LANDING KINEMATICS, KINETICS AND EMG IN MALE AND FEMALE ATHLETES AND NON-ATHLETES: IMPLICATIONS FOR ACL INJURY RISK

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Female athletes are more likely to sustain an ACL injury than male athletes. The purpose was to investigate variables that have been identified as ACL risk factors during a landing task to determine differences among male and female athletes and non-athletes (N = 100). Variables included knee angle at contact, maximum knee angle, time (contact to max angle), VGRF, and muscle activation. Male non-athletes bent the knees significantly more after contact than male athletes. Male athletes landed with significantly more force per body weight than male non-athletes or female athletes and male non-athletes landed with significantly more force than female non-athletes. No other significant differences were observed. The authors concluded that the high rate of ACL injury among female athletes cannot be explained by the landing strategy employed in a jump.

KEY WORDS: ACL, landing, knee angle, GRF, EMG.

INTRODUCTION: Anterior cruciate ligament (ACL) injuries are not uncommon in sport, but the startling fact that females are far more likely to sustain an ACL injury than males has initiated research into the causes of the dramatic increase. Sudden movements such as cutting, changing directions or landing from a jumping skill have been regarded as the main causes for a majority of ACL injuries (Moeller & Lamb, 1997). Seventy-five percent are non-contact injuries that occur when the knee is extended. The quadriceps exerts a significant anterior translational force on the tibia which stresses the ACL. When the knee is bent, the quadriceps exerts less anterior translational force on the tibia, decreasing the ACL stress. Huston, Vibert, Ashton-Miller and Wojtys (2001) found that when landing from a mild or moderate drop, females chose to land with greater knee extension than their male counterparts. These findings were substantiated by Salci, Kentel, Heycan, Akin and Korkusuz (2004), who also found that females have reduced hip flexion during landing which causes high quadriceps' compensatory knee extensor torques. When this effect is combined with a large ground reaction force, it may excessively accelerate the tibia anteriorly beneath the femur and increase the chances of ACL injuries. However, Fagenbaum & Darling, 2003 actually reported females land with greater knee flexion than males.

Females have also been reported to land with amplified vertical ground reaction force (VGRF) than males during landing tasks. When compared with males, females exhibit less angular displacement during landing. This reduces the time to maximum knee flexion which results in a more abrupt absorption of the impact forces of landing (Salci, 2004). It has been estimated that for every degree of increased extension an increase of 1% can be seen in ground reaction force (Huston, 2001). Again, conflicting results exist. Lephart, Ferris, Riemann, Myers, & Fu (2002) found no significant gender differences in ground reaction force during landing.

Neuromuscular differences have also been sited as risk factors for ACL injury. When examining lower limb muscle synchrony during landing, Cowling and Steele (2001) found that gender did not alter the landing kinematics. However, males showed a delay in hamstring activation during the drop-landing task. The authors suggested that the better synchrony displayed by males was more protective of the ACL than the less synchronous semimembranosus activity displayed by females.

The purpose of the current study was to investigate variables that have been identified as potential ACL risk factors during a landing task to determine any differences among male and female athletes and non-athletes. Variables of interest included knee joint angle at contact, maximum knee joint angle, time (contact to maximum angle), VGRF, and muscle activation onset for three muscles.

METHOD: Forty-eight healthy non-athletes (23 male, 25 female) and 52 age matched (18-25 y) healthy student-athletes (25 male, 27 female) volunteered to participate. Athletes were recruited from varsity intercollegiate teams (soccer, football, softball, volleyball, basketball, tennis, and track). All participants indicated no history of ligament injury in their dominant knee and were instructed to refrain from physical activity for three hours prior to testing.
Using a 28 cm. high box, each participant performed a two foot take-off jump and landed on the dominant leg on the AMTI force platform 40 cm away (Figure 1). The single leg landing required the participants to balance without using their non-dominant foot for support. Three trials were recorded.


Figure 1. Landing test.

