REDUCING ACL INJURY RISK BY STANDING STILL WITH ZERO IMPACT PERCEPTUAL (ZIP) TRAINING!

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This study assessed novel zero-impact perceptual (ZIP) training, in which there is cognitive but no physical workload, in reducing biomechanical risk factors associated with anterior cruciate ligament injury. Tri-planar knee moments in amateur Australian rules footballers (n=16) 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. Video-only (VO) and Cueing (Q) training groups verbally evaded opponents in 8 sessions over 4 weeks. Cueing incorporated an additional task of counting visual cues within the scene. Training groups showed reductions in peak valgus and internal rotation moments, with greater reductions observed in Q training relative to controls. Results suggest that ZIP training can reduce ACL injury risk without impacting physical workload.

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

INTRODUCTION: Workload management is a major consideration for sport science and medical staff involved in elite level sport in their efforts to reduce injury incidence (Rogalski, Dawson, Heasman, & Gabbett, 2013). Unfortunately, the containment nature of a risk minimisation management paradigm is restrictive and can serve to limit the time available for improving performance. Subsequently, specific skills and techniques not directly related to game performance (e.g. evasive sidestepping) may be overlooked when determining coaching priorities. Evasive sidestepping is a specific skill manoeuvre associated with anterior cruciate ligament (ACL) injury risk (Lloyd, 2011). *In-vitro* research has shown that the greatest ACL loads occur during a combination of applied internal rotation and anterior tibial force, with further increased load occurring when anterior tibial force is combined with valgus moments (Markolf et al., 1995). Further research has shown that knee valgus and internal rotation moments are increased when athletes have less time to plan a sidestepping manoeuvre (Besier, Lloyd, Ackland, & Cochrane, 2001). It is generally accepted that 'unplanned' scenarios are more representative of in-game scenarios where athletes must respond to a constantly evolving environment (Besier et al., 2001; Brown, Brughelli, & Hume, 2014). Current training methods focus on reducing injury risk by modifying technique (Dempsey et al., 2007b) or by training the neuromuscular system stabilising the knee during action through plyometric (Chappell & Limpisvasti, 2008) and/or strength training (Cochrane et al., 2010). Despite being effective in reducing risk factors, these methods often require significant levels of physical activity and may negatively impact on an athlete's physical workload allowance. Recent research has highlighted the need to investigate knee loads using stimuli that better represents the temporal and visuospatial demands found in competition (Lee, Lloyd, Lay, Bourke, & Alderson, 2013). Using 3D projected opponents Lee et al., (2013) observed that high-level footballers experienced lower peak knee valgus moments compared with low-level players, only when responding to a scene with multiple players. Lee et al (2010) suggested that previous research utilising non-specific stimuli such as light emitting diodes (Besier et al., 2001) and statically positioned mannequins (McLean & Lipfert, 2004) may not distinguish between high and low risk athletes as it may not account for an athletes ability to perceive task-relevant information in a game-like environment. Historically, research investigating perceptual skill in athletes has focussed on expert-novice differences during anticipatory tasks. Experts exhibit superior performance in recognition and detection of objects within the visual field (M. Williams & Davids, 1995) and more appropriate visual search behaviours (WIlliams, Davids, Burwitz, & Williams, 1994) in sporting tasks. Additionally, experts have also shown an enhanced ability to pick up advance (early) cues in

postural orientation of opponents(WIlliams et al., 1994), allowing earlier response times. Given the disparity between high and low level players in perceptual ability and associated knee loads (Lee et al., 2013), current perceptual training methodologies have the potential to reduce injury risk. To date, perceptual training research has not directly investigated injury risk in sport. The purpose of this study was to explore the potential of ZIP training programs with a view to reduce knee loads associated with anterior cruciate ligament injury during an evasive sidestepping (SS) task.

METHODS: Sixteen community level footballers (mean Age: 24.87±3.38 yr, Height: 179.81±7.56 cm, Mass: 82.19±8.96 kg), participated in a 4-week video-only (VO, n=6)) or Cueing (Q, n=7) ZIP training program (2 x 15 minute sessions/week) or acted as controls (n=3). Participants were asked to verbally evade three-dimensional (3D) projected opponents in three 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. Forty-six trials per completed in each training session. VO and Q groups viewed identical scenarios throughout training. Visual cues (purple dots) were added to Q footage in information rich areas determined during pilot testing. Additional to verbal evasion, Q group were required to count cues (n =1-4) digitally added to scenario footage.

