ORIGINAL ARTICLE

Ground reaction forces analyses during the gait of healthy individuals with and without the use of a calcaneus insole

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ABSTRACT

The foot forms the base of propulsion and balance during the gait. It is well known that excessive or prolonged pronation and supination changes the gait's mechanical movement. Hence, the use of corrective insoles is recommended when calcaneus alterations (valgus and varun) are present. **Objetive:** The main purpose of this article was to analyze the effects of a calcaneus insole on normal individuals on the Ground Reaction Force variables. **Method:** The experiment used ten adults (31.9 ± 6,7 years, 65.9 ± 15.4 kg and 1.7 ± 0.1 m) and registered no apparent changes in gait or pathologies that have an effect on the locomotor system. The following gait conditions were analyzed and compared: barefoot, using a sport shoe, and using the sport shoe with insole. The variables analyzed were vertical, medial lateral, and anterior-posterior dynamic ground reaction forces. An ANOVA one-way was used in order to compare the three different conditions. Statistically significant differences were revealed between the conditions of barefoot and sport shoe with insole for the vertical GRF during initial contact Fz_1 ($F_{2,59} = 3.4$; $p < 0.0406$) and for the GRF anterior-posterior in the terminal stance phase Fy_2 ($F_{2,59} = 3.63$; $p < 0.0332$). **Results:** These results indicated that the use of an insole increased the vertical impact on the locomotor system during the response to load phase, probably because of its greater stiffness compared to the barefoot or sport shoe trials. The insole also changed the GRF anterior-posterior during the terminal stance that corresponded with the acceleration/propulsion gait phase. **Conclusion:** Just based on the analysis of the dynamic variables, it was concluded that the use of insoles did not induce any significant increase in lateral forces that would indicate the reduction of excessive pronation or supination during the response load phase. The use of an insole produced a significant dynamic effect on the pronation/supination only in the propulsive gait phase.

Keywords: foot, gait, posture, pronation, supination

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INTRODUCTION

The foot is the support and propulsion base for the gait, being considered a dynamic shock absorber capable of bearing, without lesions, the physiological burdens imposed on it.[1-3] The support on the calcanei occurs in a balanced way between the inner and outer region of the rearfoot. There are two calcaneal deviations: the valgus and the varus. The calcaneus valgus is the projection of the calcaneus laterally to the body, making the calcaneus tendon projecting towards the inner part of the body. The calcaneus varus is the projection of the calcaneus tendon medially to the body.[3]

The postural alterations caused by the calcaneus valgus and varus are respectively related to pronation and supination of the subtalar joint.[4] The presence of excessive subtalar joint pronation or supination has been related to the development of orthopedic pathologies in the lower limbs, as well as mechanical alterations in gait.[1,2,4] It is known that proprioceptive insoles, especially, calcaneal insoles, have been frequently used to correct the calcaneus valgus and varus. This model is made of silicone, in a wedge shape, which allows positioning it under the heel in the shoe, allowing the user to step down in a position closer to neutral. Thus, the main characteristic of the heel insole, according with some manufacturers, is to correct pronation or supination of the subtalar joint, diminish the impact, and eliminate the shock and pressure of walking. However, there is no consensus on the efficacy of these insoles for such purpose.

Dynamic analysis of the gait is a tool that can quantify the gait alterations of normal individuals who wear insoles through the components of ground reaction force (GRF) during the gait cycle. These forces are known as vertical components (Fz), horizontal mediolateral (Fx), and horizontal anterior-posterior (Fy).[5] Taking into consideration that the movement of the feet is responsible for the absorption of the impact, maintenance of balance, and distribution of forces,[1] what is the influence of using calcaneal insoles to correct deviation of the GRF during the gait?

OBJECTIVE

The objective of this study was to analyze the influence of corrective calcaneal insoles on the gait of normal individuals using the dynamic variables of the GRF.

METHOD

The study was made at the Biomechanics Instrumentation Laboratory - LIB, from the Physical Education College - FEF (*Faculdade de Educação Física*), at the Campinas State University - UNICAMP, and approved by the Committee on Ethics from the Medical Sciences College - UNICAMP, according with Opinion number 789/2007. The participants were informed about the research and signed the Free and Informed Consent form.

Participants

Ten adults participated in the study; they were asymptomatic and had no deformities or visible limitations in their ankle joint range of movement, with 6 females and 4 males, average age of 31.9 ± 6.7 years, body mass of 65.9 ± 15.4 kg, and height of 1.7 ± 0.1m.

Experimental Procedures

Silicone heel insoles with elevation at the lateral or medial border of the foot: for the calcaneus insole condition, commercial corrective heel insoles were used for the deviation of the heel, of the Ortho Pauher brand, 100% silicone, weighing 200 g, that are made especially for individuals who step on their inner (pronate) or outer (supinate) sides. They have lateral tabs with calcaneal shape and medial elevation for the pronate heel and lateral elevation for the supinate heel.

