EFFECTS OF MEDIAL WEDGE INSOLES WHEN WALKING ON DIFFERENT SURFACES

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Shoe inserts are often used to correct for foot misalignment or overloading during walking and running. To understand the interaction of medial wedge insoles and different surface hardness and geometry, we investigated plantar pressure and rearfoot movement. Twenty-eight subjects with normal feet were tested when walking with and without insole on all combinations of hard and soft surface and level and upstairs walking. The main changes in load distribution and rearfoot movement were found between wearing insoles and not wearing them while differences between surfaces were small. In conclusion, surface hardness did not change the general effects of the insoles.

KEY WORDS: plantar pressure; rearfoot movement; orthoses; shoes; ankle joint

INTRODUCTION: Walking is among the most fundamental locomotory capabilities of the human body (Chen, Li & Huang, 2015). In order to protect the foot from damage caused by foot-surface interaction, people in most western populations have chosen to wear shoes. It has been pointed out that the distribution of plantar pressure may vary depending on the surface we move on. Thus, the distribution can be even or uneven, depending on the walking surface (Chen, Li & Huang, 2015).

More than 25% of working people maintain painful and tiring postures for half of their time spent at work. This can cause lower back and lower extremety pain, thus affecting their well-being, social life and overall productivity. It has been shown that standing on a soft surface increases the comfort perception and reduces postural activity (Madeleine, Voigt and Arendt-Nielsen, 1997).

A walking surface consisting of soft materials has been shown to alter the normal gait pattern of healthy people (Viera et al, 2015). Further, the normal biomechanical function could be limited when an outside factor such as an orthotic intervention is applied (Reilly, Barker & Shamley, 2006).

The purpose of the study was to investigate if there is a difference in the effect of a 10° medial-wedge insoles on a soft or hard walking surface.

METHODS: Twenty-eight healthy participants with no lower leg pain one week prior to testing or history of trauma in the last six months were included in the study. Twenty-four men and four women with an average age of 25.0±1.8 years, height 180.0±7.6 cm, mass 76.6±9.7 kg and body mass index (BMI) of 24±2 gave their consent to participate in the study. The included participants needed to have a shoe size within a range of 40-45. A sandwhich of two full-length medial wedge insole (Rehband, Technogel®-Pes Velour) to create a 10° angle (Mølgaard & Kersting, 2014) was used together with a neutral running shoe (Nike, Pegasus). To determine if the subjects are qualified as having healthy feet the six-item version of the foot posture index (FPI-6) was used and a value beween 0 to 5, was ascertained. All the assessments were made by the same researcher, a physical therapist.

A 10 m walkway with adjacent hard and soft surfaces was prepared prior to testing. The hard surface was made out of concrete, covered by hone and wood and the soft surface was constructed by applying a stiff cold-pressed foam of 3 cm on top of the hard surface. The subjects were asked to perform walking activities on a walkway with two surface hardnesses while wearing the shoes with (WI) and without insoles (WOI). in a randomized order. The order of the four testing conditions were randomized using radom.org.

Before the data collection was performed, the subjects were asked to familiarize themselves with the testing insoles for 10 minutes to ensure the proper fit of the wedge insoles and comfort of the subjects. The participants were asked to walk at a self-selected walking speed within a range of ±5% monitored with the help of a stop watch. Five trials were collected for each condition. To ensure standardization, the subjects were asked to start each trial with the same foot.

Plantar pressure was collected using Pedar-X in-shoe system (Novel GmbH, Munich, Germany) at a frequency of 100 Hz measuring the vertical plantar pressure. The data were transmitted via Bluetooth to the computer and stored on an SD card. Prior to testing all insoles were calibrated using a trublu calibration device.

