 166 ± 47 Nm; t_{105}: 151 ± 48 Nm; RWU: t_0:199 ± 48 Nm; t_{45}:173 ± 48 Nm; t_{60}: 181 ± 44 Nm; t_{105}: 159 ± 43 Nm; $P < .01$) and functional H_{ecc}:Q_{con} ratio (CON: t_0: 0.95 ± 0.20 Nm; t_{45}: 0.85 ± 0.14 Nm; t_{60}: 0.86 ± 0.20 Nm; t_{105}: 0.78 ± 0.17 Nm; RWU: t_0:1.0 ± 0.12 Nm; t_{45}:0.90 ± 0.17 Nm; t_{60}: 0.94 ± 0.16 Nm; t_{105}: 0.83 ± 0.16 Nm; $P < .03$) were observed at all times during match-play compared to pre-exercise values, for both conditions, with no significant difference observed between conditions. A trend towards increased hip extension angles at initial contact ($P = .08$) was observed in the last 15 minutes of simulated match-play. No significant changes for Q_{con}, knee abduction moments and knee extension angles were observed.

Conclusions: Re-warm up did not offset impairments in the observed markers of ACL injury risk. Reduced eccentric hamstring strength and muscle imbalances, and a trend towards erect hip landing posture, suggested a greater risk of ACL injury during the later stages of match-play. The efficacy of a re-warmup intervention towards reducing ACL injury risks remains largely unknown and requires further investigation.

Abstract #18

Effect of Prolonged Activity on Lower Limb Coordination During a Cutting Maneuver

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Context: Noncontact ACL injuries frequently occur in women during the later stages of athletic events. However, the link between prolonged activity and ACL injury risk has not been established.

Objective: This study examined the inter- and intra-segment coordination of the lower extremity during a cutting task. We hypothesize during a cutting task the movement patterns between the hip and knee would become asynchronous with prolonged activity.

Design: Cross-sectional study.

Setting: Quinnipiac University Motion Analysis Laboratory.

Patients or Other Participants: 19 female, D1 soccer players who were free of injury at the time of enrollment participated in this study.

Intervention(s): Kinematic data was recorded using a 10-camera motion analysis system while athletes performed a prolonged activity agility testing protocol. The protocol consisted of repeatedly running through a T-shaped obstacle course at maximum speed until athletes failed to have two consecutive runs within one standard deviation of their established average baseline time. An additional two trials were completed and recorded as prolonged activity trials.

Main Outcome Measure(s): Phase angles at 33 ms post heel strike for the limb performing the cut for the baseline and prolonged activity trials were calculated and determined to be either asynchronous or synchronous. To compare baseline to prolonged activity and sidestep to crossover on percentage of asynchrony cuts a generalized estimating equation with logit link was used.

Results: For hip versus knee frontal plane there were no significant effects. For hip versus knee sagittal plane, there was no effect of prolonged activity but there was an effect for cut type ($P = .017$). There was more asynchronous cuts during sidestep (84 ± 4%) compared to crossover (58 ± 10%). For knee sagittal versus frontal plane there was a significant effect for cut type ($P = .044$) and activity status ($P = .047$). Crossovers had more asynchronous cuts than sidesteps (61 ± 7% versus 41 ± 6%) and baseline had more asynchronous cuts than prolonged activity trials (59 ± 7% versus 43 ± 8%).

Conclusions: Prolonged activity seems to have an effect on the synchronicity of movement during a cutting task. With prolonged activity, the sagittal and frontal plane motions of the knee become more synchronous. Cut type also has an effect on synchronicity. Athletes who sidestep cut show more synchronous sagittal and frontal plane motions at the knee compared to those who crossover cut. Athletes who utilize certain cut types or motions in order to complete the agility test protocol do so by using a functionally preferred pattern that can be adapted based on environmental and internal restrictions while moving. However, with prolonged activity, these restrictions become too great and an athlete's ability to adapt decreases often restricting them to one movement system to complete the task. Further research is needed to determine the effect of prolonged activity on movement coordination and its relationship to injury rates.

Abstract #19

Motor Cortex Structural Connectivity After ACL Reconstruction

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Context: Anterior cruciate ligament (ACL) injury, reconstruction, and rehabilitation induces a cascade of sensorimotor compensations and altered neural control. The central nervous system changes that underlay these post-injury adaptations in neuromuscular control are not completely understood. Examining neuroplastic changes associated with brain structural connectivity after injury provides a means to quantify the nervous system sequela of musculoskeletal injury.

Objective: To determine if those with ACL reconstruction (ACLR) have altered brain white matter connectivity with the motor cortex compared to healthy matched controls.

Design: Descriptive laboratory matched control.

Setting: Neuroimaging center.

