THE RELATIONSHIP BETWEEN NEUROCOGNITION AND SIDE-STEP CUTTING BIOMECHANICS IN WOMEN'S AUSTRALIAN FOOTBALL PLAYERS

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Despite increased awareness and targeted efforts, anterior cruciate ligament (ACL) injuries continue to frequently occur within the women's Australian-rules football league (AFLW). AFLW ACL injuries frequently occur when performing a defensive side-step cut. Considering the reactive nature of this scenario, neurocognitive function may be an important risk factor. Therefore, the purpose of this study was to investigate the relationship between neurocognition and side-step cutting biomechanics in women's Australian football players. Relationships between neurocognitive measures and 3D knee loads during unanticipated side-stepping were examined. No statistically significant relationships were found. These findings provide recommendations for future research to explore different cognitive parameters and ensure sufficient cognitive demand in the testing environment.

KEYWORDS: ACL, injury prevention, cognitive function, AFLW

INTRODUCTION: Women's Australian football league (AFLW) players are six- to seven-times more likely to suffer an anterior cruciate ligament injury compared to male Australian Football League players (AFL Doctors Association et al., 2019). AFLW ACL injuries frequently occur when performing a reactive side-step cutting manoeuvre in direct defensive situations (Rolley et al., 2023). Defensive tasks are known to incur an increased cognitive demand when tracking an opponent's movement cues (Brophy et al., 2015). With neurocognitive deficits (e.g. slower reaction times) associated with increased knee loading (e.g. higher peak vertical ground reaction forces) (Almonroeder, 2017), the common AFLW ACL injury scenario may not be entirely explained by mechanical factors alone. Investigating the relationship between neurocognition and side-step cutting biomechanics may provide novel insights into factors associated with increased ACL loading and strain. Therefore, the purpose of the study was to explore the relationship between neurocognition and biomechanical performance of a reactive side-step cutting task in AFLW players. It was hypothesised that participants with poorer cognitive performance (e.g. slower reaction time) would present potentially hazardous lower limb biomechanics associated with increased ACL loading and strain.

METHODS: Nine elite (i.e. AFLW, n = 3) and sub-elite (i.e. VFLW – one competition tier below AFLW, n = 6) (mean ± SD, age = 24.11 ± 4.31 years; height = 169.93 ± 8.67 cm; mass = 69.22 ± 11.07 kg) women's Australian-rules football players participated. Participants were: (i) free of current lower limb injury; (ii) had not suffered an injury to the lower limb in the past six-weeks; (iii) had not suffered a concussion in the last six-months; and (iv) were free of any neuromuscular or musculoskeletal disorders that affected the lower limb.
Cognitive performance was determined through a neurocognitive testing battery. Reaction time and performance accuracy were assessed across different tests measuring varying cognitive parameters: (i) the Deary Liewald test (i.e. simple reaction time); (ii) two-back task (i.e reaction time, accuracy); (iii) sport-specific decision-making task (i.e. reaction time, accuracy); (iv) three-back task (i.e reaction time, accuracy); (v) one-card learning task (i.e reaction time, accuracy); (vi) one-back task (i.e reaction time, accuracy); and, (vii) the Deary Liewald four-choice reaction time task (i.e. choice reaction time, accuracy). The sport-specific decision-

making task was created for this study to include a neurocognitive assessment with greater specificity to Australian-rules football. For all neurocognitive tasks, average reaction time for correct responses and response accuracy (%) were calculated.

Biomechanical analyses involved participants performing an unanticipated sport-specific side-stepping manoeuvre in response to a life-sized video portraying an opposition player completing an attacking action. The side-stepping manoeuvre of interest (i.e. 45° side-step) was randomised within a set of three sport-specific movements. Additional movements included a straight-line run and a 180° change of direction. Approach speed was recorded and monitored by four photoelectric timing gates (Swift Performance, Wacol, Queensland, Australia). Trials were considered successful if: (i) participants reached a run-up speed of 3.5 to 4.5 $m \cdot s^{-1}$; (ii) the penultimate- and side-step foot was planted completely within the force plate boundaries; and (iii) participants performed the correct movement response.

Three-dimensional kinematics of the torso and lower limb were measured using a 17 camera (i.e. six Vero, 11 Vantage) Vicon MX motion analysis system (Vicon, Oxford Metrics Limited) sampling at 250Hz. Forty 14mm retro reflective markers were attached to designated landmarks or body locations. Twenty-four individual markers were used on landmarks on the torso and lower limbs, alongside four rigid clusters with four markers each placed on the thighs and shanks. Ground reaction forces (GRFs) were recorded using four 600x900m in-ground AMTI force-plate (Advanced Mechanical Technology Incorporated, Watertown, Massachusetts, USA) sampling at 1500Hz. Vertical GRF data exceeding a 20N threshold were used to identify foot contact periods during the cutting movement – with this time period extracted for subsequent analyses. Prior to completing the movement trials, a static calibration with the participant standing in a neutral position was performed to use in scaling a generic musculoskeletal model(Lai et al., 2017) of the torso and lower limbs. The musculoskeletal model provided by Lai et al was modified to include three degrees of freedom at the knee. Using OpenSim 4.4 (Delp et al., 2007), torque-driven simulations of the 45° side-step cutting task were generated. Low-pass fourth order Butterworth filters with cut-off frequencies of 18 and 50Hz were applied to the experimental marker and ground reaction force data, respectively. The individually scaled musculoskeletal model, and experimental marker and ground reaction force data were used in optimal control simulations (Nitschke et al., 2023) to estimate torso and lower limb joint angles and torques via OpenSim Moco (Dembia et al., 2020). Three-dimensional knee joint moments were extracted from the optimal control solutions and were used in SPM1D regression models (Pataky, 2012) to identify potential relationships with neurocognitive performance metrics. The weight acceptance phase was used as the region of interest to compare knee joint moments over the cutting movement. The first 40% of the stance phase was used as the region of interest for weight acceptance as this captured the traditional characteristics of the weight acceptance phase (i.e. the early peaks observed in knee joint moments). A Sidak correction was applied to an alpha level of 0.05 to determine statistical significance.

