A COMPARISON OF VARIABILITY IN GROUND REACTION FORCE AND KNEE ANGLE PATTERNS BETWEEN MALE AND FEMALE ATHLETES

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The purpose of the present study was to compare the variability of movement and force production in males and females during a diagonal reaction task. Male (n=8) and female (n=8) subjects performed an unanticipated diagonal side cut task eight times with a 90s rest interval between trials. Variability of dominant limb knee angle and ground reaction forces were calculated for each subject over the eight trials. No significant differences were reported between genders for variability in any of the four parameters. This indicates that the variability of sagittal plane knee movement and ground reaction force patterns is not to be related to the increased incidence of anterior cruciate ligament injury in females.

KEY WORDS: Variability, Anterior Cruciate Ligament, Gender, Side cut

INTRODUCTION: Females are reported to be two to eight times more likely to sustain an anterior cruciate ligament (ACL) rupture than their male counterparts (Arendt and Dick, 1995). Despite the abundance of research in this area, there has been no definitive cause reported for the increased injury rate in females. Recent research (Pollard et al., 2005) has, however, reported that males demonstrate higher levels of movement variability in comparison to females, during a side cut task. This increased movement variability has been linked with a reduction in proneness to injuries such as ACL injury (Hamill et al., 1999; James et al., 2000; Mc Lean et al., 2004; Pollard et al., 2005). This variability-injury hypothesis states that increased variability may allow individuals to adapt to environmental perturbations experienced in dynamic sporting tasks, whereas individuals with reduced variability may have limited adaptation and increased incidence of injury (Hamill et al., 1999). Increased variability may provide a broader distribution of loads and allow a longer adaptation time, therefore reducing or slowing the ill-effects of repeated loading (James et al., 2000)

There is a need to further investigate this association between gender, variability and injury. The analysis of lower limb loading patterns would provide a new insight into the variability-injury hypothesis. This was undertaken in this investigation with the quantification of variability in ground reaction force (GRF) in the vertical (Fz), anterior-posterior (Fy) and medio-lateral planes (Fx) and variability in knee angle displacement patterns. It was hypothesised that females would demonstrate less variable force and movement patterns compared to males during an unanticipated side cut task.

METHODS: Subjects included eight male (age 21 ± 1 yrs; height 1.79 ± 0.06 m; mass 73.82 ± 13.47 kg) and eight female (age 20 ± 1 yrs; height 1.66 ± 0.1 m; mass 65.50 ± 6.94 kg) collegiate basketball and hockey players, with equal gender distribution between sports. Subjects were required to perform a diagonal side cut task to an unanticipated direction (left or right) at a 45° angle followed by running to a marker 2.5 m away as shown in Figure 1. Each subject began in an athletic ready position 0.4 m behind the force platform. The subject was then prompted by a green light to jump forward landing on both feet (dominant leg on the force platform) while following a directional cue (0.3 s after the green light) which indicated the direction of the cut. Practice trials were provided, to allow full familiarisation with the testing procedure. Variability was quantified for knee angle, Fx, Fy and Fz of the dominant leg for each subject.

Data Collection: A five-camera high-speed motion analysis system (Hawk; Motion Analysis Corp., Santa Rosa, CA) recording at 200Hz was synchronised with an AMTI single force platform system (1000 Hz) for kinematic and kinetic data collection, respectively. Three retro-reflective markers were secured on lateral malleolus, lateral femoral epicondoyle, and greater trochanter of the dominant leg for each subject for 3D kinematic data collection. Subjects performed 12 trials of the side cut task, eight of which involved a push off from the dominant leg and were utilised for analysis. A rest period of 90 s was provided between trials. Kinematic data was filtered using a Butterworth filter at 15 Hz (Winter, 1990). Vertical GRF (>10N) data were used to define the stance phase (Cowley et al., 2006). All kinematic and kinetic data were cropped accordingly and normalised to 1001 points. Kinetic data were normalised to body weight (expressed as percentage of body weight or %BW)

Data Analysis: Variability in all parameters was quantified for each subject by calculating standard deviation values around the mean ensemble curve (of eight trials) for each of the 1001 data points. The average of these 1001 standard deviation values provided a variability score for each parameter. Gender differences were assessed by parametric independent *t*-tests and non-parametric Mann-Whitney U test when data was not normally distributed. Statistical significance was set at alpha (α) < 0.05. Cohen's *d* values were reported as a measure of effect size, where 0.2, 0.5 and 0.8 represent a small moderate and large effect, respectively (Cohen, 1990).

