CHANGES IN SUPPORT MOMENT AND MUSCLE ACTIVATION FOLLOWING HIP AND TRUNK NEUROMUSCULAR TRAINING: THE HIP AND ACL INJURY RISK

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This study investigated lower limb muscular activation strategies following an 8-week body-weight based training intervention focused on the dynamic control of the hip/trunk. Muscle activation, support moment and frontal plane knee moments of elite female hockey players (n=13) were measured during unplanned sidestepping pre/post training. Post-training, gluteal muscle activation increased (+10%;p=0.006). There was no change in support moment or frontal plane knee moments however, the contribution of hip extension to total support moment increased (+10%;d=0.56) following training. Hip/trunk neuromuscular training is effective in improving hip neuromuscular activation, allowing athletes to more effectively utilise their hip to generate their support moment, which may prevent dangerous 'dynamic valgus' knee postures during sidestepping sporting tasks.

KEYWORDS: GLUTEAL, UNPLANNED SIDESTEPPING, INTERVENTION.

INTRODUCTION: Anterior cruciate ligament (ACL) injuries are arguably the most debilitating knee injury an athlete can sustain in sport. Females are placed at 4-5 times higher risk of sustaining an ACL injury in sport relative to their male counterparts (Myer, Ford, Heidt, Colosimo, McLean & Succop, 2005). Over half of these injuries occur during non-contact sidestepping tasks, meaning that these injuries can be prevented (Cochrane, Lloyd, Besier, Elliott, Doyle & Ackland, 2010). *In-vivo* (Besier, Lloyd, Cochrane, & Ackland, 2001; Markolf, Burchfield, Shapiro, Shepard, Finerman, & Slauterbeck, 1995) and *in-silico* (Donnelly, Lloyd, Elliott, & Reinbolt, 2012b; McLean, Huang, & van den Bogert, 2008) research show that the ACL is at greatest risk of injury during the weight acceptance (WA) phase of stance, when the knee is in an extended posture, and valgus and internal rotation moments, combined with anterior drawer are applied to the knee. There are two biomechanical approaches that can be utilised to reduce an athlete's risk of ACL injury in sport. The first is to modify an athlete's technique in an effort to reduce the external forces applied to the knee during the task (Chaudhari, Hearn, & Andriacchi, 2005; Dempsey, Lloyd, Elliott, Steele, & Munro, 2009; Donnelly et al., 2012b). The second is to improve the coordinated co-activation and force generation of muscles about the knee and hip to support the knee when loading is elevated (Besier, Lloyd, Ackland, & Cochrane, 2001; Lloyd, Buchanan, & Besier, 2005).
Improved neuromuscular control of joints proximal to the knee like the hip have been suggested as an effective neuromuscular strategy to reduce ACL injury risk as these muscles can function to prevent the hip from moving into a 'dynamic valgus knee posture' which has been associated with ACL injury rates in female athletes (Besier, Lloyd, & Ackland, 2003; McLean, Huang, & van den Bogert, 2005; McLean, Huang, & van den Bogert, 2008). Simulation research has shown an athlete's technique, more specifically their upper body motor control can influence the aforementioned knee joint loading patterns during sidestepping (Donnelly et al., 2012b). From this, there is rationale to elevate the activation and/or strength of the trunk/hip musculature, in particular the gluteal muscle group (external hip rotators), when attempting to reduce an athlete's risk of ACL injury in sport. The purpose of this study was to implement an 8-week body-weight based multifactorial training intervention focused on improving the dynamic strength and control of the trunk and hip musculature so to: 1) assess neuromuscular changes following training and 2) determine the effect of these neuromuscular strategies on biomechanical risk factors associated with ACL injury.

METHODS: The Australian national women's hockey team participated in an 8-week body-weight based training intervention focused on improving the dynamic control of the trunk and hip during dynamic sporting tasks. This multifactorial intervention encompassed plyometric, balance and strength body-weight based exercises (see www.youtube.com/bodyfitworkouts for all exercises) and was implemented for 15 minutes, four times a week alongside their regular in-season training schedule. Thirteen athletes (22.2±2.9yrs, 1.67±0.1m, 66.3±6.7kg) participated in biomechanical testing prior to, and following the intervention. During biomechanical testing, athletes were asked to perform a series of planned and unplanned straight line and change of direction running tasks (Figure 1) (Besier et al., 2001; Dempsey et al., 2009; Donnelly, Elliott, Doyle, Finch, Dempsey, Lloyd, 2012a).

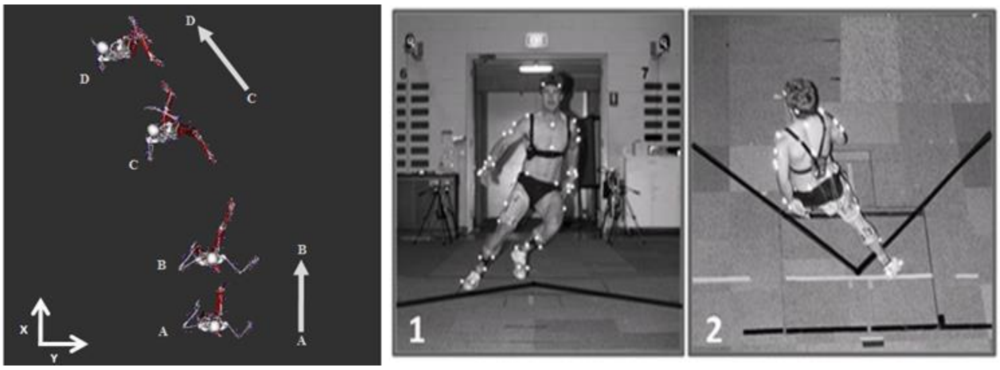

Figure 1. Transverse and frontal view of the sidestep sport manoeuvres conducted during biomechanical testing. Mid pelvis position (x, y) coordinates 50 frames prior to heel contact (A), at heel contact (B) (A-B defines the pre-contact phase), contralateral leg heel contact (C) and ipsilateral leg mid swing (D) were used to define vectors AB and CD. The cosine of the dot product between vectors AB and CD represents a participants CoD angle during sidestepping. Adapted from (Donnelly et al., 2012a).

