DIFFERENCES BETWEEN GENDERS DURING PLYOMETRIC JUMPS

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The purpose of this study was to compare men's and women's landing kinetic and kinematic parameters during plyometric jumps. 22 females and 7 males performed jumps from three heights while being videoed in the sagittal and frontal planes of motion. Force data for the right foot were also recorded. Maximal hip, trunk, knee, ankle and valgus angles were recorded, as well as peak vertical, medial/lateral forces and total contact time. Women land in a more upright posture with significantly more valgus than men. Peak vertical forces did not differ between the sexes, but mean maximal medial/lateral forces were higher in the females. Box height was not a factor in kinematic results, but the medium box showed significantly lower medial/lateral forces in both sexes. The men spent significantly less time in contact with the ground.

KEY WORDS: vertical force, medial/lateral force, valgus.

INTRODUCTION: Women's athletic shoes are known to be constructed from the same parameters as men's shoes, but on a smaller scale. Wunderlich and Cavanaugh (2001) found that women tend to have higher arches, shallower first toe, shorter ankle length and length of the outside ball of the foot, as well as smaller instep circumference. It is also well known that biomechanical differences exist between genders for different movements, even in walking (Kerrigan, Todd, & Della Croce, 1998). In sports and other activities, it has been shown that women tend to have a more upright posture (Boden, Griffen, & Garrett, 2000). This upright position increases ground reaction forces (GRFs) and maximizes forces on the anterior cruciate ligament (ACL) of the knee (Vibert, Huston & Ashton-Miller, 1999). Additionally, it has been demonstrated that female athletes exhibit more knee abduction (valgus) than males when landing (Ford, Myer, & Hewett, 2003). Knee valgus, internal hip rotation, and tibial rotation during landing have been shown to be loading pattern factors that may contribute to ACL strain. A combination of knee valgus and internal rotation increases ACL strain more than either factor by itself (Shin, Chaudhari, & Andriacchi, 2011). Injuries to the ACL are frequent in non-contact activities such as jumping and reactive movement sports; and are 6 to 8 times more likely in females (Hughes, Watkins, & Owen, 2008; Benjaminse, Gokeler, Fleisig, Sell, & Otten, 2011). A shoe that is constructed specifically for women, taking into account the differences in the sexes may help alleviate stresses placed on the knee during landing. First it is important to note if the differences between the sexes is consistent when one common shoe is worn, as the shoe itself may provide support and effect the results. The purpose of this study was to compare men's and women's landing kinetic and kinematic parameters during plyometric jumps.

METHODS: Twenty two apparently healthy females (73.8 ±8.4 kg, 1.74 ±0.06 m) and seven apparently healthy males (73.5 ±5.3 kg, 1.68 ±0.02 m) signed written consent forms from the University of Puget Sound internal review board before participating in this study. Subjects were current or recently graduated NCAA division III athletes familiar with plyometric jumping. Subjects completed all testing in one visit to the lab.

Before testing, subjects were asked to warm up for five minutes at a self selected pace on a stationary bike. Subjects performed plyometric jumps from three box heights (46 cm, 30.5 cm and 21.6 cm) while being filmed from both the front and side view. While being filmed the subjects stepped off the designated box, landed with both feet then immediately returned to a height of 46 cm. Subjects performed the jump from each box height one time. All jumps were completed as a single motion without hesitation.