Patients or Other Participants: Participants were matched on height, mass, extremity dominance, and physical activity level. Six left ACLR (25.5 ± 1.37 years, 1.70 ± 0.13 m, 75.6 ± 19.2 kg, Tegner activity level 6.0 ± 1.5, 23±18 months post-surgery) and six matched healthy controls (23.6 ± 3.14 years, 1.75 ± 0.05 m, 73.5 ± 12.24 kg, Tegner activity level 6.0 ± 1.5) participated.

Intervention(s): Diffusion tensor imaging data were collected while the participants were in a Siemens 3T MRI scanner. Image acquisition consisted of 64 gradient directions, 2.0^3 voxel size, 65 axial slices with a 8.6 TR. Data processing and analyses were completed with the diffusion toolbox in FMRIB Software Library (FSL) with standard parameters, including eddy current distortion and movement correction, followed by bayesian estimation of diffusion parameters for each subject. Probabilistic tractography analysis was carried out with the knee motor cortex as the seed region of interest with a fractional anisotropy of 0.2. The knee motor cortex localization was completed on a subject specific level from functional activation data collected during knee movement.

Main Outcome Measure(s): The brain connectivity to the motor cortex was averaged across the ACLR and control groups. The two groups were then contrasted with a mixed effects general liner model *a priori* threshold at $P < .01$ voxelwise corrected.

Results: The superior-middle temporal gyrus had significantly higher connectivity to the motor cortex in the ACLR cohort (ACL mean region t-statistic: 3.62 (maximum:11.1, minimum: 0.33), control mean region t-statistic: 0.54 (maximum:3.29, minimum:0.38), $P < .001$, 673 voxel cluster). No other regions were significantly above the threshold.

Conclusions: This initial investigation indicates a possible sensory-motor structural neuroplastic effect may occur after ACL reconstruction and rehabilitation. The function of the temporal region indicated is involved in a great deal of high-level sensory integration and environmental stimuli processing. The increased connectivity to the knee motor cortex could be the result of adapted afferent processing due to the disrupted ligament and joint integrity. These data corroborates functional neuroimaging findings that visual-motor temporal regions increase activation with knee movement after ACLR.

Abstract #20

Anterior Cruciate Ligament Reconstructed Patients Exhibit Limb Asymmetry in Sagittal-Plane Knee Joint Mechanics During Stair Ascent and Descent

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Context: The goal of anterior cruciate ligament reconstruction (ACLr) and post-operative rehabilitation is to restore ligamentous knee stability, improve physical function, and decrease the risk of ACL re-ruptures. Inter-limb differences in physical performance have been linked to increased risk for traumatic lower extremity injury. Although aberrant mechanics during low demanding walking tasks and dynamic landing maneuvers have been extensively evaluated post ACLr, less is known regarding the mechanics of challenging activities of daily living, such as stair walking. It is plausible that abnormal mechanics during activities of daily living may increase the risk of ACL re-rupture.

Objective: Determine differences in inter-limb symmetry of sagittal-plane knee mechanics between healthy and ACLr patients before and at 6-months post ACLr.

Design: Case-control.

Setting: Laboratory.

Patients or Other Participants: Twenty ACL injured patients scheduled to undergo ACLr (11 females/9 males; 20.9 ± 4.4 yrs; 1.72 ± 0.07 m; 75.9 ± 12.2 kg) and twenty healthy participants (11 females/9 males; 21.7 ± 3.7 yrs; 1.73 ± 0.09 m; 76.4 ± 19.3 kg) volunteered.

Intervention(s): Knee joint kinematics and kinetics were evaluated bilaterally during stair ascent and stair descent at two time points; pre-surgery (37.1 ± 15.3 days post-injury) and at 6-months post-surgery, or when cleared for full activity (28.3 ± 2.9 weeks post-surgery).

Main Outcome Measure(s): Peak knee flexion angle and internal knee extension moments were assessed using 3-dimensional motion analysis and a custom built staircase with integrated force-plates. Peak angles and moments (calculated using a standard inverse dynamics approach) were identified from ensemble averages that were calculated over 100% of stance phase for five ascending and five descending trials. Limb symmetry index (LSI) scores were calculated utilizing the following equation: (involved limb/uninvolved limb) × 100. Independent t-tests were performed between groups at each time point ($P \leq .05$).

Results: During stair ascent, no differences in LSI existed between groups at pre-surgery for flexion angle (Healthy: 99.8 ± 4.9, ACLr: 99.8 ± 16.4; $P = .61$) or extension moment (Healthy: 99.1 ± 14.3, ACLr: 91.2 ± 23.1; $P = .20$). At 6-months post-surgery, ACLr patients displayed less symmetry for flexion angle (Healthy: 99.8 ± 7.3, ACLr: 97.1 ± 7.7, $P = .05$) and extension moment (Healthy: 99.8 ± 7.3, ACLr: 87.9 ± 18.3; $P = .01$). During stair descent, no differences in LSI existed between groups at pre-surgery for flexion angle (Healthy: 99.9 ± 8.9, ACLr: 99.7 ± 12.2; $P = .96$), however ACLr patients experienced less extension moment symmetry (Healthy: 97.8 ± 16.8, ACLr: 86.1 ± 11.1; $P = .01$). At 6-months post-surgery, ACLr patients displayed less symmetry for flexion angle (Healthy: 99.6 ± 7.9, ACLr: 95.4 ± 6.7, $P = .03$) and extension moment (Healthy: 96.8 ± 7.3, ACLr: 86.2 ± 16.8; $P = .02$).