Data collection: for kinetic analysis, two force platforms were used (KISTLER 9286BA with dimensions of 600 X 400 mm). The platforms were built-in in the center of the laboratory, their top surfaces were level with the laboratory floor, and the data was collected at a frequency of 200 Hz. In order for the comparison of the data collected with the force platform between different individuals and different conditions, and for repetitions to be possible, it was necessary to normalize the amplitude of this data. Thus, the normalization of the data was made by the body weight (Newtons) of each participant and by the percentage of the support phase.[6-9] Emphasizing that the body weight data was normalized for each one of the conditions, that is, the participants were weighed barefoot, with the heel insoles, and wearing trainers with the heel insoles. The GRF data is shown as a function of the percentage of support phase (0% to 100%). The kinetic data was filtered by a 2nd order Butterworth filter with a cutoff frequency of 4 Hz. Routines written in Matlab language (Math Works Inc., version 7.0.8 - R 2009 a) were used for the treatment and analysis of the dependent variables.

Task: the participants were instructed to walk, at any pace they preferred, on the area volume selected, on two force platforms under the following conditions: barefoot (barefoot); wearing trainers (trainers), and last, with heel insoles accommodated inside their trainers (heel insole). Data was collected for each condition.

Dependent variables

GRF vertical component: first peak of impact (Fz_1), maximum value of first peak; valley (Fz_2), minimum value between the first and the second peak of the vertical component; and the propulsion peak (Fz_3), maximum value of the second peak (Figure 1A).

GRF anterior-posterior component: negative phase (deceleration or braking - Fy_1), minimum value of the anterior-posterior GRF on the first half of the support phase and positive phase (acceleration - Fy_2), maximum value of the anterior-posterior GRF on the second half of the support phase (Figure 1B).

GRF mediolateral component: maximum lateral force (Fx_1), minimum value of the curve; first maximum medial force (Fx_2), maximum value of the curve on the first half of the support phase; and second maximum medial force (Fx_3), maximum value of the curve on the second half of the support phase (Figure 1C).

Statistical analysis: the Kolmogorov-Smirnov test revealed that the dynamic variables reached the pre-supposed values of normality. In this way, the data related to the reaction force of the ground during the gait under the three conditions (barefoot, trainers, and trainers + insole) were treated by the one-way ANOVA, and the *post hoc* Tukey test was applied later to localize the differences between the groups (Figure 2). The significance level for the entire test was $\alpha < 0.05$.

RESULTS

The results of the present study indicated that there was no difference in the dynamic variables when they were compared between the right and left feet of the participants, there was no difference between genders, and none of the participants surpassed the vertical GRF peak of 1.2. Therefore they all were within the physiological parameters.[10,11]

For the barefoot and trainers-insole conditions, differences were found for the component Fz_1 of the vertical GRF ($F_{2.59} = 3.4$; $p < 0.0406$) and for the component

