GENDER DIFFERENCES IN CHANGE OF DIRECTION MANEUVERS WITH LONG AXIS ROTATION: A PRELIMINARY INVESTIGATION

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Females seem to have a greater predisposition to knee injuries than males (Harmon & Ireland, 2000). One extrinsic factor may be the cutting technique in a turn with long axis rotation, a movement that leaves an individual prone to knee injury. Thirty-six male and twenty female college athletes performed maximal effort changes in direction at 90 and 180 degrees. Different vertical and shear ground reaction forces were found between genders. When comparing data by gender and condition differences were found between the 90° and 180° turns for all variables. More important, gender and condition interaction effects were found. Females exhibited greater relative vertical and anteroposterior braking forces with increased long axis rotation. Gender differences in ground reaction forces may suggest differences in technique which may be associated with increased injury risk.

KEY WORDS: ACL, cutting, GRF, gender.

INTRODUCTION: Many sports and training activities require a rapid change in direction, or cutting maneuver, while running with maximum effort. Andrews et al. (1977) describe this motion as the most hazardous dynamic situation for ligaments in the knee. Interestingly, resulting injuries do not occur equally among sexes. Specifically, anterior cruciate ligament (ACL) injuries occur three to five times more frequently in female athletes. The majority of these injuries are non-contact, resulting from a change in direction (Arendt & Dick, 1995). The high occurrence of ACL injury in women has been associated with intrinsic and extrinsic factors (Di Brezzo & Oliver, 2000; Harmon and Ireland, 2000). Intrinsic factors include joint laxity, hormonal influences, limb alignment, notch dimensions, and ligament size (Di Brezzo & Oliver, 2000; Harmon & Ireland, 2000; Horton & Hall, 1989; Woodland & Francis, 1992). Extrinsic factors are those related to the type of sport, the environmental conditions, the conditioning of the athlete, and the equipment used. These factors also include conditioning, experience, skill, strength, muscle recruitment patterns, and landing techniques (Beck & Wildermuth, 1985; Chappell et al., 2002; Collins, 1987; Di Brezzo & Oliver, 2000; Harmon & Ireland, 2000). Although gender differences in such factors as ligament laxity, hormone levels, biomechanical alignment, and muscle activation during landing have been shown,
there is little support connecting those differences to ACL rupture (Harmon & Ireland, 2000). Perhaps it is a combination of intrinsic and extrinsic factors that influence the higher occurrence of female injury. By noting differences in cutting techniques between genders of similar athletic experience and training, perhaps more variables may be found that influence the higher injury rate. Cutting techniques, however, change according to the degree of direction change and long axis rotation of the body. Schot, Dart, & Schuh (1995) found significant differences in braking and propelling forces when comparing a 90 degree turn to a 45 degree turn with long axis rotation. However, they found no differences in results between genders. In order to fully understand the differences between genders in cutting techniques, a wide range of direction changes should be studied that include higher risk, extreme changes in direction. The purpose of this study was to examine a 180 degree turn in comparison to a 90 degree turn for potential differences between conditions and genders.

METHOD: Subjects were 36 male and 20 female college athletes currently participating in a sports activity that requires radical changes in direction (see Table 1 for descriptive information). These sports included soccer, American football, basketball, tennis, fast-pitch softball, and baseball. No subject had recent history (greater than one year since full recovery) of lower extremity injury. Subjects were instructed to warm up and stretch before recording data. They then performed two different changes of direction tasks in random order. One was a 180° turn with long axis rotation in a subject preferred direction and one was a 90° turn to the left with long axis rotation. All subjects were familiar with these types of maneuvers from sport specific motions and drills. Each subject ran with maximum effort to a force plate 20 m from the starting point. When reaching the plate, each performed a change in direction with long axis rotation similar to the technique used in a common line drill exercise. Finally, they ran with maximum effort back to the starting point. Trials were acceptable if the pivot foot was completely on the force plate and was the only foot in contact with the ground during the change in direction. Three repetitions were performed consecutively, with the middle repetition used for analysis. Each subject ran with maximum effort along a rectangular 15m x 5m track. The subject first ran a 5m length, then turned 90 degrees and ran 15m to the force plate to turn 90 degrees again. Finally, they ran 5m, turned, and ran 15 m back to the starting point. The trial was done once per subject. Trials were acceptable if the pivot (outside) foot landed completely on the force plate and was the only foot in contact with the ground as the subject turned sharply at 90 degrees. Force data were measured with a portable Kistler force plate (model 9286AA) with a sampling rate of 200 Hz. Kistler Bioware software was us ed for force calculation and presentation.