Conclusions: ACLr patients demonstrated greater limb asymmetry for knee flexion angle and extension moments during stair ascent and descent. These asymmetries were exacerbated at 6-months post-surgery, potentially resulting from inadequate restoration of quadriceps strength post-surgery. This data strengthens growing evidence that rehabilitation post-ACLr does not restore symmetrical knee mechanics at a time when patients are cleared for full activity.

Abstract #21

Force Generation Status of Female Anterior Cruciate Ligament Reconstruction Patients Prior to Return to Sport

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Context: Within the literature a number of authors have indicated that significant asymmetries in an individual limbs force development characteristics may be present following Anterior Cruciate Ligament Reconstruction (ACLR) surgery.

Objective: To describe force development characteristics across a variety of modes of testing in female athletes prior to return to sport.

Design: Descriptive cohort study.

Setting: University Biomechanics Laboratory.

Patients or Other Participants: 10 female ACLR patients (aged 20 ± 2.1 years; body weight 61 ± 2.6 kgs). Participants were, in the final stage of ACLR rehabilitation (6.9 ± 1.9 month's post-surgery) and cleared for return to full competitive sport, volunteered to participate. All participants were full time athletes from a variety of sports, and had received rehabilitation from the team-sport physical therapist (average 3 sessions per week).

Main Outcome Measure(s): Three tests were assessed; unilateral stance isometric mid-thigh pull (IMTP), 10 hop test and single hop for distance. IMTP involved an isometric single leg squat on a force platform pulling on a fixed bar at mid-thigh level (knee flexed 45°). 10 hop test involved undertaking 10 consecutive hops on a force platform, with maximum height each hop. The peak rate of force development (RFD) and peak force (PF) were measured during IMTP and the 10 hop test. RFD was operationally defined as the change in force divided by change in time of test period. Single hop for distance was normalised to leg length. Limb symmetry index (LSI) was calculated for all variables. Differences between limbs were assessed using paired t-tests.

Results: For the IMTP RFD was 88.7(±40.2)Nkg.s^{-1} injured limb and 105.2(±53.3) Nkg.s^{-1} non-injured, LSI 86.4%, PF was 23.9(±1.5) Nkg.s^{-1} injured limb and 25.2(±0.7) Nkg.s^{-1}, LSI 95%, for both measures there was a significant difference between limbs ($P = .016$ and $P = .014$ respectively). For 10 hop test RFD was 526.3(±108.4) Nkg.s^{-1}injured limb and 612.3(±90) Nkg.s^{-1} non-injured, LSI 86.2%, PF was 29.7(±4.2) Nkg.s^{-1} injured limb and 33.9(±3.9) Nkg.s^{-1}non-injured, LSI 88.6%, there was a significant difference between limbs for both measures $P = .01$ and $P = .024$ respectively. The single hop for distance (% leg length) was 151.8(±20.2)% for injured leg and 164.6(±20.5)% non-injured limb, LSI 92%, with a significant difference between limbs ($P = .0001$).

Conclusions: In line with previous research female ACLR patients prior to return to sport show significant limb asymmetries in force production capabilities. As rate of force development has been reported as a key element in explosive muscle actions, rapid movements and reaction to perturbation, these deficits may indicate potentially significant performance deficits in these individuals. The results indicate the need to assess force generation capacity when assessing performance in ACLR patients prior to return to sport. Further research is required to assess if these deficits are related to the high re-injury rates and poor outcomes in this group.

Abstract #22

Alterations in Hamstring Activity at Return-To-Play Post-ACLr: Protective Mechanism Among Patients That Do Not Reinjure?

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Context: Following primary anterior cruciate ligament reconstruction (ACLr), it is predicted that as many as 30% of individuals will go on to sustain a secondary ACL injury. Alterations in electromyographic (EMG) activity are associated with biomechanical changes that are thought to contribute to the high-rate of re-injury. Though these alterations in muscle activity have been well studied in primary ACLr individuals, the muscle activity of individuals who go on to experience a secondary ACL rupture has not been reported. Based on the available literature, it seems plausible that individuals that experience a subsequent ipsilateral ACL re-injury may display potentially hazardous muscle activation strategies at a time when they are returned to play following their primary ACLr.

Objective: To compare EMG of the quadriceps, hamstrings, and gastrocnemius muscles during a dynamic hopping task among individuals with a single ACL injury (ACL × 1), individuals with who went on to have secondary ipsilateral ACL injury (ACL × 2), and healthy controls (CON), at time when individuals were cleared for return-to-play post-ACLr.