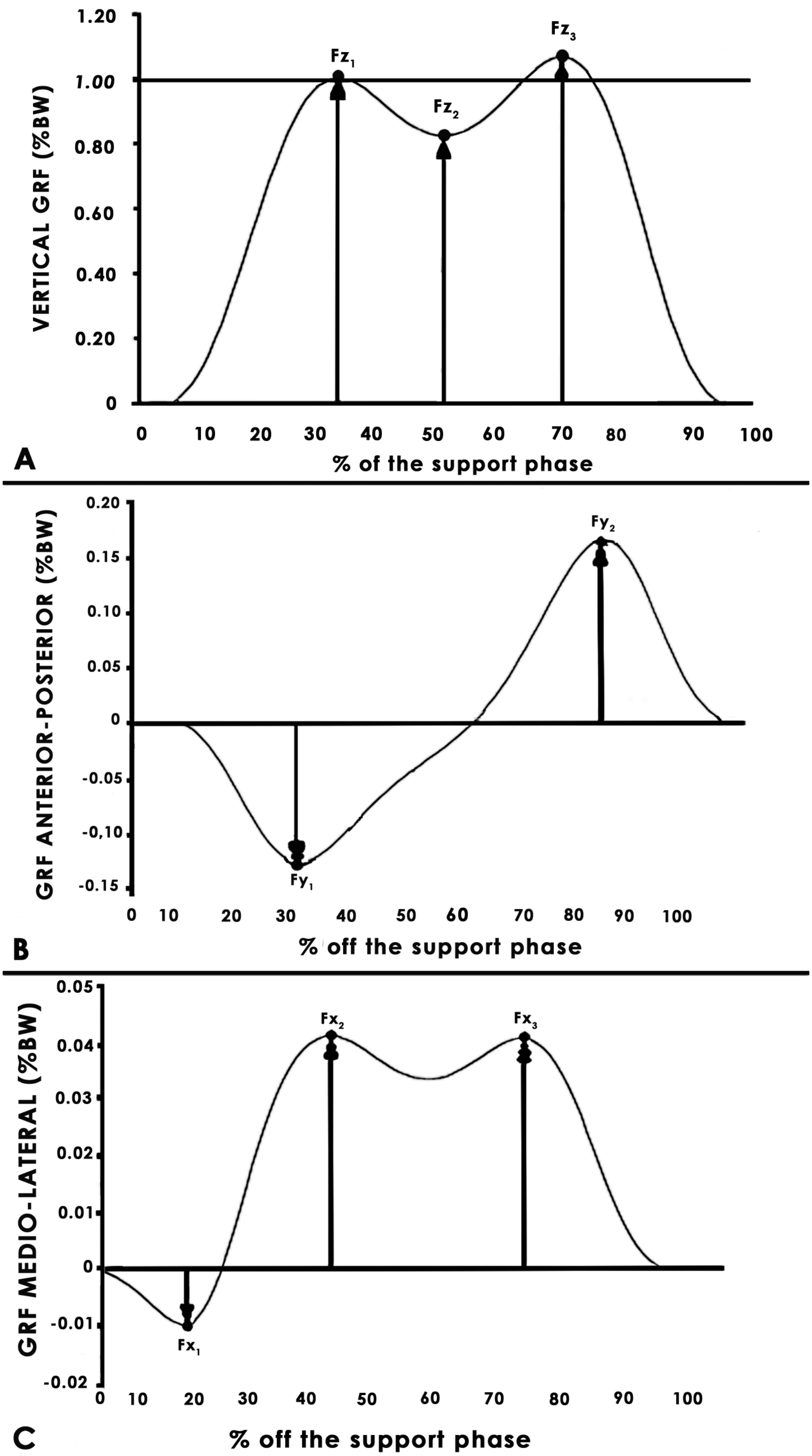

Figure 1. Variables of the GRF vertical component (1A); GRF anterior-posterior component (1B); and GRF mediolateral component (1C), represented by the averaged curve of all the participants in the barefoot condition. %BW: normalized by body weight

Fy_2 of the anterior-posterior GRF ($F_{2.59}$ = 3.63; p < 0.0332). The participants had a higher impact peak (Fz_1) in the trainers-insole trial (1.05 ± 0.04) than in the barefoot trial (1.01 ± 0.03; p < 0.05 - Figure 1A). In the Fy_2, the participants in the barefoot condition (0.16 ± 0.01) showed greater acceleration/propulsion in relation to the trainers-insole condition (0.15 ± 0.02; p < 0.05 - Figure 1B).

DISCUSSION

The objective of this study was to investigate the influence of the use of corrective heel insoles on the gait of normal individuals. It is known that heel insoles are widely used for the correction of calcaneus valgus and varus, however, there is no consensus on the effects of this insoles on the gait of normal individuals.

As for the variables of reaction force of the vertical ground (Fz), at the impact peak (Fz_1) there was increase between the barefoot and heel insole conditions. While testing the efficiency of rigid and compressible materials used in the making of trainers, Nigg et al.,[12] Robbins et al.[13,14] and Shorten & Mientjes[15] confirmed that the greater the rigidity of the trainers, the greater the impact peak of the heel on the ground. The results of the present study may be explained by the rigid characteristic of the silicone heel insole.

In addition, the gait can also be influenced by the use of shoes.[16-18] The results of this study indicate that the barefoot condition showed the lowest impact peak. The human foot constitutes a support and propulsion base for the gait, being considered as a dynamic shock absorber, capable of bearing and distributing the physiological loads imposed on it.[1-3] The movements of the feet are responsible for the absorption of impacts, maintenance of equilibrium, and distribution of loads.[1-3,11,19,20] This is why the barefoot condition demonstrates a greater flexibility of the locomotor system in reducing load and greater capacity of adaptation on various surfaces,[13,17,18] contrary to the conditions with shoes, which restrict the physiological mobility of the foot.

