Assessing the Effect of Repeated Subconcussive Head Blows on Football Defensive Linemen’s Balance Control

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**Introduction:** Velocity values of the center of pressure (COP) are sensitive enough to be used to analyze balance control in athletes. Most balance control research has been conducted on athletes who have experienced a concussion and are either symptomatic or returning to play.

**Rationale:** Minimal research has been conducted investigating the cumulative effects of subconcussive blows on balance control. The purpose of this study was to determine if there is a sensitive enough balance measure sufficient to quantify any negative cumulative effects of subconcussive head blows on balance control of football defensive linemen. It was hypothesized that as the balance task became more challenging, a more sensitive analysis would be able to demonstrate any cumulative effects of subconcussive blows.

**Methods:** Seven defensive linemen of a varsity football team participated in static balance testing every week following their Saturday game for 9 weeks. Participants stood quietly in a narrow Romberg stance under five different conditions: (1) eyes open; (2) eyes closed; (3) dual task using arithmetic; (4) dual task while performing a choice reaction time task on an iPad; and (5) horizontal head rotations. To assess static balance while standing, ground reaction forces were collected at 100 Hz using a Nintendo Wii Balance Board that acted as a force plate.

**Results:** The root mean square of COP displacement (dCOP) and velocity (vCOP) was calculated in both the anterior-posterior and medial-lateral directions. For statistical purposes, four time points (preseason, weeks 3, 4, 9) were compared to determine if subconcussive blows affected balance control. There were no significant differences in anterior-posterior and medial-lateral dCOP or medial-lateral vCOP across the four time points. However, during a competitive football season, the defensive linemen’s anterior-posterior vCOP decreased, indicating an improved level of balance control. Anterior-posterior vCOP values were sensitive enough to reveal significant changes in balance control in three of the conditions (eyes closed, dual task using arithmetic, and horizontal head rotations) ($P < .05$).

**Discussion:** These results are consistent with previous research suggesting that assessing balance control through anterior-posterior vCOP is a sensitive enough measure to detect balance control changes over time. The anterior-posterior vCOP results suggest the opposite direction of previous research, which may be due to improved neural changes following intense in-season football training.

**Importance:** The level of improved balance control indicates that there was no detectable negative concussion-like effect of repeated subconcussive blows on balance control in-season; however, long-term effects are unknown.

Chronic ACL Instability in a Ballet Athlete: The Effect of Improper Turnout

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**Background:** A ballet dancer was hopping backwards in an arabesque en pointe when her right knee exhibited extreme valgus with two distinct “pops.” The athlete had a previous history of general knee pain and had been on a hamstring strengthening program. On evaluation, range of motion was full with good strength at 4/5 in all ranges, although significant pain was noted at times. Anterior drawer and Lachman tests were inconclusive. A pivot shift recreated the injury “feeling” and was painful at a 10/10, although no dynamic subluxation was visible. Reassessment the next day revealed an audible and visible “clunk” both into and out of deep knee flexion with pain at 2/10. She was referred immediately for an orthopedic consultation.

**Differential Diagnosis:** Anterior cruciate ligament (ACL)/medial collateral ligament rupture, meniscal tear/dislocation, knee subluxation.

**Treatment:** The physician confirmed chronic ACL insufficiency with instability and scheduled a surgical repair 15 days later. Pre-surgery included quadriceps, hamstring, and gluteal strengthening and modalities to control pain and inflammation. Range of motion pre-surgery revealed 105° of external rotation of the tibia on the injured limb, compared to 59° on the uninjured.
Uniqueness: Proper turn-out is crucial to correct ballet form. From a young age, dancers are told to “turn-out” but are not always corrected on proper form. Turn-out should be initiated from the hips, with a supported and neutral pelvis using the deep rotators, sartorius, and adductor muscles. Turn-out is often forced and will typically occur at the knee instead of the hip. As turn-out is forced the tibia is driven into excessive external rotation, which places increased stress on the ACL. This chronic ACL stretching led to insufficiency and instability in this case.

