Reducing anterior cruciate ligament injury risk factors by training perception: How vital is maintaining the perception-action coupling?

Stephen Tidman[1], Brendan Lay[1], Sean Byrne[1], Paul Bourke & Jacqueline Alderson[1]
School of Human Sciences, University of Western Australia, Perth, Australia[1]

This study investigated the effect of maintaining perception-action coupling during a 4-week perceptual training program aiming to reduce biomechanical risk factors associated with ACL injury. Kinetic (valgus and internal rotation knee moments) and neuromuscular (total knee muscle activation and directed co-contraction ratios) variables were calculated during evasive sidestepping of 3D-projected opponents in 1-on-1, 2-on-2 and 3-on-3 game-based situations pre and post-intervention training. An additional transfer scenario was assessed post-intervention. Twenty-six amateur Australian Rules footballers were allocated to control (C), uncoupled (U) or coupled (PA) groups. Participants completed biweekly perceptual training containing 48 trials requiring a verbal (uncoupled) or running sidestep (coupled) response while counting the number of attentional cues displayed. Training groups showed no reductions in peak valgus and internal rotation moments, however, a small decrease in peak valgus moments was observed in the transfer condition. Coupled training displayed significant group differences in medial-lateral co-contraction ratios from controls. No changes in muscle activation patterns pre-post ARF were observed, however C and UC groups redirected co-contraction ratios laterally in the transfer condition. Results suggest that attentional cueing perceptual training with a coupled response may have a beneficial impact on kinetic ACL injury risk factors and maintain muscle activation levels associated with decreased ACL injury risk.

KEYWORDS: anterior cruciate ligament (ACL), injury prevention, perception, sidestepping

INTRODUCTION: Anterior cruciate ligament (ACL) injuries are one of the most prevalent injuries in Australian Rules football (ARF) and are expensive in terms of treatment costs and missed matches (Saw et al., 2018). It has been reported that ~56% of ACL injuries in ARF are non-contact events, with sidestepping and single-leg landing on an extended knee the most common mechanisms (Cochrane et al., 2007). Traditional ACL injury prevention programmes have largely focused on reducing these injury risk factors by modifying technique (Dempsey et al., 2007) or by training the neuromuscular system to stabilise the knee during action through plyometric (Chappell & Limpisvasti, 2008) and/or strength training (Cochrane et al., 2010). Though effective, these programmes focus on movement demands in isolation, without considering the role of environmental factors (i.e. opposing players or situational game constraints) which ultimately guide movement execution. This separation of perception and action has enabled tighter experimental control but has reduced the degree to which the task reflects naturally occurring conditions. In 2013, Lee et al. reported kinematic and knee moment differences when sidestepping in response to projected opponents compared to generic arrow stimuli. The authors suggested that higher-level players can perceive directional cues in opposing players' kinematics, affording more time and space to execute a ‘safer’ sidestep. With largely the same cohort, a more recent study by Lee and colleagues (2019) reported changes in muscle activation at the knee in response to the same stimuli. Improving perceptual-cognitive skills has been extensively investigated in motor learning literature. Interventions using video-based simulations to replicate the performer’s customary point of view have been shown to improve anticipatory responses in many sports such as tennis, squash and field hockey (Abernethy et al., 2012). Researchers have attempted to optimise perceptual training by directing players’ attention to critical anticipatory cues using a transparent red patch to highlight components of an opponent’s hitting action in badminton (Hagemann et al., 2006) and European handball goalkeeping (Abernethy et al., 2012) with mixed results. Historically, such interventions would require performers to respond to simulations verbally or with representative movements, uncoupling the functional link between perception and action. Farrow and Abernethy (2003) investigated the effect of coupled and uncoupled responses in in-situ service return in tennis players and showed improvements in predictive accuracy with a coupled response. Though numerous studies have advocated to preserve the perception-action coupling (PAC), research has only investigated its impact on anticipatory performance, and not within the injury prevention domain. Therefore, the primary aim of this study was to determine if maintaining the PAC during a 3D video-based perceptual training program reduces peak knee moments associated with ACL injury, and increases neuromuscular activation supporting the knee during an ARF sidestepping task. The secondary aim was to determine if preserving the PAC allowed for a greater skill transfer from ARF scenarios to a novel American football scenario.