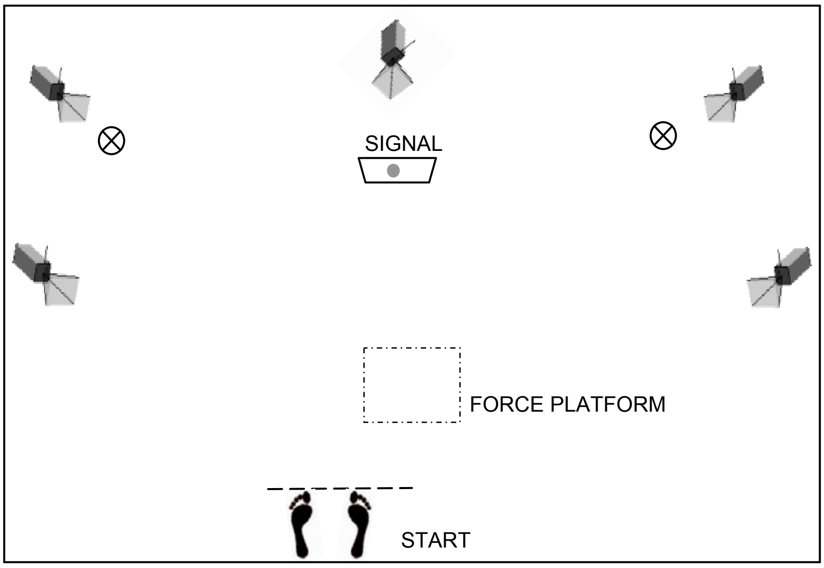

Figure 1 Experimental Set-Up

RESULTS: Variability scores for all parameters are presented in Table 1. No significant differences were found between males and females with regard to the variability of the knee angle or normalised GRF during the side cut.

Table 1 Average movement variability for each variable

Variable	Males	Females	Difference	Effect size	*p*-value
Knee Angle (°)	7.4° ±1.4	7.1° ± 1.4	0.3°	0.21	0.616
Fx (% BW)	7% ± 2	6% ± 2	1%	0.48	0.320
Fy (% BW)	7% ± 2	6% ± 1	1%	0.58	0.273
Fz (% BW)	18% ± 7	14% ± 5	3%	0.54	0.442

Figure 2 illustrates the pattern of variability for all 4 parameters. An increase in variability pattern for both genders can be seen in the GRF variability patterns (a, b, c) during the first ~15% of the stance phase. Post hoc analysis showed that the average and peak variability for Fx, Fy and Fz presented by the males during this initial phase was not significantly greater than the females, however larger effect sizes were found (Fx, Fy Fz effect sizes for average variability = 0.63, 0.73, and 0.83, while effect sizes for peak variability = 0.22, 0.53, and 0.75)

