Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Annals of Biological Research, 2011, 2 (6):226-232
(http://scholarsresearchlibrary.com/archive.html)

ISSN 0976-1233
CODEN (USA): ABRNBW

Gender differences in vertical ground reaction forces attenuation during stop-jump task

Ali Abbasi[1], Hossein Berenjeian Tabrizi[1], Hassan Sadeghi[2], Hajar Jahadian Sarvestani[1] and Kambiz Bagheri[3]

[1]Department of Physical Education & Sport Sciences, Faculty of Humanities, Kazerun Branch, Islamic Azad University, Kazerun, Iran
[2]Sports Academy, University Putra Malaysia
[3]Department of Immunology, Faculty of medicine, Kazerun Branch, Islamic Azad University, Kazerun, Iran

---

ABSTRACT

The purpose of this study was to examine gender differences in peak vertical Ground Reaction Force (VGRF) and Rate of Loading (ROL) during stop-jump task. Forty four healthy students 22 males (weight 75.89 ± 3.22 kg, height 177.84 ± 4.52 cm, age 24 ± 3 years) and 22 females (weight 64.17 ± 2.85 kg, height 164.20 ± 5.58 cm, age 22 ± 2 years,) from ki nesiology department volunteered in this study. Subjects performed stop-jump task on the force plate. Peak VGRF and ROL of subjects calculated using GRF data. To evaluate differences in peak VGRF and ROL between two groups Multivariate analysis of Variance (MANOVA) at the P level of 0.05 used. Significant differences seen between two groups for ROL ($F_{1, 41}$=5.627, Wilks' Lambda = 0.372, $P \leq 0.05$). ROL in females was 15.85 percent greater than males (479.10 ±113.30 for females and 403.20 ± 98.5 0 for males), but there was not any significant differences between two groups for peak VGRF ($F_{1, 42}$ = 2.818, $P > 0.05$). Based on our results,it seems thatincrease in female's ROL during impact of landing can increase her knee loading secondary, and consequently create higher incidence of knee injuries, especially ACL, among females compare to males. The probable reason for increase of ROL in females can be attributed to differences in their landing pattern or their neuromuscular controls.

Key words: Gender differences, Vertical Ground Reaction Force, Rate of Loading, Stop-jump task.

INTRODUCTION

Femaleshave been found to have a higher incidence of non-contact anterior cruciate ligament (ACL) injuries (4 - 8 times higher)compared to males participating in the same sports with similar rules and playing conditions[1, 2].It is reported that 70 percent of these injuries occur during landing from a jump [1, 2], and about 70 percent of this type of injury is occurred while landing [1].The Knee has been described as the primary shock absorber during landing, irrespective of gender [3], and it has been reported that knee encounters to intense injuriesduring landing [1, 2].Several factors have been postulated as contributing to non-contact ACL injuriesand subsequently to higher injury rate in females. These are environmental [2], ligamentous laxity [2, 4, 5], hormonal changes[2, 4],intercondylar notch width index [4, 5],shape of intercondylar notch [6],size of ACL [4, 7],lower extremity alignment [4], and large differences between the dominant and nondominant leg[8].However, the results of these studies are contradicting and no consensus exists as to whether one or a combination of these factors is responsible for ACL rupture.

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 [8]. Observational video analysis studies have provided support to this theory by revealing that the common position at the time of ACL injury in athletes is knee valgus[2]. The quadriceps dominance theory suggests that females tend to rely on their quadriceps more than hamstrings when compared to males [8, 9]. 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 [1, 2]. 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 due to the ineffectiveness of the hamstring to provide a posterior force when the knee is close to full extension[3, 10].

The biomechanical variables of landing are divided into three categories: kinematics, electromyography (EMG), and kinetics. The Kinematic variablesthat are related to landing injuries of the knee include the joint positions of the hip, knee, and foot, as griffin and colleagues (2000) reported that the most common mechanism of injury involves knee valgus and foot out-toeing while the knee is in a position of 20 - 30˚ of flexion[2].Kinetics reveals the ability of the athletes to absorb the impact of landing efficiently. The only kinetic variable of landing that has been reported in the literature is vertical ground reaction force (VGRF).Dufek and colleagues(1991) reported that the Ground Reaction Forces (GRF) during athletic activities can be as high as 15 times body weight[11]. The lower the VGRF the more optimal the landing strategy, while high VGRF can lead toknee injuries[11]. Hewett and colleagues(1996) also reported that a decrease in the peak landing forces is important in that it directly translates to a decrease in forces experienced at the joints of the lower extremity[9].