Design: Case-control.

Setting: Laboratory.

Patients or Other Participants: Fourteen individuals that were returned-to-play post-ACLr and seven CON individuals (22.6 ± 3.3 yrs, 1.76 ± 0.5 m, 70.8 ± 6.0 kg) participated. ACLr individuals were placed into groups depending on if they had experienced a secondary ipsilateral ACL re-injury post-primary ACLr (ACL × 1: n = 7, 17.1 ± 2.7 yrs, 1.82 ± 0.7 m, 72.7 ± 6.8 kg; ACL × 2: n = 7, 16.0 ± 1.1 yrs, 1.77 ± 0.4 m, 70.5 ± 6.5 kg, time post-return-to-play to re-injury = 1.34 ± 1.2 yrs).

Intervention(s): EMG of the vastus lateralis, biceps femoris and lateral gastrocnemius was measure during two phases: pre-activity (100 ms prior to ground contact) and reactivity (250 ms post-ground contact). To indicate ground contact, all participants were instructed to perform a single-legged hopping task onto a force platform with their ACLr limb or healthy control limb.

Main Outcome Measure(s): EMG was filtered, processed (50ms root-mean-square algorithm), and normalized to the peak activity during movement. Processed EMG data was then compared across groups utilizing One-way ANOVAs with *post-hoc* Independent t-tests where appropriate (α-level, $P \leq .05$).

Results: At preactivity, a main effect was detected for hamstring activity ($F_{2,20} = 3.974$, $P = .037$), wherein ACL × 1 (0.48 ± 0.2%max) was found to utilize significantly more hamstring activity than ACL × 2 (0.20 ± 0.1%max, $P = .018$), but not than CON (0.38 ± 0.1%max, $P > .05$). No other preactivity differences were observed ($P > .05$). A main effect was also detected for reactivity ($F_{2,20} = 3.935$, $P = .038$), where both ACL groups were found to utilize less quadriceps activity than CON (ACL × 1: 0.38 ± 0.1%max, $P = .016$; ACL × 2: 0.40 ± 0.1%max, $P = .033$; CON: 0.58 ± 0.1%max), but not than each other ($P > .05$). No other reactivity differences were observed ($P > .05$).

Conclusions: Quadriceps muscle activity during landing was diminished in all ACLr participants as compared to healthy controls. Interestingly, individuals that did not experience a secondary ipsilateral ACL re-injury utilized greater levels of hamstring activity prior to landing, which may be interpreted as a protective mechanism that is utilized to dynamically stabilize the reconstructed limb. Supported by NIH Grant K08 AR053152-01A2.

Abstract #23

Enhanced Retention of Drop Vertical Jump Landing Strategies Assessed With the Landing Error Scoring System

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Context: External of focus of attention has been shown to result in superior motor performance compared to an internal focus of attention. Adding external focus of attention may optimize current anterior cruciate ligament (ACL) injury prevention programs.

Objective: To determine the effect of internal (IF) and external focus (EF) and video instruction (VI) on drop vertical jump (DVJ) landing strategies assessed with landing error scoring system (LESS).

Design: Descriptive cohort study.

Setting: Controlled laboratory setting.

Patients or Other Participants: Forty recreational athletes performed DVJ's in five sessions: a pretest (baseline measurements), two training blocks (TR1 and TR2), a posttest directly after the training sessions and a retention test one week later. Subjects were randomly assigned to one of the four groups; IF (n = 10, 22.10 ± 2.64 years, 1.77 ± 0.08 m, 71.10 ± 6.92 kg), EF (n = 10, 22.60 ± 1.35 years, 1.80 ± 0.14 m, 72.40 ± 10.38 kg), VI (n = 10, 22.90 ± 0.57 years, 1.78 ± 0.10 m, 74.40 ± 17.10 kg) or the CTRL group (n = 10, 22.40 ± 1.35 years, 1.83 ± 0.11 m, 78.00 ± 14.79 kg), with 5 females and 5 males in each group.

Intervention(s): After a general instruction before pretest, group specific instruction was offered before TR1 and TR2 started and after every 5 trials in TR1 and TR2. The IF group received an instruction regarding attention to the body, the EF group received an instruction directed to the movement effect and the VI group viewed an expert video. Subjects in the IF, EF and VI groups were free to ask for feedback on their real time LESS during TR1 and TR2. Subjects were only aware that a lower LESS score implied a better landing strategy. A 4 × 5 × 2 repeated measures ANOVA was conducted to determine differences between groups (IF, EF, VI and CTRL), time (pretest, TR1, TR2, posttest and retention test) and gender (female and male), followed by post hoc comparisons (Bonferroni) with alpha level set at $\alpha \leq .05$ *a priori*.

Main Outcome Measure(s): Mean total LESS scores.

