GENDER DIFFERENCES IN VERTICAL GROUND REACTION FORCE ATTENUATION DURING STOP-JUMP TASK

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The purpose of this study was to examine gender differences in peak vertical ground reaction forces (VGRF) and rate of loading (ROL) during stop-jump task. Forty four healthy students from kinesiology department (22 males and 22 females) volunteered in this study. Subjects performed stop-jump task on the force plate and Peak VGRF and ROL calculated using GRF data. To evaluate differences in peak VGRF and ROL between two groups Multivariate analysis of Variance at the P level of 0.05 used. Differences in ROL was significant between two groups ($F_{1,41}$=5.63, Wilks' Lambda = 0.37, P≤0.05) but differences in Peak VGRF was not significant ($F_{1,42}$ = 2.82, P >0.05). Based on our results, Increase in ROL during impact of landing can increase knee loading and consequently create higher incidence of ACL injuries among females compare to males.

KEY WORDS: gender differences, rate of loading, vertical ground reaction force

INTRODUCTION:

Females have been found to have a higher incidence of anterior cruciate ligament (ACL) injuries (4-8 times higher) compared to males participating in the same sports with similar rules and playing conditions (Boden & Dean, 2000; Griffin & Albohm, 2000). it is reported that 70 percent of these injuries occur during landing from a jump (Boden & Dean, 2000; Griffin & Albohm, 2000). Landing is a commonly practiced activity in many sports, and the knee has been described as the primary shock absorber during landing from a jump (Decker & torry, 2003). Landing is more stressful for the ACL than the take off phase (Chappell & yu, 2002). Females experience increase proximal tibia anterior shear forces during landing compared to males (Chappell & yu, 2002). Control of moments experienced during landing in lower extremity joints presents a significant challenge to the neuromuscular system prior to and during contact.

Because the knee, especially knee ligamentous injuries occur more frequently in female athletes than males, investigators have compared the differences between genders to study this disparity. The reviews of these studies are categorized into kinematics, Ground Reaction Forces (GRF), and joint kinetics. Hewett and Stroupe (1996) have shown that there are no significant differences in GRF when comparing recreational male and female athletes in landing from 60 cm, whereas Lephart and Ferris (2002) have shown that trained females have lower peak landing forces when compared to untrained males. However, there is a discrepancy in the results of different studies when examining the gender differences in ACL injuries.

Three main theories have been proposed to explain the incidence of female ACL injury. The ligament dominance theory suggests that the lower extremity muscles of females do not effectively absorb the impact of landing, resulting in knee valgus and anterior translation of the tibia, which causes increased loading of the ACL (Ford & Meyer, 2003). Observational video analysis studies (Griffin & Albohm, 2000) have provided support to this theory by revealing that the common position at the time of ACL injury in athletes is knee valgus. The quadriceps dominance theory suggests that females tend to rely on their quadriceps more than hamstrings when compared to males (Hewett & Stroupe, 1996; Ford & Meyer, 2003). The quadriceps dominance theory is supported by cadaveric and simulation studies that have found the quadriceps to be capable of producing sufficient force eccentrically to tear the ACL (Boden & Dean, 2000; Griffin & Albohm, 2000). The straight knee landing theory suggest that females exhibit less knee flexion at the time of impact that may lead to ACL injury either by hyperextension or by anterior tibial translation (Decker & Torry, 2003; Huston

& Vibert, 2001) due to the ineffectiveness of the hamstring to provide a posterior force when the knee is close to full extension.
Imposed load on kinetic chain structures during athletic activities can increase biological strength of body component likes ligaments, tendons, muscles, bones and joint cartilages, but with increase in rate of loading (ROL), it is possible to see micro and macro degeneration in anatomical structures (Nigg & Bobbert, 1990). It is supposed that there is high correlation between landing forces and lower extremity injuries (Dufek & Gillig, 1991); therefore the purpose of this study was to examine gender differences in peak VGRF and ROL during jump-landing task.

METHODS:
Data collection: forty four healthy subjects (22 males, mass 75.89±3.22 kg, height 177.84±4.52 Cm, age 24±3 years, and 22 females, mass 64.00±2.85 kg, height 164.00±5.58 Cm, and age 22±2 years) volunteered in this study. Subjects accomplished maximum vertical jump and 50 % of this value calculated. We set a marker over the force plate that displayed 50% of high jump of subjects. Then we set another marker 70 Cm before the force plate and we wanted subjects to jump from the back of this sign with two legs, and after touching the marker over the force plate, landing on center of force plate with preferred leg. We allowed each subject sufficient practice trials to become comfortable with the landing procedure and to determine the preferred landing leg. The preferred landing leg was defined as the leg the subject chose to land on most frequently during the first 3 practice trials. The landing data are collected on force plate at a sampling rate of 200 Hz. A fast Fourier transformation analysis indicates that the raw analog signals of a single-leg stance and the jump-stabilization maneuver are below 30 Hz. Therefore, a minimum sampling rate of 60 Hz would be sufficient for collecting data. The peak GRF during landing is a key component to calculate the ROL. A sampling rate that is too low might miss the peak force and consequently cause the ROL to be miscalculated. Therefore, we selected 200 Hz to provide a sampling rate six times greater than the raw analog-signal under study.
We determined VGRF as the peak vertical force (N) recorded during landing, normalized for body weight (N), and expressed as a multiple of body weight (BW). We measured time to peak force as the time from initial ground contact to the peak vertical force during landing. ROL was calculated as the normalized peak vertical force divided by the time to peak force.

$$ROL = \left[\frac{peakFz(N)/BW(N)}{t} \right] = \frac{BW}{s}$$

Data Analysis: We used the Multivariate analysis of variance (MANOVA) at the p level of 0.05 to compare peak VGRF and ROL between two groups of males and females.