A video camera operating at 60 Hz was placed 4 m perpendicular to the sagittal plane of motion. Reflective markers were placed on the shoulder, hip, knee and ankle joints. Video trials were digitized using Peak Motus ® 8.1.0 to determine knee flexion angle at initial contact, maximum knee flexion angle and time from contact to maximum knee flexion angle.
Raw EMG data were collected using pre-amplified surface mounted silver-silver chloride bipolar electrodes. Vastus Medialis (VM), Biceps Femoris (BF), and Gastrocnemius (GC) EMG signals were sampled at 600 Hz and synchronized with the kinematic and force data. Muscle activation was visually established via the EMG recordings. Negative values indicated activation before landing and positive values indicated activation after landing.

RESULTS:

Table 1. Group Means

	Initial Contact not sig	**Maximum sig**	**Time not sig**	**VGRF/ bw sig**	**VM activation not sig**	**BF activation not sig**	**GC activation not sig**
Female Non (SD)	173.1° (4.5)	126.3° (8.3)	0.167 ms (0.038)	1.165 (0.165)	-93.3 ms (46.8)	-125.0 ms (44.0)	-125.9 ms (50.9)
Male Non (SD)	171.6° (4.5)	122.4° (5.8)	0.194 ms (0.034)	1.199 (0.206)	-87.8 ms (38.5)	-119.5 ms (76.7)	-145.35 ms (59.9)
Female Ath (SD)	172.6° (4.1)	125.0° (6.8)	0.187 ms (0.053)	1.112 (0.161)	-92.8 ms (56.9)	-147.2 ms (53.5)	-138.6 ms (52.2)
Male Ath (SD)	172.4° (4.7)	126.7° (7.9)	0.189 ms (0.059)	1.325 (0.215)	-85.8 ms (48.6)	-139.7 ms (93.9)	-166.3 ms (76.6)

No significant differences were found in knee joint angle at initial contact, in time from initial contact to maximum knee joint angle after contact or in any of the EMG activation times. The athlete by gender interaction was significant for maximum knee joint angle after contact (P=0.04). Further analyses revealed male non-athletes bent the knees significantly more after contact than male athletes (P=0.04).

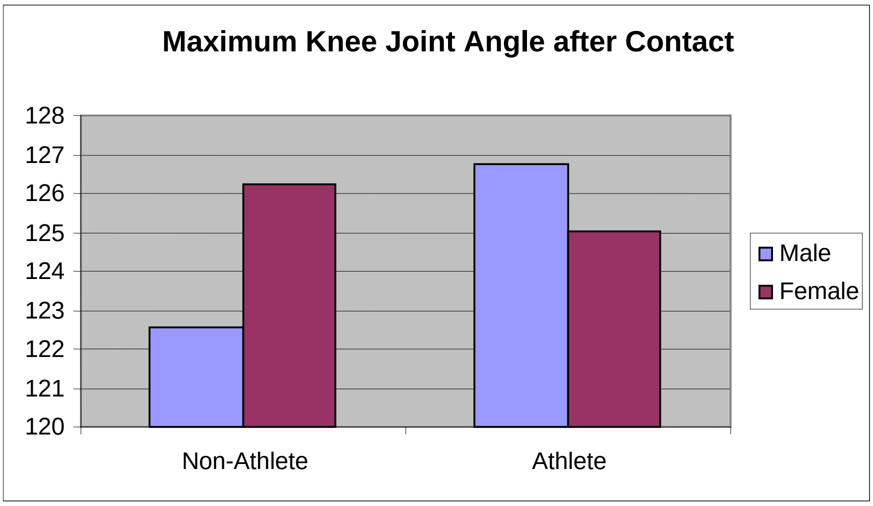

Figure 2. Maximum knee joint angle in degrees (smaller number = more flexion)

The athlete by gender interaction was significant for VGRF/body weight (P=0.02). Further analyses revealed male athletes landed with significantly more force per body weight than male non-athletes (P<0.01) or female athletes (P<0.01) and male non-athletes landed with significantly more force than female non-athletes (P<0.01).

