GENDER DIFFERENCES IN GROUND REACTION FORCES DURING RUNNING AND AGILITY-TYPE MOTIONS

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Foot and gait characteristics are different between genders. The purpose of this study was to determine if gender has an effect on ground reaction force characteristics during running and agility-type motions. Twenty-two apparently healthy female (73.8±8.4kg; 1.74 ±0.06 m) and seven male (73.5 ±5.3 kg; 1.68 ±0.02 m) current or recently graduated NCAA Division III athletes voluntarily participated in this study. Subjects wore a volleyball shoe while performing four different actions: running, cutting, shuffling, and back cutting. Three 2x4 repeated measures ANOVAs ($\alpha<0.05$) were used to determine if there were significant differences between gender and the agility-type motions for vertical force, medial/lateral force, and contact time. Significant interaction effects were observed in the vertical ($p=0.005$), medial/lateral ($p=0.046$), and contact time ($p=0.026$).

KEY WORDS: cutting, shuffling, lower body kinetics.

INTRODUCTION: Foot and gait characteristics are different between genders (Ferber, Davis & Williams, 2003; Ford, Myer, Toms & Hewett, 2005). In running, females are observed to have more hip frontal plane negative work than males, which increases eccentric demand on hip adductors (Ferber et al., 2003; Jacobs et al., 2004). When adding an agility motion, i.e. cutting, females also exhibit greater knee inversion/eversion range of motion and knee abduction angles (Ford et al., 2005). Females also generate energy through different mechanisms than males. Because males have greater muscle mass, they are able to generate more immediate velocity while females use body momentum to maximize their strength (Barfield, Kirkendall & Yu, 2002). Another study found that women perform cutting maneuvers with less flexion in their plant knee (James, Sizer, Starch, Lockhart & Slauterbeck, 2007). Less flexion may be a result of neuromuscular delay in firing of the protective muscles while cutting (Huston & Wojtys, 1996; Cowley et al., 2006). The implication that females execute the loading phase of their motions at higher velocities than males coupled with a steeper knee angle while planting and delayed neuromuscular control could increase injury risk in females. The purpose of this study was to determine if gender has an effect on ground reaction force characteristics during running and agility motions.

METHODS: Twenty-two apparently healthy female (73.8±8.4 kg; 1.74±0.06 m) and seven male (73.5±5.3 kg; 1.68±0.02 m) current or recently graduated NCAA Division III athletes voluntarily participated in this study. Apparently healthy was defined as having no leg injury or repercussion from injury within the past year and is currently active in their respective sport with full capabilities.

Before starting trials, subjects were asked to warm-up on a stationary bike for five minutes at a self-selected workload. Subjects were provided with a pair of volleyball shoes to wear while performing four different actions: running, cutting, shuffling, and back cutting. All subjects utilized the same pair of shoes. In running, subjects were asked to sprint a total of 16m, hitting the foce plate (8m) with their right foot. In cutting, the subjects were asked to sprint toward the force plate at a 45° angle, land on the force plate with their plant leg, and exit at a 90° angle by pivoting and running in that direction (Figure 1). In shuffling, the subjects were asked run straight toward the force plate, land with their plant leg, and exit at a 90° angle by shuffling (Figure 2). In the back cut, subjects were asked to run straight toward the force plate, land with their plant leg, and transition into a shuffle in the back left direction (Figure 3). A trial was successful if the subject landed their plant foot completely on the force plate and was able to generate the change in direction with that leg. For all subjects, the right leg was used as the plant leg. The number of trials per maneuver was dependent on

when the subject successfully landed on the force plate. Each movement was done while crossing a force plate (AMTI 1000; 600 Hz) Data was collected in SIMI on Motion (v6.2).

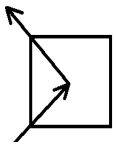

Figure 1: **Cutting**

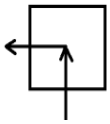

Figure 2: **Shuffling**

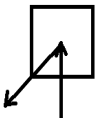

Figure 3: BackCut

Three 2x4 Repeated Measures ANOVAs ($\alpha < 0.05$) were used to determine if there were significant differences between gender and the agility motions for peak vertical and medial/lateral forces and contact time on the force plate.

RESULTS: Interaction effects between gender and the agility motions in vertical force, medial/lateral force and contact time are depicted in Figures 4-6. In all, a significant interaction effect was observed (Vertical-p=0.005; Medial/Lateral-p=0.046; Contact Time-p=0.026) (Table 1). However, consistent differences between gender were not found in the vertical (p=0.220) and medial/lateral (p=0.972) peak forces across the movements. Females exhibited similar peak vertical forces in all movements (1.77-1.97 Body Weight Unit [BWU]), while males exhibited the highest vertical force in the run (2.49 BWU) and lowest in the back cut (1.68 BWU) (Figure 4). Females generated the highest medial/lateral force in the cut (0.55 BWU), while males generated the highest force in the shuffle (0.73 BWU) (Figure 5). Both genders generated the lowest medial/lateral forces during the run (Female-0.27 BWU; Male-0.20 BWU). Females had significantly increased contact time (p=0.001) (Figure 6).

