MANIPULATING TIME: DIFFERENCES IN PEAK KNEE MOMENTS WHEN SIDESTEPPING TO TEMPORALLY CONSTRAINED QUASI-REALISTIC SCENARIOS

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This study aimed to analyse how planning time effects peak knee valgus (PKVM) and internal rotation (PKIRM) moments using real-time (RT) and above real-time (ART) game-like video clips. Twelve male Australian rules football players completed a modified sidestepping (SS) movement assessment. PKVM and PKIRM were measured across the weight acceptance phase of planned (PSS) and four unplanned SS conditions, increasing in video playback speed (UP100, UP125, UP150, UP175). No significant differences were found for PKVM or PKIRM between any SS conditions, however, the coefficient of variation in PKVM increased as the temporal constraints of the unplanned tasks increase. This study suggests that while mean group differences in PKVM may not be obvious, increased trial to trial variability is evident as planning time decreases.

KEYWORDS: cutting, above real-time, perception, anterior cruciate ligament (ACL)

INTRODUCTION: The ability to change direction quickly in response to the surrounding environment is integral to success in many field and court sports. One common technique to achieve a rapid directional change is the sidestep (SS), generally considered a vital skill for athletes (Pyne, Gardner, Sheehan, & Hopkins, 2005). However, this dynamic and typically reactive skill comes at increased risk of lower limb injury, in particular non-contact anterior cruciate ligament (ACL) injury (Cochrane, Lloyd, Buttfield, Seward, & McGivern, 2007; Johnston et al., 2018). Due to the difficult nature of measuring internal bone and soft tissue forces during the injury event, researchers must often estimate ACL injury risk via other surrogate biomechanical measures such as; peak knee valgus moment (PKVM) and peak knee internal rotation moment (PKIRM) during the weight acceptance phase of SS (Brown, Brughelli, & Hume, 2014). While a range of lower limb kinematic postures have been linked to increased peak knee moments, research has consistently shown that as planning time is reduced ACL injury risk factors increase (Almonroeder, Garcia, & Kurt, 2015; Besier, Lloyd, Ackland, & Cochrane, 2001; Mornieux, Gehring, Furst, & Gollhofer, 2014).
Agility, by definition, requires both a change of direction component (the SS) and a perceptual decision-making component (external stimulus) (Young, James, & Montgomery, 2002). One limitation of current literature is that studies that aim to quantify the effect of planning time on SS technique employ a generic arrow or light-based directional cue. (Mornieux et al., 2014; Weir, van Emmerik, Jewell, & Hamill, 2019) Despite being challenging and “reactive”, these stimuli may not accurately represent what is happening on the field. These conditions lack the element of perceptual expertise, removing any ability for the athlete to draw on past knowledge or experience to assist in execution. Some researchers have attempted to increase stimulus ecological validity by using a live opposing player (Wheeler & Sayers, 2010) or three-dimensional (3D) video stimuli (Lee, Lloyd, Lay, Bourke, & Alderson, 2013). To date, the effect of temporal constraints on SS using realistic game-like stimuli has not been thoroughly investigated.
One possible way to explore the influence of ‘time’ in game-like scenarios is to play video clips back to the player above real-time (ART). Subjective experiences of both elite and sub elite Australian rules football players found that when videos were played in real-time (RT) and ART to players, speeds played at 1.25 and 1.5 times their original speed felt most

game-like for decision making (Lorains, Ball, & MacMahon, 2013). These authors found that the use of ART video could provide a new mode for training interventions and improving decision making. As yet, this has not been tested with a sport specific action and variables associated with ACL injury risk.

The aim of this study was to assess if changing planning time effects PKVM and PKIRM during SS, in planned and quasi-realistic scenarios, using RT and ART video playback. Recent research has suggested that PKIRM is not different between planned and unplanned SS. However, to be consistent with previous studies and due to PKIRM's association with increased risk of ACL injury together with the unique task constraints imposed by this experiment, PKIRM will be reported. It is hypothesised that planned SS will elicit smaller PKVM when compared to RT and ART conditions. It is also hypothesised that as the time constraints of the unplanned conditions increase PKVM will also increase.