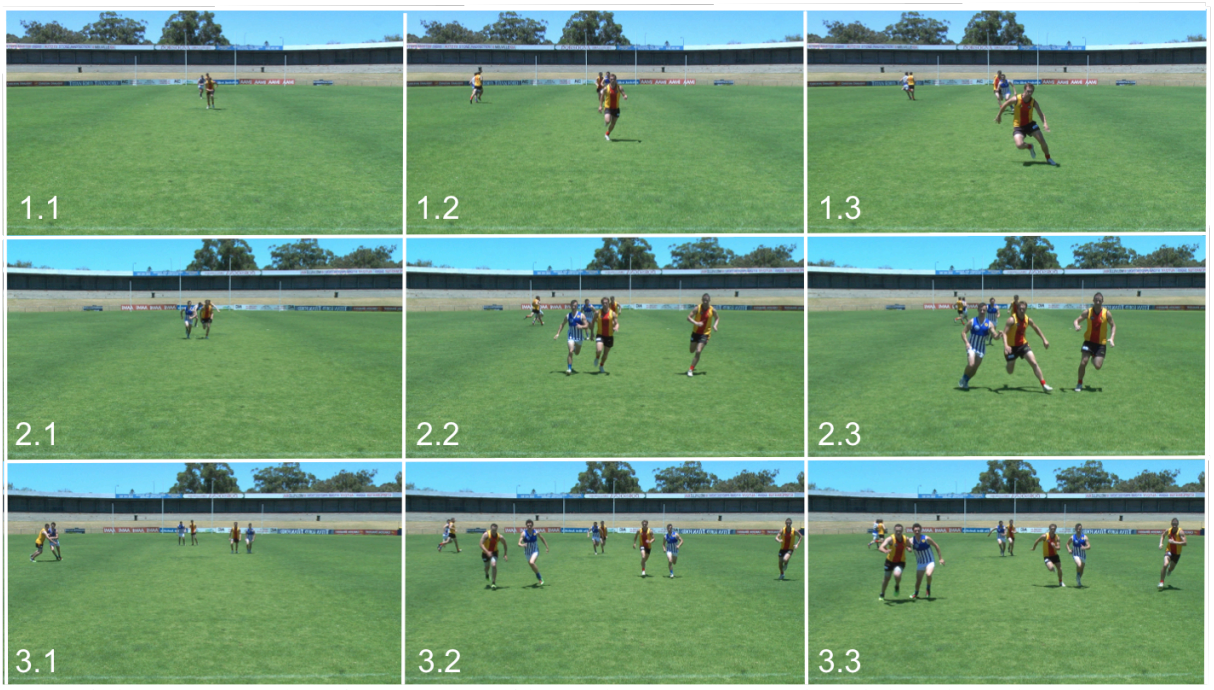

Figure 1: 2D representation of progression of 3D projected scenarios (1-on-1, 2-on-2 and 3-on-3) requiring sidestep/crosscut to the left from first frame (n.1) to approximate time of sidestep (n.3).

3D motion capture of each participant was captured using a previously published protocol (Lee et al., 2013) at baseline and post ZIP training. Players were instructed to 'run and carry' a football and evade oncoming opponents by sidestepping (SS) or crosscut manoeuvre at an angle of 45±10° from angle of approach. Thirty four retro-reflective markers were fitted as per the UWA lower-body marker set (Besier, Sturnieks, Alderson, & Lloyd, 2003). Marker trajectories were captured using a 22-camera Vicon MX/T40 system at 250 Hz (Oxford Metrics, Oxford, UK), and simultaneous ground reaction force (GRF) data at 2,000 Hz (AMTI, Watertown, MA). 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). Knee kinetics were calculated using established methods (Besier et al., 2003; Dempsey, Lloyd, Elliott, & Steele, 2007a;

Dempsey, Lloyd, Elliott, Steele, & Munro, 2009). Peak knee extension, valgus and internal rotation moments were analysed during weight acceptance (WA) of 3 successful SS in response to scenarios. SS were deemed successful if approach speed was 4.3-4.7ms^{-1} and the correct direction was chosen. All knee moments were normalised to player body mass and height (Dempsey et al., 2009; Lee et al., 2013). One-way repeated measures ANOVA (α<0.05), paired t-tests and Cohen's' d for effect sizes were calculated pre-post ZIP training, with one-way between groups ANOVA (α<0.05) used to ensure no differences between groups at baseline.