RESULTS:
Significant differences seen in ROL between two groups of males and females ($F_{1,41}$=5.627, Wilks' Lambda = 0.372, P≤0.05), but the differences in peak VGRF was not significant between two groups ($F_{1,42}$ = 2.818, P > 0.05). It is presented the mean and standard deviation of peak VGRF and ROL for males and females in the table of 1, and the results of MANOVA presented in this table too. Mean force-time curve for males and females has presented in figure 1. Horizontal and vertical axis of the curve shown time period (s) and force changes (N) on force plate respectively. As it is seen in the figure 1, the mean of peak VGRF are adequate between two groups (peak VGRF = 28.57 N), but females reach to peak VGRF 20% faster than males (mean time to peak force is 0.075 and 0.055 for males and females respectively). This difference in time to peak force caused 15.85% increase in ROL between females and this difference is significant at p level of 0.05.

DISCUSSION:
The purpose of this study was to examine gender differences in peak VGRF and ROL during jump-landing task. With respect to the result of this study, increase the ROL in females can increase the knee ROL secondary, and subsequently increase the probability of knee

injuries, especially ACL in females than males. Probable reason for increase of ROL in females can be attributed to differences in landing pattern and neuromuscular control.
Past research has reported that females had significantly less knee flexion at contact to matched males athletes (Lephart & Ferris, 2002; Decker & Torry, 2003; Huston & Vibert, 2001). This situation decreases their ability to attenuation forces imposed to their body (Griffin & Albohm, 2000). Researchers suggest that the more extension in joints during touching the toes with ground, the less time to dissipate the impact and the more impact of GRF and ROL imposed to their body (Griffin & Albohm, 2000; Hewett & Stroupe, 1996; Lephart & Ferris, 2002). This increase in ROL can impose stress on the soft tissues of the knee, especially ACL and injure this structure.

Table 1: mean and Std. peak VGRF and ROL of males and females and results of MANOVA, * significant at p level of 0.05

Parameter	group	Mean ± Std.	$F_{1,42}$	P
	Males	29.80 ± 4.30		
Peak VGRF (N)	Females	28.40 ± 4.90	2.82	0.10
	Males	403.20 ± 98.50		
ROL (N/S)	Females	479.10 ± 113.30	5.63	0.02 *

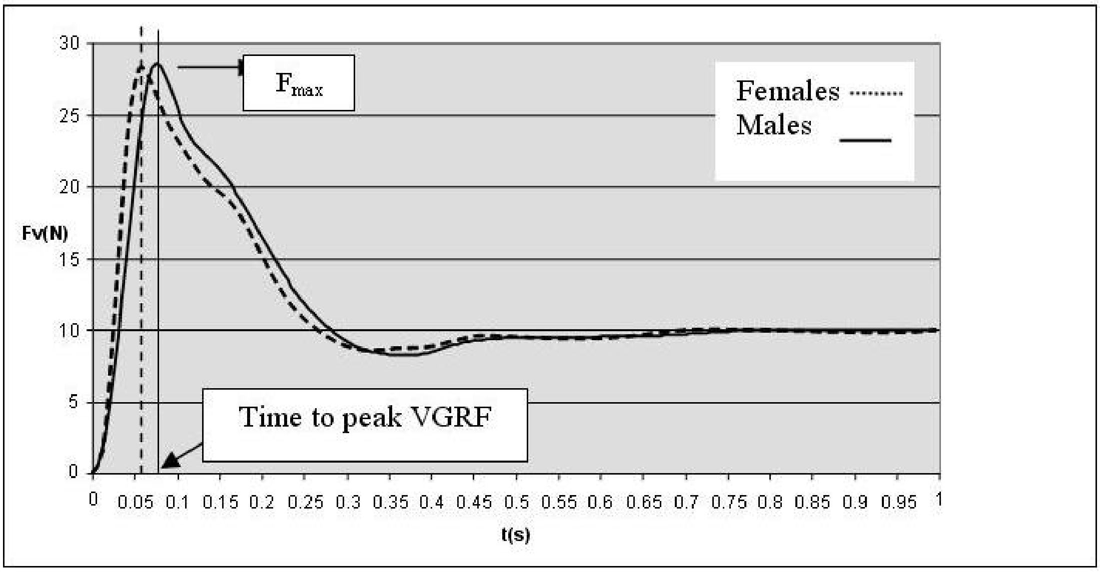

Figure1: force-time curve for males and females during landing

The second reason for more ROL in females than males can be attributed to neuromuscular control. It is suggested that the impact of GRF imposed to the body during activities can be dissipated by eccentric activity of the lower extremities muscles (Coventry & O'Conner, 2006). It is possible that females have less neuromuscular response than males to dissipate the load during landing. The term "neuromuscular factors" refers to unconscious activation of dynamic restraints surrounding a joint in response to sensory stimuli (Griffin & Albohm, 2000). The neuromuscular system prepares for the impact by activating muscles prior to contact. After contact, the muscle tendon units must generate sufficient force to stabilize the joints, control joint flexion, and reduce total body momentum (Hewett & Stroupe, 1996). Previous researchers demonstrated that females may benefit from neuromuscular training programs that are designed to decrease GRF (Hewett & Stroupe, 1996). Neuromuscular training can increase proprioception and muscle strength in females and secondary their ability to absorb the shock of GRF and ROL. It is possible that females' muscles have reduced ability to absorb the impact during contact with ground.

CONCLUSION:

ROL significantly differences between males and females participated in this study. It is appear that one reason for more non-contact ACL injuries in females than males can be in the result of high ROL imposed to their lower extremities during landing. To reduce the risk of knee injuries, it is better to focus on neuromuscular training and landing strategies in females' athletes.

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