Data Reduction: For the three orthogonal forces, the x direction was perpendicular to the runner's approach, the y was parallel to the runner's approach, and the z direction was vertical. All forces were evaluated relative to body weight (BW) and subject body weight was measured with the force plate. Data were processed by selecting the peak braking and propulsive forces for each maneuver. The forces were vertical braking, vertical propulsive, anteroposterior braking (y-direction), mediolateral propulsive (x-direction) for the 90° maneuver, and anteroposterior propulsive (y-direction) for the 180° maneuver. The xdirection propulsive force was for the 90° maneuver because it represented the new direction of motion. Subjects were removed from the analysis if they only had single vertical impulses for a trial. Data from three males and four females were eliminated for this reason, thereby leaving data from 33 males and 16 females for statistical analysis. Initially a t-test was used to compare males and females for all variables. Based on these results, a follow up 2x2 gender by condition repeated measures analysis of variance was performed to compare variables across conditions. An alpha level of 0.05 was used for all analyses.

RESULTS: Table 2 contains average relative force data for the 90° and 180° maneuvers by gender. Significant differences between genders were found for five of the eight variables. Males had significantly greater propulsive vertical and mediolateral relative forces for the 90° turn. Females had significantly greater braking and propulsive anteroposterior relative forces for the 180° turn and significantly greater braking vertical relative forces for the 180° turn. For the follow up ANOVA all variables were significantly different between 90° and 180° conditions. The same statistic yielded significant interaction effects between gender and condition for both vertical and anteroposterior braking forces and vertical propulsive forces, but not for the shear propulsive forces. See figures 1-4 for a representation of this data.

Table 1. Subject information, M (SD)

Variable	Males (n=33)	Females (n=17)
Height (m)	1.80 (0.052)	1.66 (0.079)
Weight (N)	792 (95.2)	666 (96.9)
Age (years)	19.8 (1.33)	20.4 (1.22)

Note: N = 49.

Table 2. Relative forces by gender, M (SD)

Variable	Males	Females
90° vertical braking	2.15 (0.69)	1.91 (0.69)
180° vertical braking *	1.56 (0.34)	1.83 (0.42)
90° vertical propulsive *	1.79 (0.33)	1.56 (0.40)
180° vertical propulsive	1.28 (0.25)	1.38 (0.13)
90° anteroposterior braking	0.83 (0.46)	0.89 (0.44)
180° anteroposterior braking *	0.83 (0.31)	1.13 (0.39)
90° mediolateral propulsive *	0.86 (0.23)	0.71 (.015)
180° anteroposterior propulsive *	0.57 (0.23)	0.75 (0.25)

Note: N = 49 (16 females, 33 males), * denotes a significant difference ($p < 0.05$), units: BW.

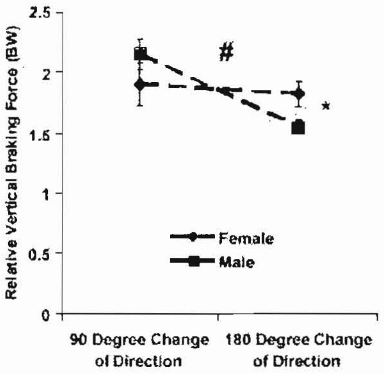

Figure 1. Relative vertical braking force for each chage of direction maneuver (M± SE). The # indicates a significant difference between 90° and 180° turns and the * indicates a significant interaction between gender and maneuver ($p<0.05$).