Digital video files were recorded on the hard drive of the computer using SIMI on MOTION (v6.2) with JVC cameras collecting at 60 Hz. The subject was represented as points designed to capture pertinent angles and velocities of the body. From the side view, the left

elbow, shoulder, hip, knee, ankle, heel and toe were digitized (Figure 1). From this, ankle, knee and hip angles were calculated as relative angles. The trunk angle was calculated as an absolute angle to the y-axis (Figure 1). The view of the subject from the front yielded valgus angles (Figure 2). The valgus angle was measured as the relative angle from the hip to knee to ankle (Figure 2). Important parameters that were collected include: maximal valgus, maximal hip, knee, trunk

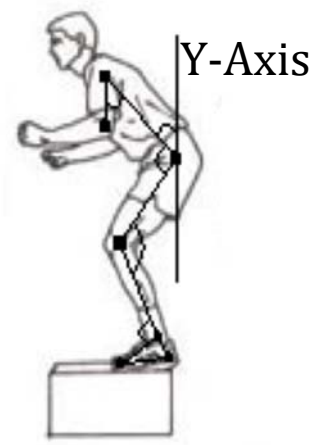

Figure 1: Sagittal kinematic view.

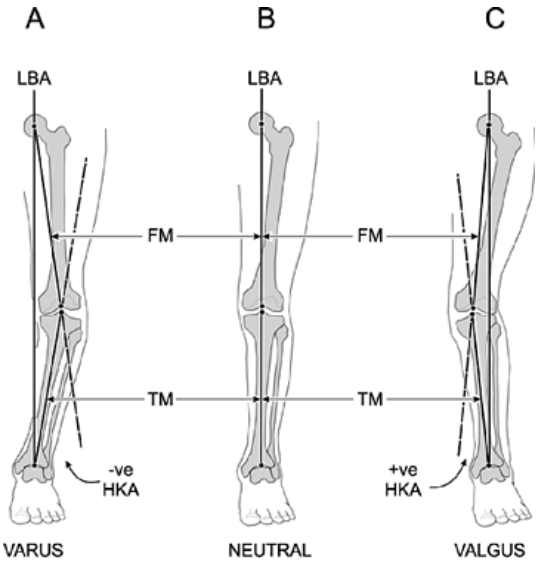

Figure 2: Frontal kinematic view.

Force data were simultaneously collected with an AMTI 1000 force platform collecting at 600 Hz. The subjects landed on the force plate with their right foot, while their left foot landed on level ground to the side of the plate. Maximal vertical forces, maximal medial/lateral forces and total time on the plate were recorded for each subject.
Repeated measures 2 (genders) by 3 (box heights) analyses variance ($\alpha<0.05$) were conducted with a Bonferroni correction factor for unequal groups. Scheffe post-hoc tests were used to indicate where differences occurred.

RESULTS: The kinematic data revealed that there were significant differences between genders in all angles measured except the ankle (Table 1). There were no significant differences between box heights or interaction between gender and box heights at any of the angles. The women were significantly more upright than the men as seen in less hip flexion, trunk forward lean and knee flexion. The ankle flexion showed a tendency for women to have less flexion than the men (p=0.057). The women exhibited a mean maximal 12°+/-7 of valgus, while the men were recorded with a mean maximal 7° ±-13 of varus**.** The women had significantly more mean maximal valgus than the men.

Table 1: Mean maximal flexion.

	Females Box Height			Males Box Height		
Variable	21.6 cm	30.5 cm	46.0 cm	21.6 cm	30.5 cm	46.0 cm
Valgus (°)	13 ±7	11 ±7	12 ±7	-8 ±12	-7 ±13	-7 ±11
Hip (°)	131 ±8	132 ±12	131 ±11	122 ±13	116 ±13	120 ±17
Trunk (°)	21 ±5	21 ±6	18 +/-6	25 ±8	28 ±7	25 ±10
Knee (°)	117 ±6	118 ±7	114 ±8	110 ±11	108 ±8	110 ±8
Ankle (°)	57 ±4	59 ±4	56 ±5	55 ±5	55 ±4	54 ±5

The kinetic data, as well as contact time can be found in Table 2. The mean maximal vertical force was not significantly different between genders or box heights, nor was the interaction between gender and box height significant. The mean maximal medial/lateral force was significantly higher for the females (0.40 ±0.27 BWU) than the males (0.25 ±0.19 BWU),

while both the low (0.42 ±0.32 BWU) and high (0.40 ±0.27 BWU) boxes revealed significantly higher forces than the medium box (0.22 ±08 BWU). The women spent significantly longer on the ground than the men, but no differences were noted between boxes or in the interaction effect.