METHODS: Twenty-six community level footballers (mean age: 24.54±5.05 years, height: 176.04±36.34 cm, mass: 86.29±10.30 kg), participated in a 4-week attentional cueing perception training protocol. Participants were quasi-randomly allocated to uncoupled (n=11) and coupled (n=8) training groups or acted as controls (n=7). 3D motion capture of each participant was captured using an established sidestepping protocol pre and post-training (Lee et al., 2013). Players were instructed to 'run and carry' a football and evade oncoming ARF opponents (Scenarios a, b & c in Figure 1) by sidestep (SS) or crosscut at an angle of 45±10°. An American football transfer (AFT) scenario (d) depicting a modified American football scenario requiring the same evasive manoeuvre, was used to assess skill transfer. A custom, thirty-four retro-reflective lower body marker set (Besier et al., 2003) was fitted and captured using a 22-camera Vicon MX/T40 system at 250 Hz (Oxford Metrics, Oxford, UK). Synchronously, ground reaction force (GRF) data (AMTI, Watertown, MA) and surface electromyography (sEMG) data (TeleMyo 2400 G2, Noraxon, Scottsdale, Arizona) was recorded at 1,000 Hz. 3D kinematic and GRF data were low pass filtered using a 15 Hz zero-lag fourth-order Butterworth filter. 15 Hz cut-off frequency was determined by residual analysis and visual inspection of kinematic data and used for both kinematic and GRF to minimise knee joint kinetics artefact (Bisseling & Hof, 2006). Peak knee valgus (PKVM) and internal rotation (PKIRM) moments were calculated using established methods (Besier et al., 2003; Dempsey et al., 2007, 2009). All knee moments were normalised to player body mass and height (Dempsey et al., 2009; Lee et al., 2013). Bipolar surface electrodes were placed on eight muscles crossing the knee joint as per Donnelly et al. (2015). sEMG data was processed using custom software in MatLab (Matlab 2014a, The Math Work Inc. Natick, MA, USA) to remove DC offsets, then band-pass filtered between 30 and 500 Hz with a zero-lag, 4th order Butterworth digital filter. The signal was then full-wave rectified and linear enveloped using a low pass with a zero-lag, 4th order Butterworth at 6 Hz. Muscle activation was normalised to the sessional maximal activation for each muscle and expressed as 0-100% maximal sessional contraction (MSC). Peak knee moments, TMA and ML/DCCR were analysed during the weight acceptance (WA) of 3 successful SS in response to scenarios. Sidesteps were deemed successful if approach speed was 4.3-4.7ms^{-1} and the correct direction was chosen. Two-way between groups repeated measures ANOVA (α<0.05) were calculated to compare training groups to control, with one-way between-groups ANOVA (α<0.05) used to ensure no differences between groups at baseline. Transfer performance was analysed using one-way between-groups ANOVA (α<0.05), and Cohen's d effect sizes.

Figure 1: 3D projected scenarios of Australian Rules football (ARF) scenarios used in training and testing including 1-on-1 (a), 2-on-2 (b), 3-on-3 (c) and an American football transfer (AFT) scenario (d) used in post-testing. Scenarios are depicted at the approximate time of sidestep.

TRAINING: Participants were instructed to evade three-dimensional (3D) projected opponents in ARF scenarios. Scenarios depicted one opponent (1-on-1), one teammate and two opponents (2-on-2), and two teammates and three opponents (3-on-3) converging on the lab-based participant. Bi-weekly training sessions included 46 trials. Uncoupled (UC) were instructed to indicate evasive direction verbally, with the coupled (PA) group evaded projected opponents by performing a running sidestep or crosscut. Attention cues (1-4 purple dots) were digitally added to scenarios to implicitly direct participants' attention to information-rich areas determined during pilot testing. In addition to indicating evasive direction, participants were required to count and report the number of attentional cues seen in each trial.

RESULTS: No significant differences in UC or PA groups' pre to post PKVM's were observed when responding to ARF scenarios. Both UC (Δ -19%, d=0.41) and PA (Δ -34%, p<0.01) reported decreases in PKVM When responding to AFT. PKIRM was unchanged in both UC and PA across pre-post ARF and AFT scenarios. Pre-post TMA showed no significant differences in ARF or AFT scenarios. Pre -post ML/DCCR for UC and PA showed no significant differences, with PA displaying significant group differences in ARF (1v1-post, 2v2-pre, and 3v3-post) scenarios compared to C. No differences were observed in ML DCCR when responding to ARF scenarios. In AFT, ML/DCCR in C (d=0.7) and UC (d=0.3) groups were redirected laterally, a result not seen in PA.

