GROUND REACTION FORCES ATTENUATION IN SUPINATED AND PRONATED FOOT DURING SINGLE LEG DROP- LANDING

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The purpose of this study was to compare the GRF attenuation between normal, supinated and pronated foot during single leg drop-landing. 30 healthy male students from kinesiology department participated in this study. Subjects were assigned to three groups by navicular drop test and performed single leg drop-landing on the force plate from the box with height of 30 Cm. peak VGRF and ROL calculated using GRF data. To evaluate differences in peak VGRF and ROL between three groups MANOVA at the P level of 0.05 used. Differences in ROL was significant between three groups ($F_{2, 22}$=15.553, Wilks' Lambda = 0.370, P≤0.05) but differences in Peak VGRF was not significant ($F_{2, 22}$ = 2.632, P >0.05). These results suggest that supinated foot is associated with specific lower extremity kinetics. Differences in these parameters may subsequently lead to differences in injury patterns in supinated foot in athletes.

KEY WORDS: rate of loading, pronated foot, supinated foot

INTRODUCTION:

Since the foot is the interface with the ground during gait, running, landing, and dynamic activities, structural changes here may cause compensatory malalignment and, consequently, mechanical deviations of the entire lower extremity (Williams & McClay, 2001). Therefore, studies focused on persons with abnormal foot structure could provide insight into abnormalities in lower extremity mechanics. Abnormal foot structure is commonly implicated as a predisposing factor to injuries such as chondromalacia patella and shin splints (Franco, 1987; Williams & McClay, 2001; Hargrave & Carcia, 2003). According to Subotnick (1985), 60% of the populations have normal arches, 20% have a cavus foot, and 20% have a planus foot. These latter 40% are most interesting, as it is commonly thought that their structure will lead to some degree of compensation in lower extremity mechanics (Subotnick, 1981). Nachbauer and Nigg (1992) examined the Ground reaction forces (GRF) in runners with differences arch structures and found no differences in GRF timing parameters when comparing arch height and arch flattening. Williams and McClay (2001) examined the lower extremity kinetics in runners with low arch and high arch structures and found that high arch runners have more rate of loading (ROL) than low arch ones.

Imposed load on kinetic chain structures during athletic activities can increase biological strength of body component likes ligaments, tendons, muscles, bone and joint cartilages, but providing increase in ROL, it is possible to see micro and macro degeneration in anatomical structures (Nigg & Bobbert, 1990). High percent of all injuries (70 %) that occur during jumping activities, and the high rate of lower extremity injuries in these sports, suppose high correlation between landing forces and lower extremity injuries (Dufek & Gillig, 1991). Supposing that excessive pronation and supination can result in differences in Vertical GRF (VGRF) and ROL imposed on lower extremities and consequently injury in the lower extremities, this study accomplish to comparison of peak VGRF and ROL between supinated and pronated and normal foot during single leg drop-landing.

METHODS:

Data Collection: 30 male students from physical education & sport science department with mean and std. (weight 75.27±4.70 Kg, height 176.50±5.30 Cm, age 23±3 years) participated in this study. Subjects were grouped (n= 10 per group) on the basis of weight bearing ND (navicular drop) (supinated, ≤ 4mm; neutral, 5-9 mm; pronators, ≥10 mm) (Cote & Brunet, 2005; Hargrave & Carcia, 2003). We positioned subjects barefoot on a box 0.3 m above the landing surface with arms aligned along the shafts of the femur and the fibula. The force plate served as the landing surface and was placed on the floor 15 Cm in front of the box

(Hargrave & Carcia, 2003). 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-landing maneuver are below 30 Hz. Therefore, a minimum sampling rate of 60 Hz would be sufficient for collecting data. The peak ground reaction forces (GRF) of the 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. We selected, therefore, 200 Hz to provide a sampling rate six times greater than the raw analog-signal under study.
Subjects landing on force plate and using the acquired force plate data, VGRF (z direction) and ROL were analyzed. 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. Rate of loading was calculated as the normalized peak vertical force divided by the time to peak force.

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

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

RESULTS:
The results of MANOVA have shown significant differences between three groups of supinated, pronated, and normal ($F_{2,22}$=15.553, Wilks' Lambda = 0.370, P≤0.05). The differences in three groups was due differences in ROL between them, while differences in VGRF was not significant ($F_{2,22}$ = 2.632, P >0.05). It is presented the mean and standard deviation for VGRF and ROL and the results of MANOVA in table 1. Peak GRF in the supinated group was 14% more than else groups, but it was not significant. ROL in the supinated group was 28% more than normal group and 31% more than pronated group. Peak VGRF and ROL in three groups presented in Figure 1 and Figure 2 respectively.

Table 1: mean and Std. for peak VGRF, ROL in supinated, pronated and normal groups and the results of MANOVA,* significant at p level of 0.05

Parameter	group	Mean ± SD	$F_{2,22}$	P
	Pronated	30.20±4.60		
Peak VGRF (N)	Supinated	34.80±5.50	2.632	0.097
	Normal	30.10±2.60		
	Pronated	327.60±31.90		
ROL (N/s)	Supinated	468±93	15.553	0.000*
	Normal	338.20±13.20		

DISCUSSION:
The purpose of this study was to examine the differences of peak VGRF and ROL between supinated and pronated and normal foot during single leg drop-landing. The supinated group has more ROL during landing in comparison of two other groups. The probable reason for increase of ROL in supinated group can be attributed to the shortening of invertors muscles of the foot in these groups and decrease the ability of these muscles to control pronation of the foot during landing.