Results: Males in the VI group had significant lower LESS scores in the post- (1.92 ± 0.27) and retention test (1.72 ± 0.30) compared to the pretest (2.72 ± 0.83) ($P < .05$). For females in the VI and EF group, the LESS score was significantly improved in TR2 (VI: 1.98 ± 1.01, EF: 1.90 ± 0.63), post- (VI: 2.16 ± 0.95, EF: 1.96 ± 0.79)) and retention test (VI: 2.20 ± 0.95, EF: (2.12 ± 0.78) compared to pretest (VI: 2.84 ± 1.03, EF: 3.32 ± 0.76) ($P < .05$).

Conclusions: This study makes a unique contribution to the field of ACL injury prevention by demonstrating the beneficial results of an external focus in females and video instructions in females and males on landing performance after a training session. Retention was achieved and it is therefore advised that training staff uses simple verbal instructions inducing an external focus of attention and include video feedback in their training regimens to improve performance and technique.

Abstract #24

The Influence of an External Focus of Attention Versus Internal Focus of Attention With Regard to Motor Learning and Skill Acquisition for Anterior Cruciate Ligament Injury Prevention

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Context: Exercise programs aimed at preventing ACL injury may decrease injurious mechanics. Wulf suggests that motor task learning is maximized when an external focus of attention (EFA) versus internal focus of attention (IFA) is provided during skill acquisition. The effect of IFA and EFA instruction during ACL injury prevention programs has not been adequately studied.

Objective: To compare the effect of EFA vs. IFA instruction on the change in magnitude of muscle activity during a 6-week neuromuscular exercise program designed to prevent ACL injury. It is hypothesized that subjects receiving EFA instruction would exhibit more desirable muscle activity patterns in muscles protective of the ACL compared to those receiving IFA instruction.

Design: Pre-Post-test group comparisons.

Setting: Research laboratory.

Patients or Other Participants: A convenience sample of 31 female recreational athletes (24.5 ± 1.8 years) with no history of knee injury/LE surgery were randomly assigned to 2 subject groups.

Intervention(s): Subjects performed a series of exercises including neuromuscular trunk and lower strengthening, balance, plyometric, agility and jump training (Hewitt, Silvers) in 8 rotating stations 2x/week for 6 weeks. Groups 1 and 2 received IFA and EFA instruction, respectively, during implementation of the exercise program. Pretraining and posttraining muscle activity for the right vastus medialis (VM), vastus lateralis (VL), rectus femoris (RF), biceps femoris (BF), gastrocnemius (GS), gluteus medius (Gmed), and gluteus maximus (Gmax) were monitored with surface electromyography (EMG) during weight acceptance of a forward jump from a platform, and a right-cut maneuver. A linear envelope filtered at 10 Hz, normalized to % MVIC, determined magnitude of muscle activity for an average of 3 trials.

Main Outcome Measure(s): Pre-post-training changes in integrated and peak EMG muscle activity (LEEMG) during weight acceptance of a forward jump and right-cut maneuver were analyzed between groups. One-tailed independent sample t-tests were performed with $P < .05$ set a priori.

Results: There were no significant differences between groups for the forward jump. For the right cut, pre-post change in peak RF (6927 ± 1.66; −0.8686 ± 1.17 % MVIC; $P < .007$) was significantly less in Group 2 than Group 1. Changes in integrated RF (0.0767 ± 0.151, −0.053 ± 0.141 % MVIC, $P < .017$) and GS (1.22 ± 0.22, −0.0129 ± 0.110 % MVIC, $P < .03$), and peak VMO (1.23 ± 4.26, −1.08 ± 2.33 % MVIC, $P < .05$) and GS (1.01 ± 2.06, −0.279 ± 1.45 % MVIC, $P < .04$) during the right cut were significantly greater in Group 1 than Group 2.

Conclusions: EFA instruction vs. traditional cues (IFA) may provide some benefit when implementing an ACL injury prevention program but may not be generalizable across all ages, motor tasks and muscles. Future research should examine whether a specific type of instruction affects motor learning, as well as motor skill retention.

Abstract #25

Sex Specific Motor Learning Strategies: Implications for ACL Injury Prevention

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Context: Retention of learned motor skills is superior when subjects adopt an external focus.

Objective: Determine the effects of an internal focus (IF) and an external focus (EF) on movement patterns during sidestep cutting in females and males.

Design: Descriptive cohort study.

Setting: Controlled laboratory setting.

Patients or Other Participants: Ninety (45 females, 22.33 ± 3.69 years, 175.96 ± 6.71 cm, 67.78 ± 8.44 kg; 45 males, 24.90 ± 4.61 years, 190.88 ± 6.66 cm, 82.26 ± 8.52 kg) experienced basketball athletes were randomly allocated to one of the three groups: control (CTRL), internal focus (IF) and external focus (EF), with 15 females and 15 males in each group.