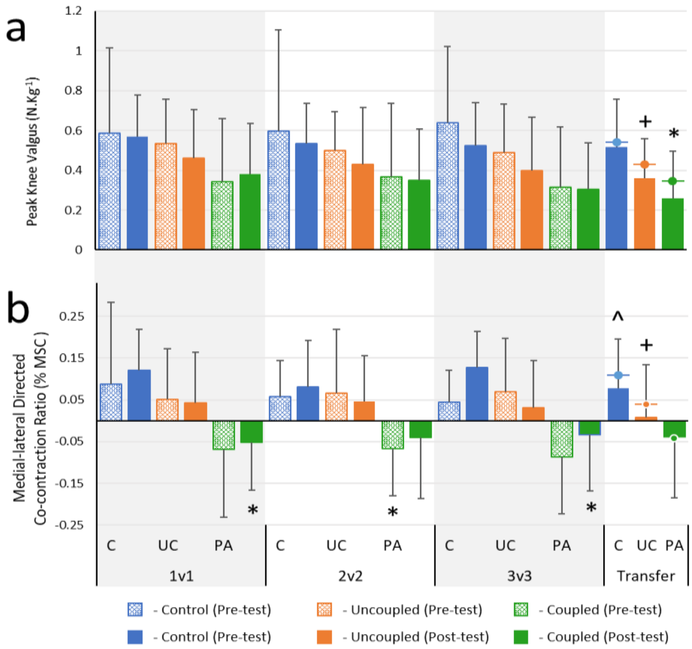

Figure 2: Mean (standard deviation) normalised (Ht*BW) peak knee valgus moments (a) and medial/lateral directed co-contraction ratios (b) for control (c), uncoupled (UC) and coupled (PA) groups during the weight acceptance phase of sidestep. * Denotes p<0.05, effect sizes denoted by ^ (moderate, 0.5>d>0.8) and + (small, 02<d<0.5).

DISCUSSION: To date, interventions aimed at reducing ACL injury risk factors have disassociated perception and action components of evasive sidestepping. Results suggest that maintaining a functional link between perception and action components, though not critical, optimise perceptual training methodologies. Significantly lower PKVM recorded by PA in AFT indicates that coupling perception and action allows for a greater transfer of skill into a novel setting. It should be noted that UC displayed marginal reductions in PKVM in AFT, suggesting that perceptual training programmes utilising uncoupled responses may still be effective in reducing kinetic injury risk factors. As such, athletes with restricted movement due to injury may still benefit from such a programme. Interestingly, both C and UC redirected ML/DCCR laterally in AFT, which is thought to be an ineffective neuromuscular strategy to support against valgus knee moments (Donnelly et al., 2105). Given UC displays a small decrease in PKVM, a marginal lateral redirection of ML/DCCR alone may not constitute an increase in ACL injury risk. However, the reduced PKVM and preservation of ML/DCCR exhibited in AFT by PA further indicates a need to maintain a functional link between perception and action. Future research should explore whether movements that are representative of the action assessed could maintain neuromuscular strategies. Interestingly, no differences in peak knee moments or neuromuscular activation were observed in ARF post perceptual training. Research investigating perceptual skill has measured anticipatory reaction times and accuracy to assess skill learning. In 2014, Mornieux and colleagues investigated the effects of temporally constrained, light-based stimuli during sidestepping. Significantly lower PKVM were reported when responding to stimuli presented 850ms before Ss (planned) when compared to 500-600ms (unplanned), while comparative PKVM were observed under 500ms and 600ms constraints. These results would suggest that improvements in anticipatory performance in evasion may need to be larger than 100ms to elicit kinetic differences during Ss. Given no differences in PKVM were observed in post-test ARF, it is plausible that changes in anticipatory performance were less than 100ms.

CONCLUSION: This is the first study to examine the impact of coupling perception and action on kinetic and neuromuscular ACL risk factors using perceptual training. Consistent with current research, our findings suggest that preserving a functional link between perception and action is beneficial for evasive performance and kinetic and neuromuscular risk factors associated with ACL injury. Future research should explore the degree of coupling that is required to maintain neuromuscular strategies used in sidestepping.

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