Conclusions: This athlete has returned with no complications following a modified rehabilitation program specific to ballet. Attention was given to reestablishing correct turn-out; exercises included pelvic stability and deep external hip rotation strengthening. Ballet-specific rehabilitation was conducted in front of a mirror to master proper turn-out. Cardiovascular retraining was completed on a bike so that the foot and knee remained in neutral, this was important because prior to surgery a significant whip kick motion due to the laxity at the knee joint was evident. This type of compensatory turn-out pattern is not uncommon, but limited understanding regarding the incidence and severity of ACL insufficiency and associated instability exists. Further, there is paucity with respect to teaching proper turn-out mechanics and, as evident by this case, serious consequences can occur from forcing turn-out incorrectly.

Multi-disciplinary Approach to Concussion Diagnosis and Recovery
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Introduction: The ability to successfully diagnose and treat concussions has recently received more attention as a result of the problems encountered in professional sports. However, most diagnostic tools still rely on subjective symptom checklists and/or expensive equipment and personnel to operate.

Rationale: The research group aims to use readily available technology to help health care professionals identify and track concussions and the recovery process using both motor and cognitive processes. This technology would serve to supplement the expertise of athletic/physical therapists to use on the sideline and in clinics.

Methods: The research program consisted of three distinct phases: (1) validating new technology for sideline assessment of concussions by comparing a low-cost motion tracking device, the LEAP motion tracker, to a research-grade system (Optotrak); (2) evaluating the sensitivity and specificity of a new assessment protocol by comparing 12 healthy controls to individuals with a prior history of concussions (12 asymptomatic, 8 symptomatic) using a bimanual coordination paradigm (in-phase movements at 1 Hz); (3) testing the feasibility of implementing the technology (LEAP) and protocol (bimanual coordination and balance testing) by following 5 (3 males, 2 females) varsity hockey players over a season (5 minutes before and after practice).

Results: The mean difference between the LEAP motion and Optotrak demonstrated 7.7 ms movement time and 17.3 mm movement amplitude between the two systems. The sensitivity (85%) and specificity (75%) of the protocol (bimanual coordination) demonstrated a high ability for detecting those with history of concussion. Finally, the feasibility of implementing the technology demonstrated logistical (eg, scheduling, practice cancellations) and technical (eg, sensor malfunction) barriers over the 10-week study period.

Discussion: Although technological advancements are making it easier for researchers to collect objective data, there is still much work needed to standardize and implement such devices outside the lab. More work refining the technology and/or exploring other technology and larger sensitivity studies are needed before we can create standardized protocols.

Importance: The aim of the research program is to create reliable and valid tools for health care providers to better diagnose concussions at the sideline so that the athlete is not prematurely returned to play. These tools may also prove useful in monitoring recovery. Using a multi-disciplinary approach, the authors have taken steps to create a feasible tool to inform health care providers in determining whether a person has sustained a concussion and should be taken out of the game.

Effects of Mild Traumatic Brain Injury on 3D Multiple Object Tracking Performance
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Introduction: The authors sought to determine if Three-Dimensional Multiple Object Tracking (3D-MOT) can serve as an effective concussion assessment tool.

Rationale: The 3D-MOT is a task where an individual must allocate attention to multiple moving objects with-
The Effects of a Neuromuscular Exercise Training on Core Stability and Hip External Rotation Strength in Female Adolescents: Preliminary Results

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Introduction: Weakness of core and hip musculature may contribute to an abnormal movement pattern during sport participation. This can lead to an increased risk of anterior cruciate ligament (ACL) injury, specifically in the adolescent female population. Establishing effective exercise programs to improve core stability and hip external rotation strength could be beneficial for injury prevention in this population.

Rationale: Research suggests that neuromuscular exercise (NME) training programs improve knee joint stability. However, the specific effects that NME training has on core stability and hip external rotation strength have not been reported. The objective of this research is to examine the effect of an NME training program on core stability and hip strength in adolescent females.

