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The Peak Vertical Ground Reaction Forces Differences between Foot Types During Landing

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ABSTRACT: The aim of this study was to compare the peak Vertical Ground Reaction Forces (VGRF) between supinated, pronated, and normal feet during single leg drop landing. Thirty healthy male students from physical education & sport sciences department [mass 74.32 ± 6.50 kg, height 176.20 ± 5.43 cm, age 23 ± 2 years] participated in this study and assigned to one of three groups by navicular drop test (10 per groups) [pronated (≥10mm), neutral (5-9mm), or supinated (≤4mm)]. Participants performed single leg drop-landing on the force plate from the box with height of 0.30 m. Peak VGRF were calculated using GRF data. There were no significant differences in Peak VGRF between three groups ($F_{2, 27} = 0.510$, $P > 0.05$). These results suggest that foot types are not associated with specific lower extremity kinetics. Not differences in these parameters may be resulting of existence another factors influencing VGRF.
Keywords: Ground Reaction Force, Pronated foot, single leg drop-landing, supinated foot.

INTRODUCTION

Lower extremity injuries are common in sports and are caused by the interaction of modifiable and non-modifiable risk factors (Cameron, 2010). Modifiable and nonmodifiable risk factors that predispose individuals to injury and specifically to the anterior cruciate ligament (ACL) include: anatomical structure, neuromuscular response, hormonal, and environmental (Cameron, 2010). Conceptualizing modifiable and nonmodifiable risk factors enables clinicians and injury researchers to understand and propose evidence base injury prevention interventions (Cameron, 2010).

High rates of lower extremity injuries have been documented with ACL knee injuries recorded as one of the highest (Kellis & Kouvelioti, 2007; Renstrom, et al. 2008; Cameron, 2010). Noncontact ACL tears are prevalent in the U.S. (Hewett, Schultz, & Griffin, 2007). Sports medicine professionals have addressed the concern of noncontact ACL and lower extremity musculoskeletal injury risk, injury prevention, and management in a multi facet approach. A biomechanical approach provides quantifiable data on the force acting on the body that explain injury.
During ambulation and athletic performance, the body is subjected to great forces specifically from landing. Forces applied to the body are multidirectional resulting in forces in the vertical, horizontal (anterior/posterior), and from the side (medial/lateral direction. Ground reaction force (GRF) has been reported to be approximately three times a person's body weight during running and significantly higher from a vertical jump and landing (Devita & Skelly, 1992; Munro & Miller, 1987).

Studies on landing are of great importance to investigate and address injury prevention and treatment concerns of the lower extremity. Since the foot interfaces with the ground during dynamic activities such as gait, running and landing, structural changes may cause compensatory malalignment and mechanical deviations of the entire lower extremity (Williams et al., 2001). Therefore, studies on persons with abnormal foot structure could provide better insight into abnormalities in lower extremity mechanics. Lower extremity malalignments, especially in foot segment, can result in mechanical deviations that increase risk of injuries for athletes (Williams et al., 2001). Abnormal foot structure is also commonly implicated as a predisposing factor to injuries such as chondromalacia patella and shin splints (Williams et al., 2001; Hargrave et al., 2003). There are three broad classes of feet: neutrally aligned (the bisection of the posterior surface of the calcaneus is close to perpendicular to the ground and the arch is at a normal height), pronated foot or pes planus (the calcaneus is everted and the arch is low or absent) and supinated foot or pes cavus [the calcaneus is inverted and the arch is high] (Ledoux & Hillstrom, 2002).

Subotnick (1985) reported that 60% of the population has normal arches, 20% have a cavus foot, and 20% have a planus foot. These latter 40% are most interesting in lower extremity mechanics, as it is commonly thought that their structure will lead to some degree of compensation in lower extremity mechanics.