Gender differences in regards to VGRF during landing have been inadequately researched, and the results of these studies are contradictory. Some studies suggest that males and females land with similar normalized VGRF[8, 12], whereas other studies found that males land with greater normalized VGRF[9], or that females exhibit higher normalized VGRF during landing[13]. In a perspective study Hewett and colleagues (2005) reported that female athletes whounderwent ACL injuries,showed higher VGRF than athletes with no ACL injury history[14]. In a biomechanical study Hewett and colleagues (2005) also reported that females subjects who underwent a neuromuscular training program, effectively decreased their peak landing forces and suffered less ACL injuries than a control female group[9].The same findings are supported by another study where a group of young female gymnasts was able to decrease maximum ground reaction forces during landing by 50-63% after they received biofeedback training in order to land more softly[11]. However the results of previous studies on gender differences in VGRF are contradictory and we consider VGRF as an important variable in our study because of the significant evidence that links high VGRF to knee injury[9, 11].

Imposed load on kinetic chain structures during athletic activities can increase biological strength of body component likes ligaments, tendons, muscles, bone and joint cartilages. However, providing increase in ROL, it is possible to see micro and macro degeneration in anatomical structures [15]. There is no significant study which compared ROL between male and female during landing. Because of high percent of all injuries (approximately 70 %) that occur during jumping activities and the high rate of lower extremity injuries in these sports[11], we can suppose high correlation between landing forces and lower extremity injuries.therefore the purpose of this study was to examine gender differences in peak VGRF and ROL during jump-landing task.

MATERIALS AND METHODS

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. This research accomplished in the sport biomechanics laboratory of TarbiatMoallem University of Tehran and was approved by the university institutional review board. All participants signed an informed consent document approved by the Institution human subjects review board. Studies investigating landing biomechanics often employ two different landing protocols: one that requires subjects to land from absolute heights, and another in which landing heights are determined based on a percentage of the subject's maximum voluntary jump (MVJ). We used the landing protocol according to percentage of MVJ of participants in this study.

At the beginning In order to perform stop-jump protocol on force plate, 50% of maximum vertical jump of participants have been computed. The maximum vertical jump of participants has been assessed by Sargeant jumping device (SportsImports, Columbus, OH). Each participant has been asked to perform vertical jump three times and after recording, the average score of three jumps was considered as maximum vertical jump. The maximum vertical jump has been divided by twoand this digit was equal to the mark of 50% of participant's maximum vertical jump. There wasa scaled bar with arrow at one side of force plate, and the height ofarrow has been shown the 50% of maximum vertical jump. Thena spot has been marked on the floor 70 cm far from the center of force plate. The participants have been asked to jump with double leg behind the mark (70 cm) and after touching the arrow, get landed with one foot (dominant feet) at the center of force plate, and immediately after landing put his hands around pelvic, keep the head up and look at the forward, attemptingto keep his balance (figure 1).

Before performing the test, participants have been known about stop-jump movement protocol. The participants have been allowed to train several times stop-jump movement to feel convenient during landing, meanwhile we determined the subject's dominant leg.The dominant leg for landing has been determined by three primary jumps that participants have frequently done the stop-jump task. Peak VGRF and ROL during landing have been calculatedusingforce plate data. The peak VGRF was recorded as maximum vertical force (N) while landing that was normalized by divide to participant's body weight (N) and was declared as multiple of body weight (BW). Then the time of reaching to maximum force which is a time distance between first touch of foot to force plate and reaching to maximum vertical force during landing was calculated and named ROL[16]. The ROL was calculated by normalized maximum vertical force divide to time of reaching maximum force.

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

Figure 1: stop-jump protocol,before jumping, while jumping and landing

In order to compare peak VGRF and ROL between male and female, MANOVAat P-level of 0.05 has been.

RESULTS

Results of MANOVA has shown significant difference between male and female ($F_{1, 42}$= 5.627, P = 0.022) while peak VGRF and ROL were consider together. This difference was due to group differences at ROL, whilethere is no significant difference at peak VGRF between two groups($F_{1, 42}$= 2,818 and P=0.101). The mean and standard deviation at peak VGRF and ROL for both male and female and the results of MANOVAare presented at table 1. The female's mean peak VGRF is 4.5% less than male but this difference is not statistically significant. The mean time-force graph for males and females isshown at figure 2. The horizontal line is the exertion time of force on force plate (second) and vertical line is VGRF (Newton). As it can be seen at figure 2, peak VGRF in both genders are approximately equal but at reaching time to maximum force,females are reaching to peak VGRF 20 percent faster than males. This matter caused increased ROL in female by 15, 58% than male that this difference statistically is significant (P≤ 0, 05).