Methods: A prospective cohort pilot study was performed on recreationally active adolescent females with no recent trauma to the lower extremity. An NME program was administered according to previously described and validated methodologies. A trunk stability test was used to evaluate core stability. With eyes closed, one leg is lifted off the ground for three trials of 30 seconds, for each leg. The percentage of participants who passed the core stability test pre-NME versus post-NME was recorded and analyzed. Hip external rotation strength was evaluated using handheld dynamometry while the individual was in a standardized seated position. The average of three trials was used for data analysis. A paired t test was used to assess hip external rotation strength pre-NME and post-NME training.

Results: Four females (age: 13.7 ± 0.5 years; height: 165.0 ± 6.5 cm; BMI: 23.5 ± 6.9 kg/m²; right leg dominant) participated in the preliminary data collection. Following the completion of the NME training program, hip external rotation strength increased for both the right (pre-NME: 114.6 ± 8.5 N, post-NME: 128.9 ± 31.6 N) and the left (pre-NME: 93.1 ± 14.8 N, post-NME: 112.5 ± 13.3 N) leg. The number of participants who passed the core stability test increased following the completion of the NME program for both the right (pre-NME: 60%, post-NME: 100%) and the left (pre-NME: 70%, post-NME: 100%) leg.

Discussion: Data indicate that NME training can increase hip strength, as measured by external rotation, and improve core stability. These results suggest that an NME program may be effective in addressing weakness in hip strength and core stability in adolescent females at risk for lower extremity injuries.

Importance: Health care providers should incorporate core stability and hip strengthening exercises in their rehabilitation protocol and as part of a preventative program.
Introduction of Entrustable Professional Activities in an Athletic Therapy Curriculum
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Introduction: Educating and assessing students in an athletic therapy curriculum requires careful planning. The athletic therapy program at Mount Royal University is undergoing a significant transformation to a competency-based education model employing a clinical presentation approach to execute the competency-based curriculum recommendation from the CATA Education Task Force (Lafave et al., 2016). Transformation requires an assessment plan and partnership with practicum placement supervisors.

Rationale: Practicum placement supervisors aim to provide an optimal learning environment in both a clinical and field setting. However, they need to determine which clinical presentations athletic therapy students can competently evaluate and manage at a reasonable and safe level while they are in their practicum placements (ie, entrustable professional activities [EPAs]).

Methods: Professors developed an assessment framework that included EPAs and mapped them over the course of a 4-year athletic therapy curriculum. Epidemiological literature was employed in the temporal design (Darrow et al., 2009; Swenson et al., 2013). Practicum placement supervisors were consulted with the framework and given the opportunity to provide feedback to ensure the map was valid, reasonable, and realistic based on their past supervisory experiences.

Results: A framework and map that outlines when students will be exposed to clinical presentations over the course of their academic program was created and agreed upon (validated) by practicum placement supervisors.

Discussion: It is critical to map out a teaching and assessment plan and to ensure all professors and practicum placement supervisors agree with the plan (Eva et al., 2015). Practicum placement supervisors may have a sense of confidence that students will be prepared with specific EPAs temporally throughout the formal academic program. Further, the teaching, learning, and assessment experiences for all stakeholders (ie, students, professors, and practicum placement supervisors) will be systemically aligned (Higgs, 1996).

Importance: Educating professionals requires a partnership between educational institutions and community partners to help bridge theory to practice. EPAs are an important piece of this complex task of optimal professional education. In addition, measuring EPAs at the appropriate time periods throughout the educational process is critical. It is crucial that students be evaluated in their practicum settings so that competence is measured over time and not merely in small windows such as those completed for summative examinations or credentialing examinations (Eva et al., 2015).

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Introduction: Dynamic balance, the ability to maintain postural stability while completing a movement task, is required in the athletic population. It is often affected by injury, particularly to the anterior cruciate ligament (ACL). The Star Excursion Balance Test (SEBT) and Y-Balance Test (YBT) are commonly used to assess dynamic balance of the lower extremity. Test performance can be used as a functional screen to identify athletes at risk of injury, assess deficiencies following injury, and monitor rehabilitation progress.