Many athletes perform jump-landing during training activities and competitions. Research focusing on jumping seeks to understand how one generates and uses the energy necessary to propel oneself. Research on landing however, focuses on the biomechanical implications of impact and the resulting loads placed on the lower extremity tissues (Devita & Skelly, 1992). It is reported that landing from a jump can involve forces that are two to 12 times the body weight, which could be related to lower extremity injuries (Hargrave et al., 2003), therefore this has led to an increased focus on landing techniques (Dufek & Bates, 1991). It is reported that increase in rate of vertical loading subsequently can increase the tibial impact and knee pain (Radin et al., 1991). Imposed load on kinetic chain structures during athletic activities can increase biological strength of body component likes ligaments, tendons, muscles, bone and joint cartilages.

Since the repetitive application of high-impact forces can lead to injury and decreased performance, the ability to control and adequately absorb these forces during dynamic, functional activity is the key to prevention of injury (Nigg et al., 1985). High percent of all lower extremity injuries (approximately %70) that occur during jumping activities, can lead us to suppose high correlation between landing forces and lower extremity injuries (Dufek & Bates, 1991).

Therefore, the examination of VGRF may give better insight in differences injuries in athletes with high and low arches. Supposing that excessive pronation and supination can result in differences in peak VGRF on lower extremities and consequently injury in the lower extremities, the aim of this study was to compare peak VGRF between supinated and pronated and normal foot during single leg drop-landing.

MATERIALS AND METHODS

Thirty male students from physical education & sport science department [mass 74.32 ± 6.50 kg, height 176.20 ± 5.43 cm, age 23 ± 2 years] participated in this study. Subjects were grouped [n= 10 per group] on the basis of weight bearing navicular drop (ND) [supinated, ≤ 4mm; neutral, 5-9 mm; pronated, ≥10 mm] (Hargrave et al., 2003; Cote et al., 2005). This study was approved by the university institutional review board. All participants signed an informed consent document approved by the Institution human subjects review board. Subjects positioned barefoot on a box 0.30 m above the landing surface with arms aligned along the shafts of the femur and the fibula.

The force plate (MIE, 40 × 60) served as the landing surface and placed on the floor 0.15 m in front of the box (Hargrave et al., 2003) [figure1]. Before testing, subjects identically were instructed about landing protocol. Subjects stood on the box in a comfortable, full weight-bearing, double-leg posision. They were instructed to drop off the box, not lower themselves from it, and perform a single-leg landing on the force plate with preferred leg. Upon landing, subjects were encouraged to try to maintain their balance after contact with the force plate. Subjects were allowed sufficient practice 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. Subjects then performed drop jumps until 3 acceptable trials were recorded. Acceptable trials were defined by the following landing criteria: (1) contact of the forefoot first, (2) maintenance of balance, (3) ability to land without hopping, and (4) knee flexion less than 90° during the whole landing contact.

RESULTS

The results showed differences in peak VGRF was not significant ($F_{2,27} = 0.510$, $P > 0.05$). It is presented the mean and standard deviation for peak VGRF and the results of one way ANOVA in table 1. Peak VGRF in the supinated group was greater than other groups, though it was not significant. Peak VGRF in three groups are presented in Figure 1.

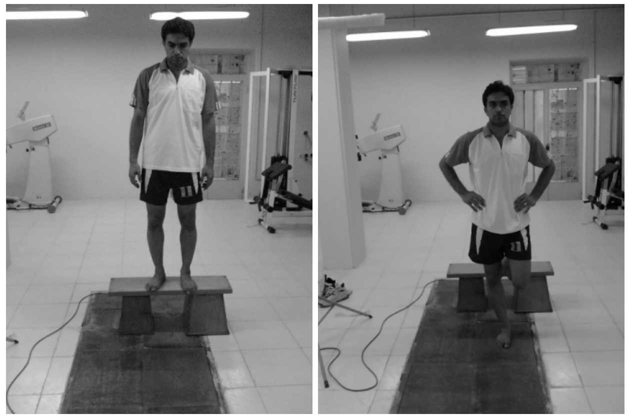

Figure 1. subject position before and after landing

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 landing maneuver are below 30 Hz. Therefore, a minimum sampling rate of 60 Hz would be sufficient for collecting data. We selected, 200 Hz to provide a sampling rate six times greater than the raw analog-signal under study. Subjects landing on force plate and the acquired force plate data, VGRF (z direction) were analyzed. Peak VGRF determined as the peak vertical force (N) during landing. The data were normalized with respect to body weight (N), and expressed as a multiple of body weight (×BW). We used one way ANOVA at the p level of 0.05 to compare Peak VGRF between three groups.