Table 2
Mean Maximal Kinetic Data and Contact Time

	Females			Males		
	Box Height			Box Height		
Variable	21.6 cm	30.5 cm	46 cm	21.6 cm	30.5 cm	46 cm
Vertical Max Force (BWU)	1.91 ±0.44	2.15 ±0.34	2.01 ±0.50	2.00 ±0.41	2.10 ±0.67	2.29 ±0.53
Medial/Lateral Max Force (BWU)	0.55 ±0.36	0.23 ±0.09	0.45 ±0.24	0.22 ±0.07	0.19 ±0.07	0.32 ±0.11
Ground Contact Time (seconds)	0.47 ±0.20	0.35 ±0.06	0.51 ±0.19	0.33 ±0.11	0.30 ±0.08	0.32 ±0.12

DISCUSSION: As expected, the women in this study had a more upright posture than their male counterparts (Boden et al., 2000). The women had less maximal flexion in their knees, hips and less forward lean in their trunk than the men. Surprisingly the amount of flexion did not vary due to box height for either the men or women. Valgus angle also did not differ with box height, but was significantly more in the females. The females had mean maximal valgus angles of 12°, while the men had mean varus angles of 7° (Figure 2). This is a 20° difference in mean maximal valgus angle between the sexes. Ford et al. (2003) reported that women had significantly higher valgus angles in landing activities, which held true in this study. In a separate study Hughes, Watkins & Owen found that women had significantly more valgus in landing activities. This increased angle could result in higher stresses being placed on the ACL (Shin et al., 2011). The increase in valgus angle with the females was also evident in the mean maximal medial/lateral forces. The women on average had .15 BWU more in medial/lateral force than the men. While medial/lateral forces did decrease from the low box to the high box in the women and increase with the men, the lowest values were seen with the medium box for both sexes. It may be that the low box loads are incurred quickly and proper alignment cannot occur in the short period of time. Although the valgus angles were very similar in all three boxes for both sexes this did not directly affect the force values. According to the data in this study, although valgus angles remained relatively constant, the medial/lateral forces were lower with the 30.5 cm box. Further investigation of this finding is needed to determine why this might be occurring in both sexes.

Vibert et al. (1999) found that vertical forces were higher in females, while the current study did not find any significant differences in mean maximal vertical force. The women did have more upright posture and seemed to “stick“ the landing, yet the mean maximal vertical forces did not differ between the sexes. It may have been that the women’s peak vertical force was attributed to landing, while the men’s peak vertical force was attributed to pushing off, or propelling the body upward. The subjects were instructed to perform the jump as one fluid motion, but it may have been that the women landed more heavily and thus the maximal forces were seen in the landing phase. The men may have landed gently generating an upward force as their maximal value. This may be why the men had significantly less time on the ground than the women. The men may have been preparing for the jump before the landing. Hewett et al. (1996) have had success in training females to decrease vertical ground reaction forces by increasing hamstring torque. It may be that the female athletes in this study are exhibiting a protection mechanism limiting the forces through muscle activation. This may in turn lessen the forces felt by the ACL (Vibert et al., 1999).

A shoe design that takes into account the differences in landing techniques between the genders may help women avoid increased stress on the ACL. The amount of valgus and

increased mean maximal medial/lateral forces may be dampened with a slight medial post in womens' shoes.
A future study may want to investigate muscle emg values as they pertain to the corresponding force values. This may help determine the role of the muscles in peak vertical forces.

CONCLUSION: Women land in a more upright posture with increased valgus angles when compared to men. The women did not have higher mean maximal vertical values than the men, but they did have higher peak medial/lateral forces. The only value that changed with box height was the peak medial/lateral force, with the medium box height having the lowest mean/maximal values. The men had less time on the ground than the women.

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