Table 1: Mean and standard deviation of peak VGRF and ROL in males and females and results of MANOVA

Parameter	group	Mean ± S.D	F	P-value
Peak VGRF (N)	Males	29.80 ± 4.31	2.818	0.101
	Females	27.45 ± 4.93		
ROL (N/ms)	Males	403.17 ± 98.53	5.627	0.022*
	Females	479.12 ± 113.33		

** Significant at P-level of 0.05*

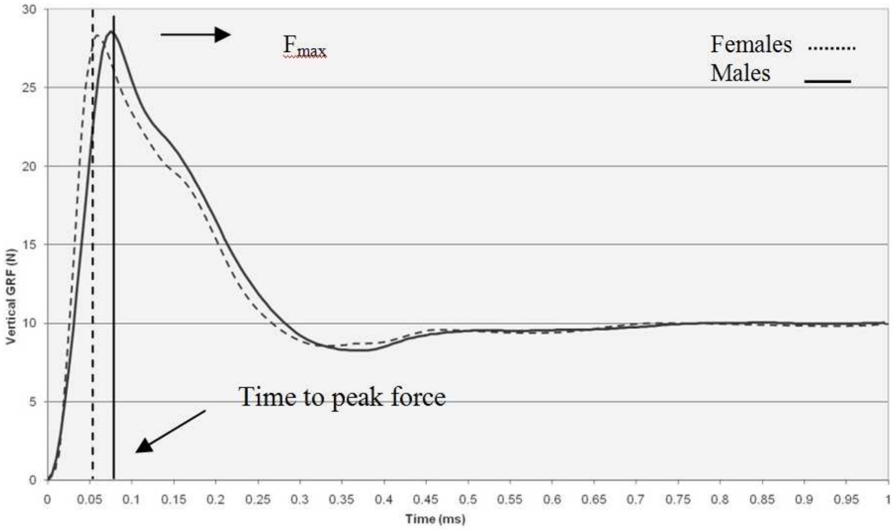

Figure 2: force-time graph during landing in females and males

DISCUSSION

The main purpose of present investigation was to examine gender differences in peak VGRF and ROL during stop-jump task. Regarding observed results, high ROLin female can increase secondary ROL in knee joint and in consequences it increase possibility of knee injuries in female rather than male, particularly ACL. The possible reason for high ROLobserved in female can be attributed to difference in landing pattern andalso difference of neuromuscular control between male and female[2-4, 17, 18]. It has been reported thatknee extensor muscles contribute to energy absorption alternatively during different landing conditions[19]. Decker and colleague (2003), and Zhang and colleagues (2000) as well have been reported that exerted force on lower extremity during landing can be modified by eccentric contraction of knee and hip extensors and ankle plantarflexors during flexion of knee and hip and also ankle dorsiflexion[3, 19]. These researchers have reported thatduring landing from height, knee joint extensors have been activated at the beginning and their eccentric actions results in modification of landing forces, and then hip extensors and ankle plantarflexors contraction help to decrease body acceleration while landing. Therefore, knee extensor muscles, and hip extensors as well as ankle plantarflexior musclesdescribed as primary and secondary shock absorption respectively[3, 19].It have emphasized in many investigations that VGRF could be manipulated by knee flexion, hip flexion and ankle plantarflexion [4], and it is assumed that a more erect (faster or/and more rigid) landing decreases forces modification capacity [17]. Studies have shown that females land more erect than males, which it is identified by lesser knee and hip flexion angles during first contact with ground [18], this action can decrease those capabilities fordistribution(absorption) of force on body [2]. Investigators suggest that the more extended knee angle during foot contact with ground, the less time to impact absorption,and therefore imposed impact of GRF and ROL on knee structure will be greater[2, 3]. This over loading can impose doubled pressure on soft tissues of knee, especially ACL and causes injury. There is a possibility that time reductionin reaching to peak VGRF and then increased ROL in female is due to landing with extended joints [1-4]. The secondary reason for high ROLin female can be attributed to difference in neuromuscular control between males and females. It was reported in previous investigations that imposed GRF impact duringdynamic activities can be modify through eccentric activities of lower extremity muscles [20]. There is a possibility that female have less neuromuscular response than males to modifyROL during landing. Before contact, neuromuscular system gets ready by muscle activation to impact absorption. After contact, muscle-tendon unit must generate enough force for joints stability, joint's flexion control and also to reduce whole body momentum[9]. It has been reported in previous studies that females can benefit from neuromuscular exercise training which planed to reduce GRF [9],because these kinds of trainings can enhance proprioception and muscle strength, and secondary they can enhance their ability to GRF shock absorption and ROL.In consequence, there is a possibility that female's muscles have less capability for impact absorption during contact with ground and it causes time reduction for absorption of GRF impact while ground contact, and finally it causes increased ROL among females compare to males.In theory, it is logical that females, who jump faster with less flexibility and less ability to modifyimposed force on lower extremity, potentially are in greaterrisk for serious knee and ACL injuries, there are not any significant differences in VGRF between males and females in this study, and it is possible it isbecause of jumping protocol used in this study. As it was explained in methodology, we used 50% of maximum participant jump height for executing jump-landing protocol, and this height was 27 cm for participants in average. The investigations that have found significant difference in VGRF between males and females mostly have been used jump task from stable height for instance 50, 60 and 100 cm. These heights areapproximately two to four times more than the height which was used in present investigation. Definitely landing from higher height can cause faster contact of body with ground that could have differentGRF. But more researches are required to identify relationship between ACL injury and GRF. Overall, it could be said that ROL was significantly different between males and females who participated in this study, and it seems one reason for increasing noncontact ACL injury in femalesthan males is in result of ROL imposed on their lower extremity during landing.