Table 1. mean and Std. for peak VGRF in supinated, pronated and normal groups

Parameter	group	Mean ± Std.	$F_{2,22}$	P
	Pronated	27.02 ± 3.41		
Peak VGRF (N)	Supinated	27.49 ± 5.03	0.510	0.606
	Normal	25.68 ± 1.21		

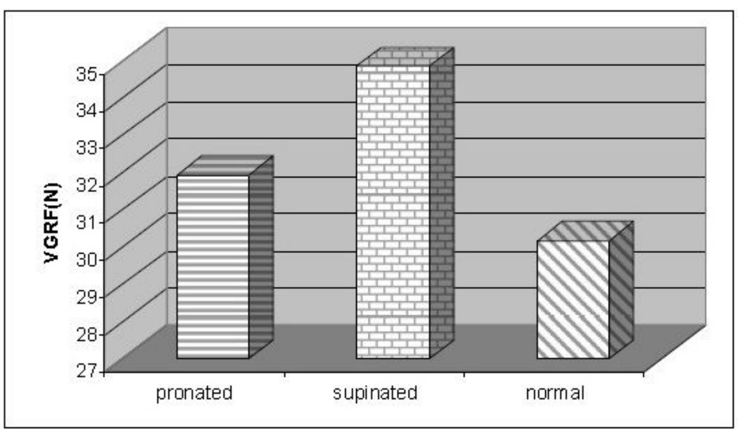

Figure 1. mean and Std. for peak VGRF in supinated, pronated and normal groups

DISCUSSION AND CONCLUSION

The aim of this study was to examine the differences in peak VGRF between supinated and pronated and normal foot during single leg drop-landing. Our finding was that peak vertical forces during a single-leg drop landing were not different among subjects as a function of ND scores. Hence, although excessive pronation is thought to play a critical role in shock absorption and injury risk, our finding suggests that differences in ND do not substantially alter biomechanical function during a landing task. We suspect that there may be several reasons for these findings. Although ND is a valid measure of subtalar motion during gait (Cornwall & McPoil, 1999), it may not be representative of actual subtalar motion during landing. Given these findings, more direct measures of dynamic motion are warranted.

In landing from the drop jumps, the initial ground contact is made with the forefoot first and the biomechanical sequence of events that follows has not been clearly documented. On the basis of what we know about subtalar motion during gait, the midtarsal joints are typically locked in supination when weight is transferred onto the forefoot (Purcell, 1986; Smith et al., 1997). Thus, it may be that full subtalar pronation in a forefoot-to-heel sequence is not the same as in a heel-to-forefoot sequence and subtalar pronation may have critical role in shock absorption during walking and running. Devita and Skelly (1992) noted that the ankle plantar flexors and the knee extensors were the muscle groups primarily responsible for deceleration during landing, with the ankle plantar flexors becoming more active as knee excursion decreased. The posterior lower-leg muscles would seem to be a more effective and powerful decelerator of, and shock absorber for, the body during this type of landing, which may lessen the impact and relative contribution of subtalar joint in shock absorption during landing.

Landing from a jump can involve forces that are 2 to 12 times the body weight whereas heel-toe running at 4.5 m/s produces forces that are 2.8 times the body weight (Hargrave et al., 2003). Regarding our results it is seems that pronated foot, supinated foot and normal foot have the same kinetics during landing. Our findings are limited to a drop landing, and other dynamic activities that involve full weight acceptance and then push-off (e.g. countermovement jumps and cutting maneuvers) may show greater reliance on pronated and supinated foot to dissipate forces. These results suggest that foot types are not associated with specific lower extremity kinetics. Not differences in these parameters may be resulting of existence another factors influencing VGRF.

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