Intervention(s): Subjects performed sidestep cutting maneuvers in three sessions. In session 1 (S1), feedback was provided to the EF (watching own best performance) and IF (receiving verbal instructions) groups after every successful sidestep trial. This training session was followed by two retention sessions at one week (S2) and four weeks (S3) after S1, without any feedback. To determine differences between groups (CTRL, IF and EF), sessions (S1, S2

and S3) and sex (female and male), a 3 × 3 × 2 repeated measures ANOVA was conducted, followed by post hoc comparisons (Bonferroni) with $\alpha \leq .05$ set *a priori*.

Main Outcome Measure(s): 3D kinematics and kinetics at time of peak valgus/varus moment. Moments expressed as external moments.

Results: Males in the EF group had greater vGRF (S1: 25.35 ± 3.07 N/kg, S2: 25.79 ± 2.94 N/kg, S3: 25.19 ± 3.16 N/kg) compared to the male IF (S1: 20.55 ± 3.79 N/kg, S2: 20.78 ± 3.73 N/kg, S3: 20.56 ± 3.52 N/kg), male CTRL (S1: 21.69 ± 3.34 N/kg, S2: 21.99 ± 4.01 N/kg, S3: 22.45 ± 3.10 N/kg) ($P <$ .05) and female EF (S1: 18.26 ± 2.56 N/kg, 18.48 ± 3.50 N/kg, S3: 18.76 ± 3.43) groups ($P <$ .001). Males in the EF group had greater knee flexion moments (S1: –3.82 ± 0.90 Nm/kg, S2: –3.99 ± 1.21 Nm/kg, S3: –3.92 ± 1.28 Nm/kg) compared to the male IF (S1: –2.79 ± 0.62 Nm/kg, S2: –3.04 ± 0.76 Nm/kg, S3: –2.94 ± 0.89 Nm/kg), male CTRL (S1: –2.70 ± 0.65 Nm/kg, S2: –2.75 ± 0.65 Nm/kg, S3: –2.92 ± 0.45 Nm/kg) ($P <$ .05) and female EF (S1: –2.54 ± 0.74 Nm/kg, S2: –2.47 ± 0.77 Nm/kg, S3: –2.66 ± 0.81 Nm/kg) groups ($P <$ .001). These effects remained over time, with a strong learning effect in S1 ($P =$ .042). Furthermore, the male EF group showed greater knee flexion angles (S1: –55.76° ± 5.32, S2: –57.05° ± 4.82, S3: –55.89° ± 6.07) compared to the female EF group (S1: –52.73° ± 5.05, S2: –51.24° ± 4.70, S3: –49.87° ± 6.67) ($P =$ .047).

Conclusions: This study makes a unique contribution to understanding motor learning during complex tasks to improve ACL injury prevention. Male subjects benefit more from the visual feedback compared to female subjects. It may be that females need different feedback modes to learn correct movement patterns.

Abstract #26

Current ACL Injury Prevention Recommendations May Not Be Appropriate for All Cutting Tasks or Sexes

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Context: Cutting is necessary for successful participation in multi-directional sports but is also associated with non-contact anterior cruciate ligament (ACL) injuries. Potentially injurious knee frontal plane loading has been associated with greater trunk lean, hip abduction and limb rotation during cutting tasks to 45 degrees in women. As a result, injury prevention programs discourage lower extremity and trunk frontal and transverse plane movement. However, these hip and trunk movements differ when individuals perform cuts to more acute angles. It is thus unclear whether these recommendations are applicable to all cutting tasks in males and females.

Objective: The purpose of this study was to: (1) determine the effects of sex and cut angle on peak knee adductor moment (pKAM) and hip and trunk kinematics and (2) identify predictors of pKAM.

Design: Cross-sectional.

Setting: Research laboratory.

Patients or Other Participants: Twenty-five (12 females) soccer players (22.4 ± 3.9 yrs, 1.74 ± 0.1 m, 70.9 ± 9.3 kg) with no history of knee injury.

Intervention(s): Subjects performed two sidestep cutting tasks to 45° (CUT45) and 90° (CUT90) as fast as possible. Three-dimensional kinematics were collected using a 10-camera motion capture system (Qualisys, Inc. Sweden), 250 Hz. Ground reaction forces were quantified using AMTI force platforms (Newton, MA, USA), 1500 Hz. Inverse dynamics were used to determine net joint moments. pKAM and initial contact kinematics were determined. 2 × 2 repeated measures ANOVA and stepwise multiple linear regression was used to determine the effects of sex and cut, and best predictors of pKAM, respectively ($\alpha \leq .05$).

Main Outcome Measure(s): pKAM; hip and trunk frontal plane angles, hip transverse plane angle, pelvis rotation.

Results: Compared to CUT90, individuals exhibited smaller pKAM (0.76 ± 0.25 Nm/kg; $P =$ .001), less hip abduction (20.04 ± 1.71°; $P <$ .001) and pelvic rotation (34.54 ± 2.63°; $P <$ .001) and more trunk lean (1.80 ± 0.78°; $P =$ .008) during CUT45. Females exhibited less trunk lean than males across cuts (1.72 ± 0.78°; $P =$ .044) and were more internally rotated at their hip during CUT45 compared to CUT90 (6.37 ± 2.02°; $P =$ .024). When these variables were considered in a regression model, hip frontal plane angle was the only predictor of pKAM during CUT45 in females, explaining 66% of the variance ($P =$ .001). No variables predicted pKAM during CUT45 in males. Similarly, during CUT90, regression models did not identify any kinematic predictors of pKAM in either males or females.