METHODS: Twelve male Australian rules football players (21 ± 2.2 yrs; 1.83 ± 0.07 m; 79.7 ± 5.87 kg) completed a custom evasive SS protocol, adapted from Lee et al. (2013). Following three straight runs and three planned sidesteps (PSS), participants performed a series of quasi-randomised SS or crossover cuts in response to custom stereoscopic 3D projected opponents. Each 3D video scenario depicted variations of one teammate and two opponents converging on the lab-based participant. Each video clip was edited within Adobe Premiere Elements 9, using the time stretch feature (Lorains et al., 2013) to increase the speed of each clip 1.25 x, 1.5 x and 1.75 x the original (1.0 x) two second clip, resulting in one RT and three ART unplanned conditions; UP100, UP125, UP150 and UP175. Each unplanned condition provided the same contextual/ visuospatial information across increasingly more challenging temporal constraints, with the UP175 condition imposing the highest level of difficulty (figure 1). Videos were triggered as the players passed through the first set of timing gates with the second set (set 7 m apart) used to validate approach velocity (4.5 ± 0.2 m.s^{-1}). Players were instructed to 'run and carry' a football and evade oncoming opponents by either a SS or crossover cut at an angle of 45 ± 10° from the line of approach. The convergence point of each scenario was always set at the same point such that, as video speed increased the video start time became increasingly delayed.

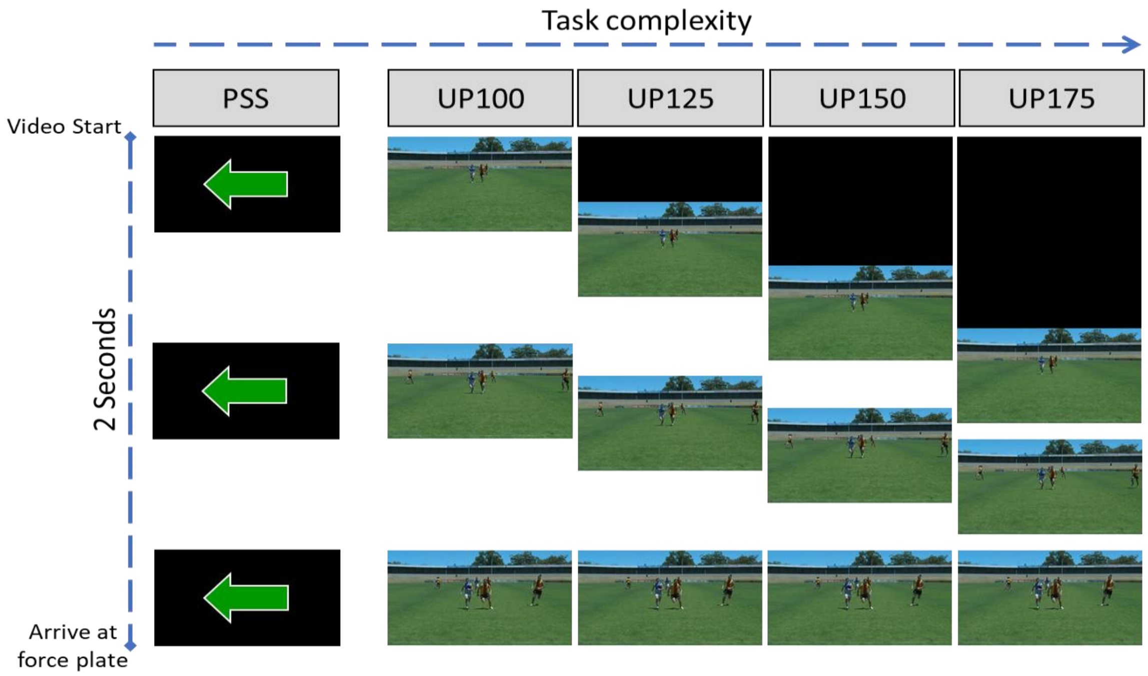

Figure 1. Example of start time and delay for planned sidestepping (PSS) and quasi-realistic video stimulus conditions increasing in difficulty from left to right for a left directed sidestep (off a right stance limb).