RESULTS AND DISCUSSON: To date, no perceptual training methods have been utilised to reduce injury risk factors in sport. Historically, perceptual training has been successful in improving predictive and anticipatory performance in sporting tasks (Farrow & Abernethy, 2002; Jackson & Farrow, 2005). With time to plan a critical factor in knee injury risk (Brown et al., 2014), improving anticipatory and predictive performance may give an athlete more time to plan evasive action. Athletes who participated in ZIP training (VO and Q) showed overall reductions in peak knee moments associated with ACL injury, when compared with controls, suggesting ZIP training had a positive effect on reducing ACL injury risk. Prior to ZIP training, peak knee moments between groups were not significantly different. Peak knee valgus moments showed the greatest reductions post intervention, with notably greater reductions in Q (1-on-1 (p=0.49) and 2-on-2 (p=0.45) , 3-on-3 (d=1.05) compared to VO, (2-on-2 (d=0.84), 3-on-3 (d=0.89)). This combined with peak knee internal rotation reductions observed in Q (1-on-1 (p=0.034), 2-on-2 (d=0.73),3-on-3 (d=0.61)), suggests that Q was a more effective at reducing injury risk. It should be noted that the use of raw video footage without modification is easier to implement into a training environment and should not be overlooked as a potential training tool. These results highlight the potential benefit of orienting attention to information rich areas within the display that may be missed by adding visual cues.

Table 1
Peak Tri Planar Knee Moments during Weight Acceptance (Nm kg^{-1} m^{-1})

	1v1		2v2		3v3	
Valgus	Pre	Post	Pre	Post	Pre	Post
Control (C)	0.49±0.14	0.74±0.19*	0.40±0.07	0.82±0.18[a]	0.56±0.21	0.74±0.04[a]
Video-Only (VO)	0.44±0.28	0.40±0.09	0.47±0.21	0.29±0.22[a]	0.48±0.31	0.26±0.16[a]
Cueing (Q)	0.54±0.0.26	0.28±0.21*	0.51±0.0.22	0.29±0.0.25[a]	0.40±0.25	0.11±0.0.30[a]
Extension						
Control (C)	2.38±0.13	2.03±0.65[a]	1.73±0.65	2.24±0.25[a]	1.95±0.45	2.21±0.36[b]
Video-Only (VO)	1.48±0.79	1.58±0.62	1.52±0.62	1.40±0.99	1.40±0.56	1.45±0.69
Cueing (Q)	1.52±0.55	1.30±0.32	1.49±0.32	1.34±0.63	1.34±0.81	1.31±0.68
Internal Rotation						
Control (C)	0.07±0.02	0.14±0.07	0.07±0.03	0.12±0.06[a]	0.08±0.05	0.13±0.04*
Video-Only (VO)	0.06±0.04	0.06±0.03	0.05±0.04	0.07±0.04	0.06±0.05	0.06±0.03
Cueing (Q)	0.12±0.10	0.03=±0.3*	0.08±0.03	0.05±0.05[b]	0.08±0.09	0.04±0.02[b]

* denote *p*<0.05, [a] denote strong *cohen's d* effect size (d>0.8), [b] denote moderate *cohen's d* effect size (d>0.5)

CONCLUSION: To our knowledge, this is the first demonstration of visual perceptual training's capability to reduce ACL injury risk. Traditional injury prevention training modalities such as plyometric, strength and technique modification training have been shown to be effective in reducing ACL injury risk but add to total player workload. These methods may

not be viable at an elite level if deemed to be too costly from a player workload perspective. Results suggest that zero impact perceptual (ZIP) training has the potential to provide coaches with a training platform that does not adversely impact player physical workloads, allowing for skills/techniques associated with injury to be trained without compromising performance goals. ZIP training also provides injured or rehabilitating players a low-risk, stable environment in which to continue training.

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