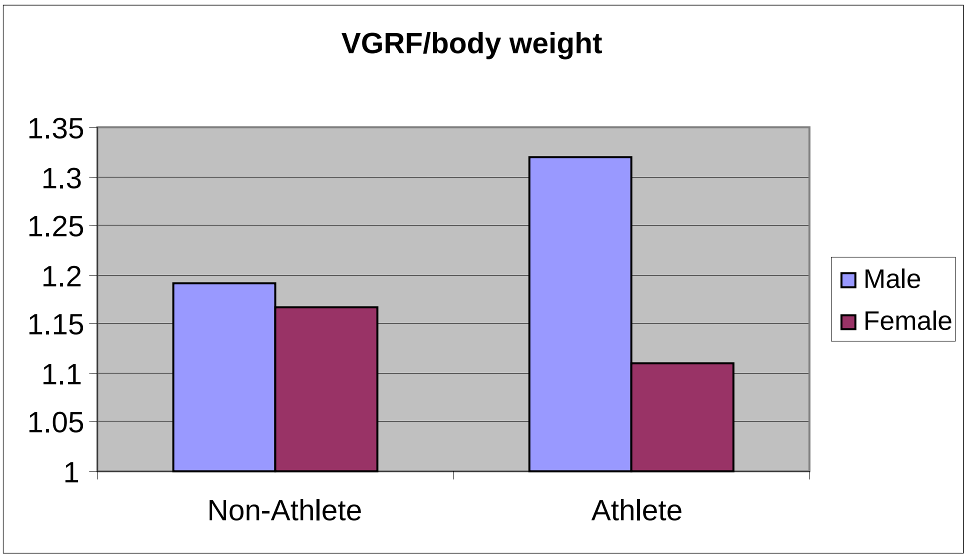

Figure 3. VGRF normalized to body weight

DISCUSSION: No significant differences were found in knee joint angle at initial contact, supporting the results reported by Cowling (2001) and Chung-Hwi, So-Yeon & Sang-Heon (2004). Huston (2001) found significant gender differences at 40 and 60 cm, but not at 20 cm. Likewise, Salci (2004) found significant differences during a 40 cm landing with males landing in a more flexed knee posture than females. No significant differences were found in the time from initial contact to maximum (full) flexion failing to support Lephart (2002).
Among the four groups, male non-athletes displayed the greatest maximum knee flexion angles, significantly more than their athletic counterparts. There was no gender difference among the athletes, supporting the results of Huston (2001) and failing to support Lephart (2002) or Chung-Hwi (2004). Fagenbaum (2003) actually reported females landed with greater flexion at contact and achieved greater maximum flexion than males.

Vertical ground reaction force per body weight was significantly higher for male athletes than female athletes. The male athletes also exhibited the smallest maximum knee flexion. Generally it is expected that greater flexion will help absorb some of the impact force. Lephart (2002) found no significant gender difference, whereas Salci (2004) found males land with significantly less force per body weight.
All three muscles activated before initial contact, supporting the results of Cowling (2001). However, Cowling (2001) also found that males significantly delayed onset of the semimembranosus activation relative to females. The current study did not find any significant difference related to muscle activation onset. However, semimembranosus activation was not reported.
Based on the results of the current study, the authors concluded that the high incidence of ACL injuries in female athletes cannot be explained by differences in landing techniques. The sample size (N = 100) in the current study was at least twice the size of the largest sample in the literature compared above, lending support for this conclusion.

CONCLUSION: The authors concluded that the high rate of ACL injury among female athletes cannot be explained by the landing strategy employed in a jump. Based on previous studies, the authors recommend that coaches, athletes and non-athletes focus on strengthening the knee musculature as the most effective strategy to avoid injury (Medrano & Smith, 2003).

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