RESULTS: No statistically significant relationships between cognitive metrics (see Table 1) and three-dimensional knee joint moments during unanticipated side-step cutting were found.

Table 1: Reaction time for correct response (m/s) and accuracy (%) for neurocognitive tests.

Neurocognitive Test	Reaction Time (mean ± STD) (m/s)	Accuracy (%)
1. Simple Reaction Time	281.22 ± 32.90	N/A
2. One-Back Task	959.63 ± 317.97	97.74 ± 4.20
3. Sport-Specific Decision-Making Task	-16.43 ± 80.49	97.33 ± 2.06
4. Four Choice Reaction Time	443.35 ± 48.54	92.50 ± 10.00
5. Two-Back Task	1494.76 ± 707.45	84.33 ± 11.12
6. One Card Learning	1389.96 ± 471.80	82.14 ± 5.60
7. Three-Back Task	1849.25 ± 1219.61	81.64 ± 5.65

DISCUSSION: AFLW ACL injuries frequently occur when performing defensive reactive side-step cuts (Rolley et al., 2023). This study aimed to explore the relationship between neurocognition and biomechanical performance of a side-step cutting manoeuvre. Our hypothesis was not supported, with no statistically significant relationships found between any neurocognitive metrics and knee loads.

The relationship between neurocognition and lower limb injury risk is a novel area of research. Our findings, however, contradicts the small body of research performed in this space. Early research found athletes who sustained non-contact ACL injuries had poorer cognitive function (e.g. reaction time) compared to uninjured athletes (Swanik et al., 2007). More recent research has then tried to identify the mechanistic link between cognitive function and ACL injury risk, with conflicting results (Almonroeder, 2017; Shibata et al., 2018). In one study, participants with a slower reaction time demonstrated higher peak vertical ground reaction forces during side-step cutting compared to a fast reaction time group (Almonroeder, 2017). In contrast, Shibata and colleagues (2018) found no differences in knee joint angles and moments when performing an unanticipated side-step cut between low and high cognitive performers. The variable findings across the literature and the current study may be explained by the different neurocognitive metrics, athletic population and side-step cutting manoeuvres used. This variability may therefore explain how these relationships may be specific to the population examined, task performed, and neurocognitive metric tested.

Another possible explanation for the lack of statistically significant relationships in the present study is that neurocognition may be more closely related to biomechanical performance over ACL injury risk. It is plausible that athletes with faster reaction times produce faster side-step cuts. Side-step cuts performed at faster speeds are desirable from a performance perspective, however could subsequently induce greater ACL loading and strain (Fox, 2018). As the current study had an ACL injury risk focus, only cognitive metrics to 3D knee loads (i.e. given their association to ACL load and strain) relationships were investigated. Future research however could investigate relationships between cognitive function and performance-related metrics (e.g. cutting speed, stance time, impulse) to determine whether a stronger relationship exists.

To enhance ecological validity in the laboratory, the use of a life-sized video stimulus of an attacking player was used in the present study. Previous research that observed potentially hazardous lower limb characteristics when performing a reactive side-step cut used a light stimulus to trigger specific movement tasks (Dempsey et al., 2009). Specifically, increased knee abduction and internal rotation moments during early weight acceptance were observed in unanticipated versus anticipated conditions (Dempsey et al., 2009). In contrast, participants in the present study typically demonstrated minimal or no knee abduction and internal rotation moment peak early in the cutting stance. We hypothesise that the life-sized video stimulus used in this study may not have achieved the desired effect of replicating the increased cognitive demand placed on players during a match when performing unanticipated side-steps. A practical implication from this study therefore, to closer replicate potentially hazardous situations experienced in a competitive match, laboratory environments must strive to replicate higher cognitive demands.

The desirable knee joint torque results of the present study indicates that ‘safe’ lower limb postures were employed during the unanticipated side-step cutting task. This finding contradicts previous research with knee loads and forces associated with increased ACL loading and strain consistently found during unanticipated side-stepping (Dempsey et al., 2009). Cognitively demanding stimuli is known to significantly impact lower limb biomechanics, with greater cognitive demand resulting in elevated knee loads (Lee et al., 2013). Incorporating dual-tasking to increase cognitive demand has been used in previous investigations of side-stepping biomechanics (Almonroeder et al., 2019). For example, when required to carry a basketball and execute a pass, female basketball players exhibited characteristics associated with increased ACL loading and strain (i.e. reduced knee flexion, increased knee abduction) when performing an unanticipated side-step task (Almonroeder et al., 2019). Although the videos used in the present study provided a more sport-specific stimuli, the simplistic nature of these were potentially ineffective in increasing the cognitive demand required to replicate those in an AFLW match when ACL injuries occur. Examining side-step cutting in more complex scenarios with higher cognitive loads (i.e. greater number of players, dual tasking) may incur more hazardous knee loading states that yield better insights to the relationship between neurocognition and ACL injury risk during side-step cutting.

CONCLUSION: This study found no statistically significant relationships between neurocognitive performance metrics and knee loads during unanticipated side-stepping. To gain greater understanding of the relationship between neurocognition and side-step cutting biomechanics, future research should include cognitive parameters not explored in this study. Additionally, increased consideration to ensuring sufficient cognitive demand is created in the testing environment is needed (e.g. dual-tasking).

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