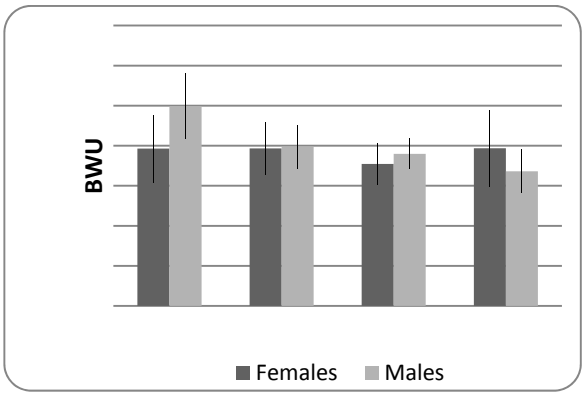

Figure 4: Mean Peak Vertical Forces

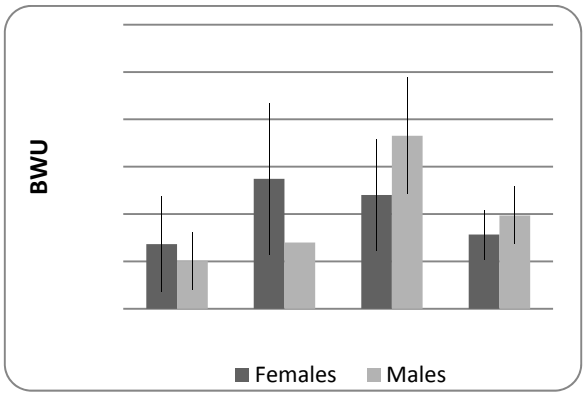

Figure 5: Mean Peak Medial/Lateral Forces

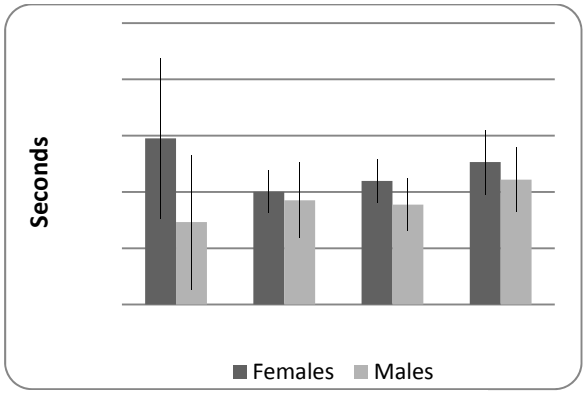

Figure 6: Mean Contact Time

Table 1: Statistical results for Vertical Force, Medial/Lateral Force, and Contact Time.

	p-value		p-value		p-value
Vertical		*Medial/Lateral*		*Contact Time*	
Gender	0.220	Gender	0.972	Gender	0.001
Movement	0.002	Movement	0.000	Movement	0.204
Interaction	0.005	Interaction	0.046	Interaction	0.026

DISCUSSION: Although kinematic lower body differences between genders have been documented (Ferber et al., 2003; Ford et al., 2005; James et al., 2007), gender-related force differences have yet to be established. This study found that ground reaction forces in both the vertical and medial/lateral directions presented no consistent differences between males and females. However, there were significant interaction effects occurring between gender and the agility movements (Table 1).

Peak vertical force in females remained constant through the different movements (Figure 4). This suggests that females approached the plate with identical velocity regardless of the motion being performed. Males, however, saw a decrease in vertical force, which corresponded with the severity of the change in direction of the ensuing movement (i.e. straight running had a greater vertical force than back cut). This could suggest that technique had an influence on the force generated.

The mechanisms through which ground reaction forces are generated seem to originate from a collection of various attributes. It has been noted that attributes such as footwear, joint angles, neuromuscular performance, and technique play a role in generating ground reaction forces (Luethi, Frederick, Hawes & Nigg, 1986; Huston & Wojtys, 1996; Ferber et al., 2003; James et al., 2007). The current study did not look at lower body kinematics; only the ground reaction forces of the plant foot. Therefore, male and female differences may have occurred, but were not measured. James et al. (2007) concluded that male and female athletes execute running and cutting differently. Females tend to achieve velocity and plant with a greater knee angle than males (James et al., 2007). Huston & Wojtys (1996) concluded that neuromuscular performance was different in females, causing females to fire hamstring muscles later than the males. When planting to perform an agility motion, the neuromuscular delay increases the risk of injury and reduces maximal performance of the motion. These trends could have occurred in this study. With a straighter plant leg, more force could have been transferred into the plant foot, increasing the ground reaction forces. This phenomenon could also explain the lower medial/lateral forces produced by the females when breaking out of the shuffle and back cut. It should be noted that males exceeded the gain on the force plate in the medial/lateral direction during the cutting motion, thus resulting in a low value. It was observed that females did not make as sharp a cut as the males did on many of the trials.

Future research should focus on developing a protocol to assess technique differences between genders and determine which factors, and to what degree each factor, has on ground reaction forces. Ford et al. (2005) concluded that although male and female athletes completed identical cuts, females exhibited dynamic motion that enhances ACL injury rates. If this is the case, the body may be compensating in different areas to achieve analogous ground reaction forces to remain competitive in sport-based actions, while stressing other components of the lower body kinematic system.

CONCLUSION: Ground reaction forces were not different between genders. However, males and females reacted differently to the agility-type motions.

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