The rearfoot movement of the left foot was measured using an electrical goniometer mounted on the heel. The goniometer was comprised of a guiding sleeve gliding on a plastic lever. The sleeve was secured on the bisectional line of the posterior aspect of the shank. The lever was coupled using a two-joint mechanism with a rectangular tail of thermoplastic which was custom-shaped to each subject's heel and mounted on the bisectional line of the calcaneus following the lever's alignment. On the two-joint mechanism, a potentiometer (MPC05 R5K, Megatron, Putzbrunn) was attached such that it followed the natural movement of the joint. A calibration was done prior to testing by recording the values of 0° and ±45°. A frequency of 200 Hz was used to record the rearfoot angle. Data were transmitted to a minicomputer and saved as ASCII file. The Pedar-X and the goniometer were synchronized using the sync device from Pedar-X recorder software. A reference measurement was made by collecting a static trial barefoot (BF), WOI and WI. The shod static trials were made by recording a static double limb support period of two seconds prior to every trial.

For the data analysis, only the data from the left foot were used and any faulty readings displayed by the pressure sensors were corrected using Pedar Emedlink version 22.3.3 (Novel GmbH, Munich, Germany). A total of four conditions were analyzed: walking wearing the wedge insoles on the hard (WI1) and soft surface (WI2) and walking without the wedge insoles on the hard (WOI1) and soft surface (WOI2). Around 2800 steps were loaded into Novel Database Pro m version 22.3.41 (Novel GmbH, Munich, Germany) were the foot was analyzed and descriptive statistics were rendered for the maximum force, contact time and force-time integral.

The data from the goniometer were synchronized with the force profiles from the Pedar-X and processed in Matlab R2015b version 8.6.0.267246 (©1994-2016 The MathWorks, Inc., US), where the data were filtered using a second order Butterworth filter and divided into steps. For each step the take-off (TO), touch-down (TD), maximum angle (Max), minimum angle (Min), velocity (Vel) and static measurement were computed. The data were exported into Excel for further processing and the following definitions were established for the angles: negative angle values will describe a supinated foot and the positive values will characterize a pronated foot.

The statistical analysis was realized in R version 3.2.3 (© 2015, The R Foundation for Statistical Computing) and all data were checked for normal distribution using the Shapiro-Wilk test and a Q-Q plot was created. The data were not normally distributed; thus, a Kruskal-Wallis test was performed to discern statistical significant differences. The statistical significance value was set at $p < 0.05$.

RESULTS: The plantar pressure results are presented in Table 1, where WI1 is walking on a hard surface while wearing the wedge insole, WI2 is walking on a surf surface while wearing the wedge insoles, WOI1 is walking on a hard surface without wearing the wedge insoles and WOI2 is walking on a soft surface without the wedge insoles.

Table 1
Plantar pressure parameters (Mean±SD): maximum force (MF), contact time (CT) and force-time integral (FTI) in the total foot over all walking conditions. * indicates a significant difference (*p*<0.05).

	Maximum force(N)	*Contact time (ms)*	*Force-time integral(N*s)*
WI1	792.7 ± 38.0 *	747.4 ± 41.8 *	420.0 ± 26.3
WI2	795.2 ± 32.7 *	764.2 ± 38.9 *	432.4 ± 23.8
WOI1	778.7 ± 31.0 *	726.9 ± 36.9 *	432.3 ± 24.3
WOI2	792.5 ± 32.9 *	752.5 ± 38.3 *	435.3 ± 25.3

The presence of the 10° medial wedge insole showed significant increases in maximum force of 1.8% when walking on a hard surface and with 0.3% on a soft surface. Also significant increases were seen between the hard surface and the soft surface in both insole conditions: while wearing the 10° medial wedge with 0.3% and while not wearing the insole with 1.8%.
The significant effect of wearing the wedge insole is also seen over the contact time on both surfaces. On the hard surface the insole produced an increase in contact time of 2.8% and on the soft surface with 0.6%. The soft surface showed a significant increase in contact time, present both while wearing the wedge insole with 2.2%, respectively with 3.4% while not wearing the wedge insole. However, the force-time integral did not show any significant changes neither while wearing the insole nor walking on a soft surfaced floor.
The rearfoot movement results are presented in Table 2, where WI1 is walking on a hard surface while wearing the wedge insole, WI2 is walking on a surf surface while wearing the wedge insoles, WOI1 is walking on a hard surface without wearing the wedge insoles and WOI2 is walking on a soft surface without the wedge insoles. The hard surface is represented as HS and the soft surface is represented as SS. Also, negative angle values define a supinated foot and the positive values, a pronated foot.