Hip (sagittal plane), knee (sagittal and frontal plane) and ankle (sagittal plane) moments, stance limb support moment and the activation of nine muscles of the lower limb were calculated during the weight acceptance (WA) phase of unplanned sidestepping (UnSS) prior to, and following training. Muscle activation was measured with surface electromyography (sEMG) using a 1500Hz Noraxon Telemetry system (TeleMyo 2400 G2, Noraxon, Scottsdale, Arizona). 3D marker trajectories were collected using a 12 camera Vicon MX system (Oxford Metrics, Oxford, UK) at 250Hz. This was synchronized with a 1.2m x 1.2m force plate (AMTI, Watertown, MA) recording at 2,000Hz. Customised software in MatLab (Matlab 7.8, The Math Works, inc., Natick, Massachusetts, USA) was used to process sEMG data, as per Donnelly et al (2011). Maximum functional excitation of each muscle (n=9) recorded during any of the dynamic trials was used to normalize each muscle's sEMG signal to 100% activation. Total muscle activation (TMA) of all lower limb muscles and individual muscle groups (gluteal, quadriceps, hamstrings and gastrocnemii) were calculated. Pre to post training, changes in muscle activation, support moment and frontal plane knee moments during the pre-contact (PC) and weight acceptance (WA) phases of stance of unplanned sidestepping were assessed using effect sizes (Cohen's d) and a repeated measures ANOVA in in SPSS 17.0.1 (SPSS Inc, IBM Headquaters, Chicago, Illinois) (α = 0.05).

RESULTS AND DISCUSSION: Following training there was no significant changes in TMA during PC and WA of unplanned side-stepping tasks. However, TMA of the gluteal (grouped maximus and medius) improved by 10% during WA (p=0.006, power=0.864). No statistically significant changes in support moment were observed, however a moderate effect size (d = 0.56) was present, showing a 10% increase in hip extension towards the total support moment (Figure 2). There were no changes in frontal plane knee moments following training (p=0.73, d<0.01). There was no change in frontal plane knee loading following training (p=0.73, d<0.01). This may be due to the small sample in this study, however values were lower than that reported in the literature (Robinson, Donnelly, Tsao, & Vanrenterghem, 2013). These findings in combination suggest athletes better utilize their hip musculature to generate their support moment, which may result in improvements in the biomechanical risk factors associated with ACL injury. This can be concluded in two parts, firstly; the complex line of action of the ACL requires combined knee loading in all three planes to maximize ligament strain, therefore redistributing the support moment to the hip musculature may effectively reduce ACL injury risk by decreasing loading at the knee. Secondly, as the gluteal muscle group functions to externally rotate the hip, the elevated neuromuscular response following training signifies an increase in eccentric control of hip internal rotation, which would function to prevent the valgus collapse or 'buckling' at the knee, which has been associated with elevated frontal plane knee moments, ACL injury risk and ACL injury rates (Besier et al., 2001; Hewett et al., 2005; McLean et al., 2005).

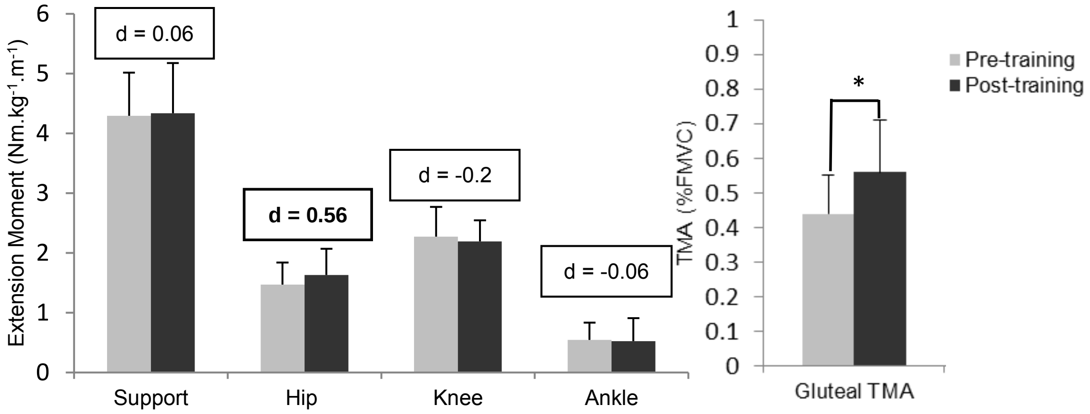

Figure 2. Support moment and contribution of sagittal plane moments ($Nm.kg^{-1}.m^{-1}$), and gluteal TMA during weight acceptance of unplanned sidestepping, prior to and following training.

CONCLUSION: Following an 8-week multifactorial body-weight based hip and trunk neuromuscular training intervention, increased gluteal total muscle activation and an elevated contribution of hip extension moment to the total support moment during the weight acceptance phase of unplanned sidestepping was observed. This is a positive neuromuscular strategy that may reduce risk of ACL injury via redistribution of forces to the hip, control of the upper body and prevention of dynamic knee valgus postures. Supporting previous simulation research (Donnelly et al., 2012), training protocols focused on the dynamic control of the trunk and hip are recommended to reduce an athlete's peak knee loading and ACL injury risk in sport.

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