Robbins & Hanna[13] discuss a lower frequency of lesions in barefoot populations in comparison with populations that wear shoes, and suggest that adaptations produced by the barefoot would be related to the lowering of the medial longitudinal arch. In contrast, the shod foot would be incapable of deflecting the arch, accounting for more frequent lesions. While investigating the

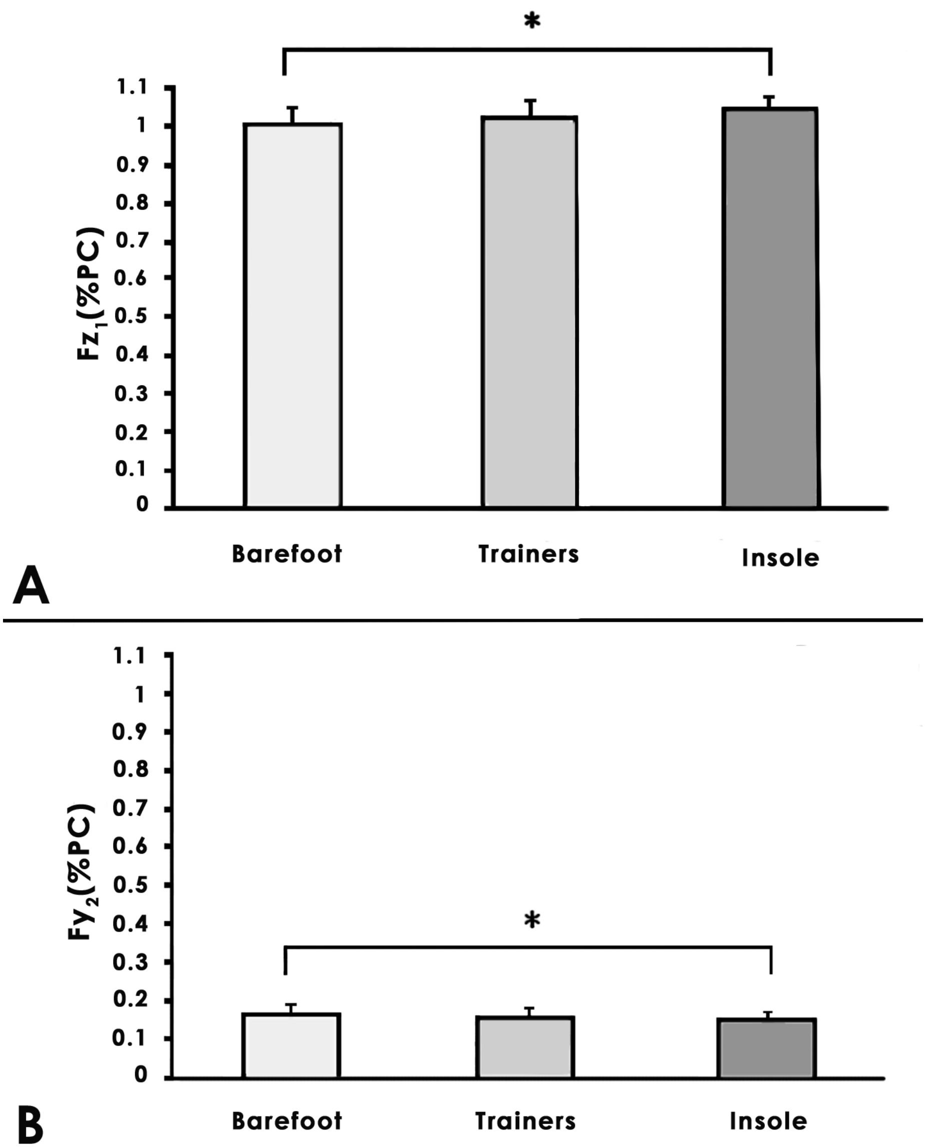

Figure 2. Results comparing valleys between conditions for Fz1 (A) and Fy2 (B). %BW: percentage of body weight; * differences revealed by the Tukey test.

relationship between the mobility of the ankle and foot and the magnitude of the ground reaction vertical force, Viana& Greve[21] found that there is a relationship between the mobility of these joints and the impact peak.

Based on the findings by Robbis & Hanna[13] and Viana & Greve[21] we can hypothesize that the use of trainers with heel insoles may restrict the medial-foot deflection more than the use of of trainers without this implement. First, because the heel insole is positioned under the heel thereby elevating it beyond what the sole of the shoe does, and second, by having a slope and irregular height in its shape, characteristics which induce the individual to step down in the most neutral position possible, that is, restricting the vertical movement of flattening the foot generated during the gait.

The adaptations produced by a bare foot may also have influenced the propulsion results (Fy_2). For Fy_2 the barefoot condition showed greater GRF than the trainers-insole condition. Studies point out that walking with shoes on shows less acceleration/propulsion than walking barefoot.[12,13,18]

The present study had some limitations such as reduced sample size, which may have influenced some results. Furthermore, the inclusion of kinematic data such as articular angles of flexion/extension and pronation/supination must be considered in a later analysis, for they would help to explain some of the results presented.

CONCLUSION

The use of corrective heel insoles did not show any significant effect on the lateral GRF component, suggesting that these insoles do not have any effect on the pronation/supination control during the gait. The use of heel insoles produced a significant dynamic effect on the pronation/supination only on the propulsion phase of the gait.

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