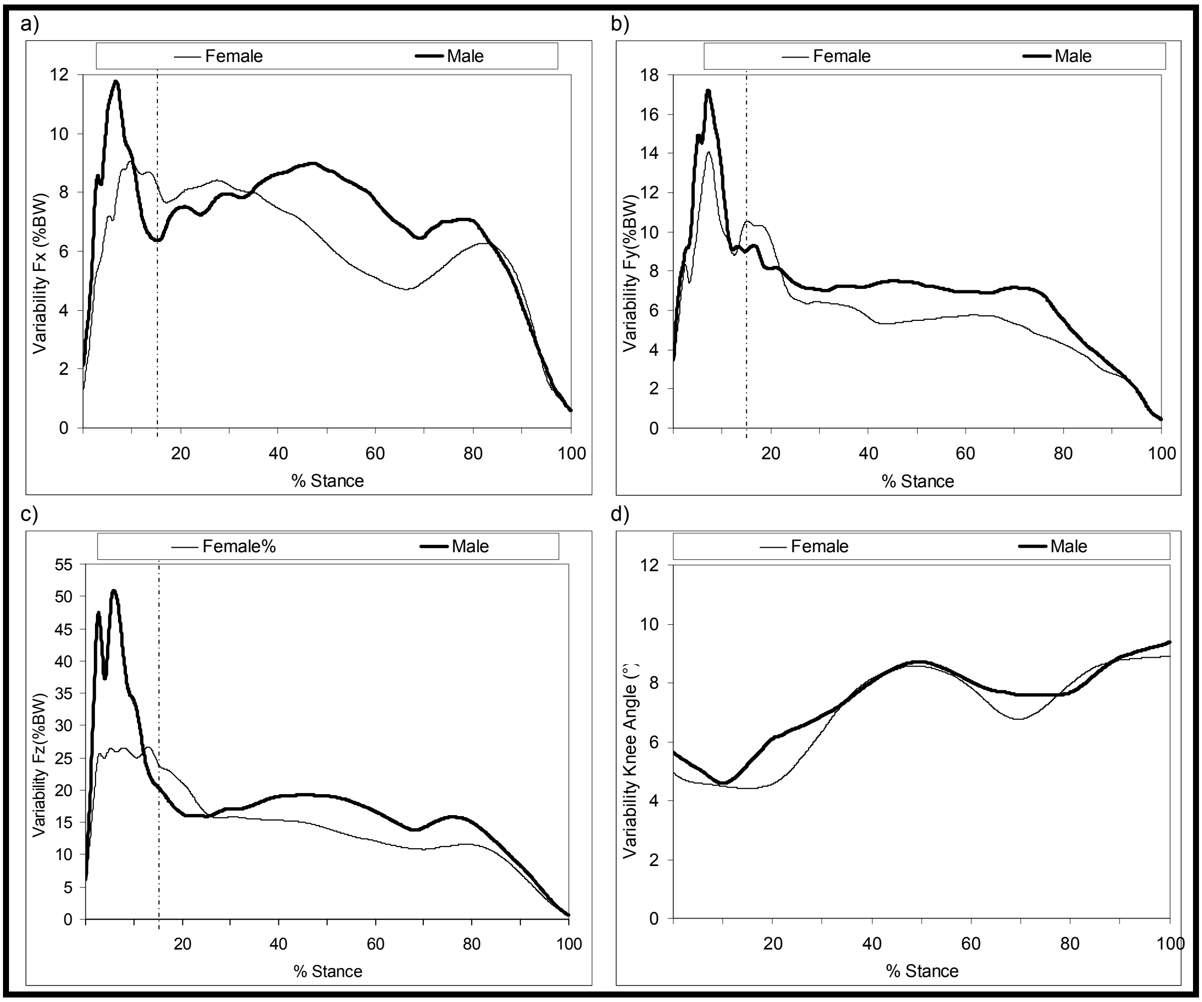

Figure 2: Standard deviation curves indicating mean variability within each gender for each parameter across the stance phase

DISCUSSION: The purpose of the present study was to compare variability for movement and force production in males and females during a diagonal reaction task. The variability in movement and force production patterns was not shown to differ significantly between males and females, and the hypothesis that females would be less variable was not supported.

The gender similarities do not support the proposed link between decreased variability in females and increased risk of ACL injury in accordance with the variability-injury hypothesis (Hamill et al., 1999; Pollard et al., 2005). The lack of differences in variability between genders also disagrees with the gender differences presented by Pollard et al. (2005) for intra-limb coupling variability. When this study is considered alongside the work of Pollard et al. (2005) it indicates similar variability in the resultant forces applied to the ground between genders, despite greater variability in the coordination of lower limbs in males. This implies that the higher movement coordination variability seen in males is somehow counterbalanced between limbs to result in more repeatable GRF profiles.

Although no statistically significant differences in variability were recorded, the effect sizes of differences did indicate moderate-large effects of gender. The effect sizes were particularly large for the first 15% of the stance phase. This is especially relevant in the case of ACL injury as the mechanism for an ACL injury is reported to occur just after foot contact during the first 20% of the stance phase (Boden, 2000). The higher levels of variability in male GRF patterns during the initial 15% of stance could depict a broader distribution of loads through the joints of the lower limb. Based on the large effect sizes, it is possible that future studies on a larger cohort of subjects would show this increased variability in males to be statistically significant. The reduction of inter-subject variability by controlling for exit velocity (running velocity when leaving the force plate) would assist in increasing the sensitivity of future research in this area. This future research is required to further investigate the role of movement variability in the gender imbalance of ACL injury risk.

CONCLUSION: No statistically significant gender differences were recorded in the variability of GRF or sagittal knee angle pattern data during an unanticipated side cut task. This indicates that despite previously reported increased variability in male lower limb coordination patterns, the resultant GRFs produced may not exhibit these same gender-related differences. Further research is necessary to investigate the relationship between variability in movement kinematics, coordination and GRFs and ACL injury risk with a view to the development of appropriate preventative training programmes.

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Acknowledgement

The authors would like to thank the following for their contribution to the data collection process: Brian Canty, Caroline Walsh, Derina Bourke, Eoin Kerin, Sinead Bruton, and Thomas Twomey. The Irish Research Council for Engineering and Science are also acknowledged for the funding provided which supported this work.