Rationale: The literature lacks normative dynamic balance scores for healthy and injured adolescent females. Investigations of this population are important because adolescent females are four to six times more likely to sustain an ACL injury than their male counterparts. Clarification of common misconceptions in the interpretation and interchangeability of the SEBT and YBT is required so that researchers and health care providers can properly evaluate dynamic balance. The purpose of this investigation was to compare performance on the SEBT and YBT in adolescent females.

Methods: Recreationally active adolescent females with no recent trauma to the lower extremity were recruited. Participants completed a modified-SEBT (three of the eight reach directions: anterior, posteromedial, and posterolateral) and YBT according to previously established protocols. The average of three maximal reach trials for each direction and a composite score for each leg were used for data analysis. All measurements
were normalized and expressed as a percentage of the stance limb length. Paired t tests were used to assess for differences between the right and left leg within each test, and between the SEBT and YBT scores.

Results: Five females (age: 13.7 ± 0.5 years; height: 165.0 ± 6.5 cm; BMI: 23.5 ± 6.9 kg/m²; right leg dominant) participated in the preliminary data collection. There was no significant difference between the right and left leg scores within each test. Between tests there were significantly different scores in the anterior right leg (SEBT: 102.3 ± 9.5%, YBT: 68.6 ± 7.6%, P < .001), anterior left leg (SEBT: 101.5 ± 5.9%, YBT: 68.1 ± 6.0%, P < .001), and posterolateral left leg (SEBT: 89.4% ± 9.3%, YBT: 101.4% ± 10.5%, P = .011).

Discussion: Data suggest that there are differences in the anterior and posterolateral reach distances for the SEBT and YBT in adolescent females. Researchers and health care providers should be careful when interpreting and comparing performance on dynamic balance tests, because the values for the SEBT are not transferable to the YBT.

Importance: The SEBT and YBT can both be used to clinical measure dynamic balance in adolescent females, but the scores should not be used interchangeably.

Wii Balance Board and Electromyography to Assess Postural Adjustment After Perturbation
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Introduction: Balance assessments are sometimes difficult for clinicians to conduct because they rely on subjective analysis and can vary in reliability and sensitivity. As a reliable, portable, and cost-effective system, the Nintendo Wii Balance Board may be used efficiently in clinical and research settings as a measurement tool. Range of center of pressure and recovery time after perturbation are two common measurements of balance. To safely complete an assessment, body weight support may be required when testing clinical or elderly individuals.

Rationale: This study investigated the influence of body weight support on recovery time in response to virtual perturbation and bilateral lower limb muscle synergies using a customized Wii Balance Board computer program.

Methods: Fifteen participants (10 female, 5 male) performed a dynamic balance task while standing on a Wii Balance Board under three randomized conditions: (1) no body weight support harness, (2) body weight support harness with no support, and (3) body weight support harness with 10% body weight support. Participant center of pressure was represented as a dot on a laptop screen using a customized LabVIEW program. During each trial (n = 5), a target dot moved in random sequence among eight cardinal and ordinal directions. Participants were instructed to redistribute their weight on the Wii Balance Board to meet the target dot with their center of pressure dot. Bilateral electromyography of the medial gastrocnemius, peroneus longus, and tibialis anterior muscles and time to recover from virtual perturbation were recorded.

Results: Results showed increased bilateral peroneus longus activity when recovering from targets to the north, northwest, and northeast. The tibialis anterior shows asymmetrical peak muscle activity when recovering from targets to the north and south. One-way between-subjects analysis of variance revealed that time to return to center and total recovery time were significantly different among three conditions (P ≤ .005). Post-hoc comparisons indicated that the recovery time in the harness without body weight support (M = 2.039, SD = 2.00) was significantly greater than both the 10% body weight support condition (M = 1.88, SD = 0.52) and no body weight support (M = 1.86, SD = 0.38) conditions (P = .005).

Discussion: The data suggest that body weight support has significant effects on recovery time after virtual balance perturbation. To effectively evaluate muscle synergies in balance control with the Wii Balance Board system, the influence of body weight support should be considered.

Importance: This Wii Balance Board body weight support system could potentially be used as an objective tool in measuring balance deficits related to concussion and neurological disorders.

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