Conclusions: Injury prevention recommendations of reduced hip frontal plane position may be only appropriate for females performing cuts to smaller angles (45°) but not to larger angles (90°). Trunk position and limb rotation may not be as important, as they did not predict pKAM for either task or sex. Finally, considering that no kinematic variable predicted pKAM during CUT90, instructions on body positioning alone may not be adequate to reduce potentially injurious knee loading during more acute cutting tasks.

Abstract #27

Kinematic Landing Differences Following Biofeedback Training in Female Athletes

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Context: The use of biofeedback modalities may compliment current screening and training programs that target female athletes at high risk of an anterior cruciate ligament (ACL) injury. Furthermore, innovative biofeedback focused on what potentially underlies modifiable risk factors may transfer changes across multiple sport movements.

Objective: To determine if one session of biofeedback training modifies landing biomechanics.

Design: Randomized control trial.

Setting: Controlled, laboratory setting.

Patients or Other Participants: 25 collegiate aged females participated in the current study. Participants were randomized into one of three intervention groups: Biofeedback (BF) (n = 8, 61.9 ± 7.5 kg, 165.8 ± 9.6 cm), Instruction (IN) (n = 9, 65.2 ± 9.7 kg, 161.2 ± 7.2 cm), and Control (CT) (n = 8, 66.1 ± 10.0 kg, 166.1 ± 7.4 cm).

Intervention(s): All participants performed 3 drop vertical jumps (DVJ) and 3 single leg hops (SLH) prior to and one week following a structured training session. The training session involved a battery of single leg and double leg squats and squat jumps. During the intervention, the CT group performed the training movements without any feedback while IN received consistent verbal instructions and feedback in order to promote increased hip eccentric and concentric musculature torque. The BF group also received the same verbal instructions and feedback as IN but was also provided with biofeedback of their hip extensor torque with real-time 3D motion capture (Cortex, Motion Analysis Corp.; Visual3D, C-Motion). Specifically, a real-time avatar and hip extensor moment data curve with a highlighted goal region were displayed on a 95 ft^2 screen. An ANCOVA was used to determine differences in post test kinematic landing measures while controlling for initial pretest values ($P <$ .05).

Main Outcome Measure(s): Hip and knee frontal plane kinematics at initial contact during SLH and DVJ.

Results: Hip abduction during both SLH ($P =$ .015) and DVJ ($P =$ .044) at post test was different among groups following the intervention. Specifically, during SLH greater hip abduction was found in BF compared to IN ($P =$ .016) with a trend towards a similar difference compared to CT ($P =$ .099) (BF: –9.8° (95% CI, [–12.4, –7.1]), IN: –4.4° (95% CI, [–6.8, –1.9]), CT: –5.6° (95% CI, [–8.3, –3.0])). Additionally, during DVJ greater hip abduction was found in BF compared to CT ($P =$ .043) (BF: –7.0° (95% CI, [–9.0, –5.1]), IN: –4.8° (95% CI, [–6.6, –3.0]), CT: –3.6° (95% CI, [–5.5, –1.8])). Knee abduction angle was not statistically different at initial contact among groups ($P >$ .05).

Conclusions: Providing biofeedback to promote increased hip extensor moments appears to increase hip abduction at initial contact. A goal of biofeedback training is to facilitate motor learning of improved and safe movement patterns without the need for continued use of biofeedback. While knee abduction angle was not modified, greater hip abduction at initial contact was a positive change following a single bout of biofeedback.

Abstract #28

Injury Prevention Program Effects on Balance and Performance Measures in Youth Athletes

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Context: Incorporating injury prevention programs (IPPs) in middle-school aged sports may enhance long-term IPP fidelity, however it is unknown if a younger population would see greater benefits when using a simplified program. Success with IPPs is dependent on promoting correct movement technique, but too many cues may be overwhelming for young athletes. Additionally, demonstrating a link between IPP use and improvement in balance and performance measures could enhance coach buy-in and IPP adherence. Although IPPs have demonstrated performance enhancement, it is unknown if a simplified IPP can elicit similar results in a youth population.

Objective: To determine the effect of a simplified injury prevention program on dynamic balance, as measured by the Y-balance test (YBT) and long jump performance.

Design: Randomized Controlled Trial.

Setting: Soccer fields.

Patients or Other Participants: Nineteen youth soccer teams (n = 170, age = 11 ± 3 years) across two different leagues were cluster-randomized into IPP groups: Basic (BAS) = 6 teams [n = 24 males, n = 21 females]; Traditional (TRAD) = 7 teams [n = 31 males, n = 29 females]; Control (CON) = [n = 36 males, n = 29 females].