3D marker and ground reaction force (GRF) were synchronously collected using a force plate (AMTI, Watertown, MA) and a 22 camera Vicon motion capture system (Oxford Metrics, Oxford, UK) recording at 2000 Hz and 250 Hz respectively. Three-dimensional kinematic and GRF data were low pass filtered using a 14 Hz zero-lag fourth order Butterworth filter. A 14 Hz cut-off frequency was determined by residual analysis and visual inspection of kinematic data and used for both kinematic and GRF data (Bisseling & Hof, 2006). Knee kinetics were calculated using an inverse dynamics approach and normalised to player body mass and height ($N.kg^{-1}$) (Dempsey et al., 2007; Lee et al., 2013). PKVM and PKIRM were analysed during the weight acceptance phase of 3 successful SS for all 5 conditions. Trials were deemed successful if the approach speed was within 4.5 ± 0.2 $m.s^{-1}$ and the correct direction was chosen. PKVM and PKIRM during weight acceptance of PSS, UP100, UP125, UP150 and UP175 were compared using one-way repeated measures ANOVA ($\alpha<0.05$). Coefficient of variation (CV) expressed as a percentage was reported for both between subject and within subject means.

RESULTS: Contrary to the original hypothesis, mean PKVM was not significantly different across the SS conditions. While no significant differences were observed, it is important to note that within, and between subject, CV appears to increase alongside unplanned task complexity in the RT and ART conditions. While not statistically analysed, these authors observed greater range in PKVM values as the tasks become more time constrained (table 1). No significant differences were observed in PKIRM.

Table 1: Mean ± SD of peak knee valgus (PKVM) and peak knee internal rotation (PKIRM) moments alongside the coefficient of variation (CV) for between and within subject means and SD for planned (PSS) and quasi-realistic unplanned (UP100, UP125, UP150, UP175) sidestepping conditions.

Task	PKVM ($N.kg^{-1}$)	CV between (%)	CV within (%)	PKIRM ($N.kg^{-1}$)	CV between (%)	CV within (%)
PSS	0.27 ± 0.18	69%	65%	0.06 ± 0.02	36%	36%
UP100	0.41 ± 0.18	44%	29%	0.08 ± 0.03	41%	30%
UP125	0.42 ± 0.22	52%	39%	0.07 ± 0.04	49%	50%
UP150	0.42 ± 0.29	69%	65%	0.08 ± 0.03	40%	35%
UP175	0.44 ± 0.29	66%	77%	0.08 ± 0.03	37%	31%

DISCUSSION: This is one of the earliest studies to report the effect of temporal constraints on peak knee moments during a SS task using quasi-realistic stimuli. Despite not finding statistical differences between conditions, higher between and within subject variability in PKVM was observed as the temporal constraints increased across conditions. Recent research has shown that there is higher co-ordinational variability in SS as task complexity increases from planned to unplanned, particularly in sagittal and frontal plane kinematics (Weir et al., 2019). The average PKVM values in this study might not have changed as playback speed increased, however, the chance of being exposed to an unexpected PKVM becomes greater and is emphasised in this study by the within subject CV values. Future research should explore further the question of whether a relatively low PKVM could still be associated with increased risk of injury when it is not expected or anticipated. A high CV was also found for PKVM in PSS despite a standard deviation comparable to UP100. Both tasks have the same relative amount of variability in PKVM however in PSS these values are fluctuating around a smaller mean, resulting in a higher CV.

Research investigating the role of different visual stimuli on knee kinetics in evasive SS has found that compared with a planned arrow condition, responding to 3D projected defenders produced different knee moments (Lee et al., 2013). Lee and colleagues' (2013) reported PKVM for planned and quasi-realistic 3D scenarios similar to the results of the present study. Lee et al., (2013) also noted no significant differences in PKVM across game-like conditions

despite varying levels of complexity. In support of a possible increase in co-ordinational variability these authors did find differences in trunk and hip kinematics between the game-like conditions. Additionally, they also found differences in PKVM when dividing the group by expertise level. Unsurprisingly, this suggests technique variability increases in tandem with task complexity and that playing experience may impact ACL risk factors.
One of the key limiting factors for this investigation is sample size. These authors acknowledge that this is a preliminary investigation and a greater sample may help to provide significance and allow for a deeper kinetic and kinematic analysis.

CONCLUSION: This is the first study to manipulate the play back speed of quasi-realistic (stereoscopic) game scenarios to investigate temporal constraints on SS. This novel approach to manipulating planning time may better represent the cognitive and environmental demands of the on-field scenarios players will find themselves in. As the task becomes more difficult by increasing playback speed and tightening the temporal constraints, each individual's performance becomes more inconsistent from trial to trial. These results have two key implications for future research; first, whether the inconsistency of key variables known to be implicated in ACL injury is as important as the peak values themselves and, second, whether inducing increased trial to trial performance variability in training and preparation could be an important strategy for injury prevention.

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