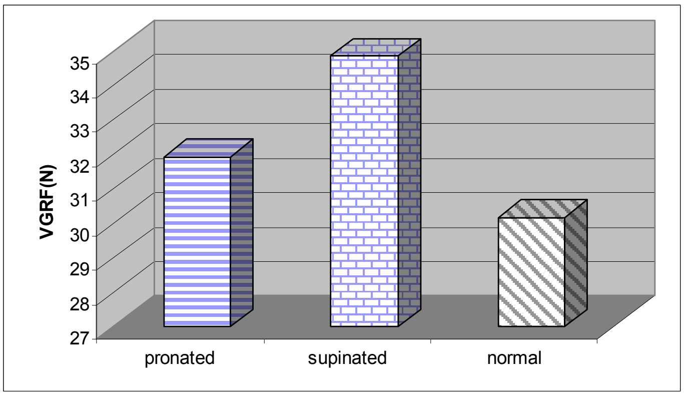

Figure 1: mean and Std. for peak VGRF in supinated, pronated and normal groups

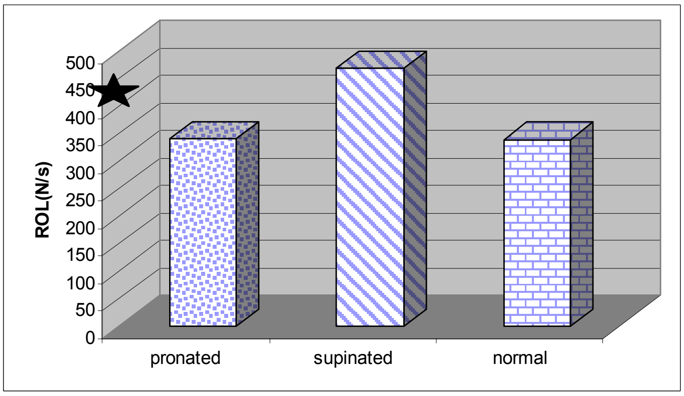

Figure 2: mean and Std. for ROL in supinated, pronated and normal groups, ★ significant differences

Williams and McClay (2001) reported that persons with supinated foot are susceptible for knee and shank injuries, because of increase in ROL. Although previous investigations of foot deformities and impact forces have focused primarily on gait and running and our study has did during single leg drop-landing, nonetheless our results about ROL in supinated foot is similar with previous investigations. It can be explanatory to this topic that increase of ROL in supinated foot secondary can increase the shank and knee ROL during landing and pose these subjects at risk of knee and shank injuries.

Neely (1998) reported that pronation unlocks the midtarsal joint and depresses the medial longitudinal arch of the foot, allowing the foot to become flexible and absorb shock during weight bearing. But with regards to our finding, there are not any significant differences in ROL between pronated foot groups and normal groups. The probable reason for not significant differences between theses two groups can be attributed to the differences in landing and running mechanics. Ground contact during heel-toe running is normally initiated with the rear foot, whereas ground contact during landing is normally initiated with forefoot. 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 & Carcia, 2003); yet specific variables affecting the impact forces of the two activities have not been clearly distinguished.

CONCLUSION:

These results suggest that supinated foot is associated with specific lower extremity kinetics. Differences in these parameters may subsequently lead to differences in injury patterns in supinated and pronated foot in athletes. It seems that athletes with supinated foot may benefit from training programs to reduce the VGRF and ROL during dynamic activities like jump-landing.

REFERENCES:

Cote, K.P., Brunet, M.E., Gansneder, B.M., Shultz, S.J. (2005). Effect of pronated and supinated foot postures on static and dynamic postural stability. Journal of Athletic Training; 40(1):41-46.
Dufek, J.G., Gillig, S.E. (1991). Biomechanical factors associated with injury during landing in jump sports. Sports Medicine; 12:326-37.
Franco, A.H. (1987). Pes cavus and pes planus. Physical Therapy; 67:688-693.
Hargrave, M.D., Carcia, C.R., Gansneder, B.M., Shultz, S.J. (2003). Subtalar pronation does not influence impact forces or Rate of Loading during a single-leg landing. Journal of Athletic Training; 38(1): 18-23.
Nachbauer, W., Nigg, B.M. (1992). Effects of arch height of the foot on ground reaction forces in running. Medicine and Science in Sports & Exercises; 24:1264-1269.
Neely, F.G. (1998). Biomechanical risk factors for exercise-related lower limb injuries. Sports Medicine; 26:395–413.
Nigg, B., Bobbert, M. (1990). On the potential of various approaches in load analysis to reduce the frequency of sports injuries. Journal of Biomechanics; 23:2-12.
Subotnick, S.I. (1981). The flat foot. The Physician & Sports medicine; 9:85-89.
Subotnick, S.I. (1985). The biomechanics of running: Implications for the prevention of foot injuries. Sports Medicine, 2, 144-153.
Williams, D.S., McClay, I.S., Hamill, J., Buchanan, T.S. (2001). Lower extremity kinematics and kinetics differences in runners with high and low arches. J of Applied Biomechanics; 17:153-163.

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