Intervention(s): Teams were tested on YBT and long jump performance during the first week of soccer practice (PRE) and again immediately following the 8-week intervention period (POST). Athletes completed two recorded trials for YBT in all three directions (Anterior, Posteromedial, Posterolateral) and two recorded trials for standing long jump. Teams in the BAS or TRAD groups were assigned a research assistant who implemented the IPP as a team warm-up prior to each practice 2–3 times per week. The BAS and TRAD groups performed IPPs with the same exercises, however the BAS IPP only received verbal feedback cues focusing on flexion and force absorption in the sagittal plane. The TRAD IPP received feedback for movement corrections in all three planes of motion. CON teams performed their normal warm-up as determined by each team's coach.

Main Outcome Measure(s): YBT scores were normalized to leg length (from ASIS to medial malleolus). We used a mixed model analysis of covariance to compare differences between the three groups (BAS, TRAD, CON) and time (PRE, POST) for each dependent variable controlling for gender and soccer league. Separation of 95% confidence intervals was used to evaluate pairwise comparisons for post hoc testing ($\alpha < .05$).

Results: The TRAD IPP (PRE: 135.79 $\pm$ 18.82 cm; POST: 141.15 $\pm$ 22.12 cm) resulted in significant improvements in long jump compared to the CON program (PRE: 143.99 $\pm$ 20.57 cm; POST: 140.34 $\pm$ 20.24 cm) ($P = .003$). No other significant differences were observed ($P > .05$).

Conclusions: The TRAD program involved a larger variety of verbal feedback and athletes in this group increased long jump performance from PRE to POST as compared to the control group. These results further support evidence that IPPs improve athletic performance, which could promote coach buy-in for IPP adherence.

Abstract #29

Factors That Influence Female Adolescent Athletes' Willingness to Perform an Injury Prevention Program

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Context: Injury prevention programs (IPP) reduce lower extremity injury rates in female adolescent athletes. Despite their success, IPPs are underutilized at the high school level. Understanding current beliefs and factors that influence athletes' perceptions regarding use of IPPs may increase athlete compliance with IPPs.

Objective: To examine what factors influence a high school female athlete's willingness to perform a lower extremity IPP.

Design: Cross-sectional study.

Setting: High School.

Patients or Other Participants: Seventy-six healthy, high school female athletes (Age = 15 $\pm$ 1 yrs, Mass: 59.9 $\pm$ 10.3 kg, Height: 65.6 $\pm$ 2.5 cm) (Field Hockey = 21, Soccer = 31, Volleyball = 24) volunteered to participate in the study.

Intervention(s): The participants were randomized into an intervention (IPP) or control group. The IPP group performed an IPP prior to sport practices during the fall sport season (8–10 weeks). Athlete compliance with IPP was recorded through attendance at IPP sessions. Prior to the intervention, athletes answered six questions that evaluated their beliefs and willingness to perform an IPP if data indicated they would run faster, jump higher, change direction better, suffer fewer ACL injuries and also their belief that an IPP could improve their sport performance, overall health, and quality of life. All questions utilized a five-point Likert scale (5 = Strongly Agree, 1 = Strongly Disagree). Responses were dichotomized (4–5 = Yes, 1–3 = No).

Main Outcome Measure(s): Participants' compliance was divided into quartiles and operationally defined a Low compliance group using the bottom quartile (<57% compliance) and a High compliance group from the top quartile (>85%). Chi-Square tests were performed on all variables to evaluate players' willingness to perform an IPP ($\alpha \leq .05$).

Results: Regardless of compliance, athletes were willing to perform an IPP if data indicated that they would run faster: $\chi 2$ (1,N = 75) = 52.920, $P <$ .001 (92%,69/75 athletes); jump higher: $\chi 2$ (1,N = 75) = 46.413, $P < .001$ (89%,6/75 athletes); less likely to suffer ACL injuries: $\chi 2$ (1,N = 76) = 72.053, $P < .001$ (99%,75/76 athletes); sport performance: $\chi 2$ (1,N = 75) = 46.413, $P < .001$ (89%,67/75); overall health: (1,N = 75) = 37.453, $P < .001$ (85%,64/75); and quality of life $\chi 2$ (1,N = 75) = 12.813, $P < .001$(71%,53/75). Players with High compliance believed that an IPP could improve overall health more than the Low group $\chi 2$ (1,N = 39) = 4.916, $P = .027$ (45%18/34 High,0% 0/5 Low).

Conclusions: Players are willing to perform a lower extremity IPP if data indicated that the program could improve performance factors and lead to fewer injuries. Researchers and clinicians need to educate athletes of the benefits of an IPP in order to increase player awareness and implementation of IPPs at the high school level. Players' beliefs and willingness prior to the intervention did not appear effect their compliance. Supported by a NATA Research and Education Foundation Doctoral Grant.