REFERENCES

[1]Boden, B.P., et al., *Orthopedics*, **2000**. 23(6): p. 573-578.
[2]Griffin, L.Y., et al., *Journal of the American Academy of Orthopaedic Surgeons*, **2000**. 8(3): p. 141-150.
[3]Decker, M.J., et al., *Clinical Biomechanics*, **2003**. 18(7): p. 662-669.

[4]Huston, L.J., M. Greenfield, and E.M. Wojtys, *Clinical orthopaedics and related research*, **2000**(372): p. 50-63.
[5]Uhorchak, J.M., et al., *The American Journal of Sports Medicine*, **2003**. 31(6): p. 831.
[6]Tillman, M.D., et al., *The Knee*, **2002**. 9(1): p. 41.
[7]Shelbourne, K.D., T.J. Davis, and T.E. Klootwyk, *American Journal of Sports Medicine*, **1998**. 26(3): p. 402.
[8]Ford, K.R., G.D. Myer, and T.E. Hewett, *Medicine & Science in Sports & Exercise*, **2003**. 35(10): p. 1745.
[9]Hewett, S.,et al, *American Journal of Sports Medicine*, **1996**. 24: p. 765–773.
[10]Huston, L.J., et al., *The American journal of knee surgery*, **2001**. 14(4): p. 215.
[11]Dufek, J.S., B.T. Bates, *Sports medicine (*Auckland, NZ), **1991**. 12(5): p. 326.
[12]Lephart, S.M., et al., *Clinical Orthopaedics & Related Research*, **2002**. 401: p. 162.
[13]Shultz, S., Carcia, C., Hargrave, M., and Docherty, C, *Journal of athletic training*, **2002**. 37(2): p. s-19.
[14]Hewett, T.E., et al., *American Journal of Sports Medicine*, **2005**. 33(4): p. 492.
[15]Nigg, B.M. and M. Bobbert, *Journal of Biomechanics*, **1990**. 23: p. 3.
[16]Hargrave, M.D., et al., *Journal of Athletic Training*, **2003**. 38(1): p. 18-23.
[17]Lephart, S.M., et al., *Clinical Orthopaedics & Related Research*, **2002**. 401: p. 162-169.
[18]Swartz, E.E., et al., *Journal of Athletic Training*, **2005**. 40(1): p. 9-14.
[19]Zhang, S.N., B.T. Bates, J.S. Dufek, *Medicine & Science in Sports & Exercise*, **2000**. 32(4): p. 812-819.
[20]McNitt-Gray, J., et al., *Journal of Biomechanics*, **2001**. 34(11): p. 1471-1482.