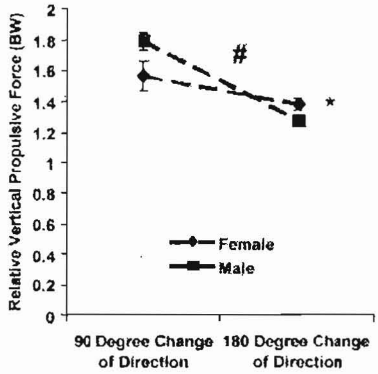

Figure 2. Relative vertical propulsive force for each change of direction maneuver (M± SE). The # indicates a significant difference between 90° and 180° turns and the * indicates a significant interaction between gender and maneuver ($p<0.05$).

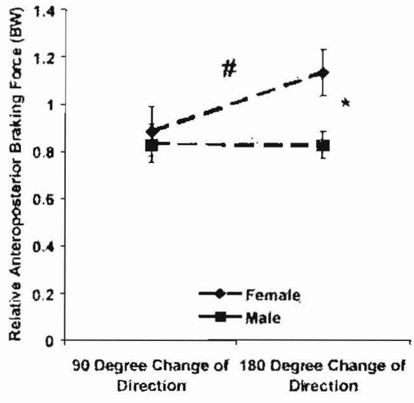

Figure 3. Relative anteroposterior braking force for each change of direction maneuver (M± SE). The # indicates a significant difference between 90° and 180° turns and the * indicates a significant interaction between gender and maneuver ($p<0.05$)

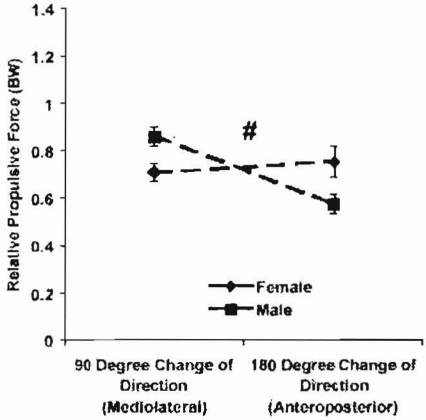

Figure 4. Relative anteroposterior propulsive force for each change of direction maneuver (M± SE). The # indicates a significant difference between 90° and 180° turns ($p<0.05$), no interaction was present.

DISCUSSION: Similar to Schot et al (1995), differences were found for the vertical and shear braking and propulsive forces in different cutting maneuvers. All relative forces seemed to decrease for the 180° turn, except for the anteroposterior braking force, which increased for that condition. Based on the interaction effects, males and females seemed to adopt different ground reaction force strategies when performing these cutting maneuvers. It seems females use greater braking relative force for turns as the amount of long-axis rotation involved increases. Further, males seem to decrease vertical propulsive forces in greater amounts as long axis rotation increases. The combination of greater braking and propulsive forces together may compound the injury risk to females. If females use greater relative force in turns that require more rotation, then an increased risk of injury to the ligaments in the knee may be likely due to the greater ligament laxity inherent in their knee (Di Brezzo & Oliver, 2000). The exact nature of the technique differences will require additional kinematic and kinetic evaluation to determine whether other technique differences, such as body position during the turn, deceleration of the center of mass, and penultimate step forces, are similar to differences in ground reaction forces during the turns. Moreover, it is not known how other extrinsic or intrinsic factors, such as sport or Q-angle, will influence comparisons of change of direction maneuvers.

CONCLUSION: This study has shed light on another possible extrinsic variable to explain the higher tendency for knee injuries in females. Some gender differences in ground reaction forces may exist in change of direction maneuvers. The differences seem to be related to the type of maneuver performed, where increased long-axis rotation increases the anteroposterior and vertical braking forces of females, but not males. Additionally, the approach to vertical propulsive forces also seems be unfavorable to the females. Technique differences between genders will need further examination to better understand this issue. Training of proper cutting techniques that decrease the relative force used by the planting leg may help. Increased caution may be warranted with females (especially untrained ones) to decrease the potentially increased injury risk from larger relative forces.

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