Table 2
Rearfoot angle parameters (Mean±SD): touch-down (TD), take-off (TO), minimum angle (Min), maximum angle (Max), angular velocity (Vel) and static barefoot angle (Barefoot). * indicates a significant difference (*p*<0.05).

	TO (°)	*TD (°)*	*Min (°)*	*Max (°)*	*Vel (rad/s)*	*Barefoot(°)*
WI1	-0.6 ± 2.0*	-0.9 ± 2.1*	-1.9 ± 2.0*	0.7 ± 2.1*	0.04 ± 0.01	-0.4 ± 0.0*
WI2	-0.7 ± 2.3*	-1.0 ± 2.5*	-2.4 ± 2.4*	0.8 ± 2.4*	0.02 ± 0.01	-0.5 ± 0.0*
WOI1	0.7 ± 2.3*	0.9 ± 2.6*	-0.6 ± 1.9*	2.3 ± 2.9*	0.02 ± 0.01	-0.8 ± 0.0*
WOI2	0.7 ± 2.5*	0.5 ± 2.7*	-1.0 ± 1.9*	2.3 ± 3.0*	0.02 ± 0.01	-0.8 ± 0.0
HS	-	-	-	-	-	-0.9 ± 0.4*
SS	-	-	-	-	-	-0.8 ± 0.3*

All the rearfoor angle parameters, except the angular velocity (Vel) showed significant differences. The touch-down angle was significantly reduced by 198% on the hard surface and with 294% on the soft surface. This effect of the wedge insole was seen over the TO angles, the maximum and the minimum. However, in the static measurements the wedge insole effect had a significant increase in the barefoot condition both on the hard surface with 60% on the soft surface with 42%. Also, a statistically significant increase of 56% was recorded while standing on a hard, but not when standing on the soft surface.

DISCUSSION: Walking on a soft surfaced floor likely alters afferent feedback from cutaneous sensors as well as muscle and joint receptors. These effects may lead to certain adaptations in the negation of an increased sinking-in and, potentially, the need to elevate the foot higher during the swing phase (Viera et al 2015). These adjustments may result in higher vertical forces, which is confirmed by the results of the present study. Moritz and Farley (2004) state

that during dynamic movements, such as running and hopping, on extremely soft surfaces, mechanical adjustments in the lower limb are needed leading to a longer contact time with the surface. This is confirmed by the results of this study as we showed prolonged contact times when the surface was soft.
The results from the present study show statistically significant differences in rearfoot angle between wearing and not wearing a medial wedge insole. These findings stand in contradiction to Rodrigues et al. (2008) who found no significant modifications between two inserts. While this may be due to the fact that we used quite extreme inserts, their study confirmed that the application of a medial wedge insole improves pain relief and functionality to the lateral compartment of the knee (Rodrigues et al. 2008).
The results regarding the ankle movement velocity showed no statistical significant change between the surface hardness and insole conditions. These observations contrast the findings by Tessutti et al. (2010) who reported an increase in peak ankle velocity on surfaces with higher stiffness.
The rearfoot movement amplitude and velocity around the left ankle in the sagittal plane displayed no statistical significance between the hard and the soft walking surfaces. These results are also confirmed by the findings presented in Madeleine et al. (1997).

CONCLUSION: The application of the wedge insoles led to changes in plantar pressure and amplitude of the rearfoot movement. The fact that the wedge insoles showed no significant changes when the hardness of the surface varied attests the effectiveness of the medial wedge insoles. The study design allows the appraisal of multiple surface conditions to be tested in regards to medial wedge insoles.
The methodology and data obtained from this study can be used for modifications and improvements to the insole design to maximize the desired effect of a corrective insole. The results showed that a 10-degree medial wedge insole maintains its effects through a multitude of variables, potentially indicating that injury risk may not be increased when wearing quite extreme insoles on changing surfaces. Future investigations should be conducted to understand the full biomechanical effect of wearing a wedge insole. The study design can be used to assess other shapes of insoles or surfaces assessing the consistency of corrective inserts during daily use.

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