



Original Article

Stabilization of postural sway on a sideward slope using cuboid support insoles

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Abstract. [Purpose] The purpose of this study was to elucidate whether insoles alter postural sway on a sideward slope rather than on level ground. [Participants and Methods] This study involved 20 flat-footed individuals and 20 normal-footed individuals. The postural sway was determined based on the total length of the locus and the body sway area, which were measured using the Zebris system. The participants were divided into three groups: the BMZ insoles, Superfeet insoles, and no insole groups. These insoles were worn by the participants with their normal shoes worn daily. [Results] The total length of the locus of the BMZ group was significantly lower than those of the Superfeet and no-insole groups. The body sway area did not significantly differ based on the insole condition. [Conclusion] BMZ insoles improve postural sway in both normal-footed and flat-footed individuals on a sideward slope.

Key words: Sideward slope, Insole, Postural sway

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INTRODUCTION

Standing with good balance on uneven ground is important for the prevention of falls. The arches of the foot, which have shock absorption capabilities, are important structures for maintaining body weight¹⁾. A flat-footed deformation leads to postural sway instability due to foot arch dysfunction²⁾. The arch structure of the foot absorbs the body weight¹⁾. The environment we live in is not limited to flat areas. Sidewalks and roads are built on slopes, and our activities on the ground are not limited to flat indoor environments; therefore, these outdoor environments need to be considered to assess the risk of falls and other physical effects.

Individuals with flat feet have an abnormal foot structure. Surgery is the treatment of choice when reconstruction is required, whereas physical therapy, exercise therapy, and prosthetic therapy are performed when conservative therapy is required. Among these therapeutic options, insole therapy, a prosthetic therapy, is frequently prescribed with the purpose of regaining foot structure^{3, 4)}.

Previous studies have reported that the use of insoles improves the support given to the arch of the foot⁵⁾ and the postural sway^{6, 7)}. There are various shapes of insoles, and it was found that insoles that support the inside of the foot significantly improve postural sway compared to those that support the outside of the foot⁸⁾. We examined the effects of two types of insoles on standing balance on the level ground: BMZ insoles (BMZ[®] complete sports, BMZ, Gunma, Japan) and Superfeet insoles (Superfeet Green Insoles, SUPERfeet, Ferndale, WA, USA) versus no insoles. The BMZ and Superfeet insoles were

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chosen as they support the cuboid and sustentaculum tali, respectively. It was found that Superfeet insoles significantly improved the standing balance on the level ground.

BMZ insoles have been reported to improve the stability of the supporting leg during the Star Excursion Balance Test and dynamic balance⁹. Improved dynamic balance may enable stable standing on uneven terrains such as slopes. However, there are no reports of the effect of wearing insoles on postural sway on a sideward slope, which is related to the risk of falling.

The purpose of this study was to investigate whether insoles alter postural sway on a sideward slope in both normal-footed and flat-footed individuals.

PARTICIPANTS AND METHODS

In this study, 20 flat-footed (10 males and 10 females) and 20 normal-footed individuals (10 males and 10 females) participated (age, 20.9 years [range, 20–23]; body mass index, 21.5 kg/m²).

The Bone Arch Index (BAI) was used for evaluating the presence or absence of flat feet¹⁰.

BAI is calculated by dividing the navicular tuberosity height by the foot length. BAI values below 0.21, between 0.21–0.27, and above 0.27 were classified as low arch, normal arch, and high arch, respectively.

The participants were made to stand on a sideward slope with a 15° tilt. The participant's postural sway was evaluated using center of pressure (COP) (Fig. 1) while the participant looked 2 m ahead. Postural sway was measured for 30 seconds, with the participants standing upright, with their feet 10 cm apart. All measurements were taken using the Zebris FDM-SX system (Zebris® Medical GmbH, Am Galgenbühl, Germany). In this study, the sway of the COP was measured when the left leg was on the left side slope and the right leg was in the upper position. We calculated the total length of the locus (TLL) and the body sway area (BSA).

The measurements were made with the participants using the following⁹: BMZ insoles (Cuboid Power Standard, BMZ, Japan) and Superfeet insoles (Superfeet Green Performance Insoles, SUPERfeet, Ferndale, WA, USA) and no insoles. These insoles were worn by the participants with their normal, daily wear shoes. All measurements were made thrice for the three insole conditions, and the average of the three measurements was used for the analysis.

Results of the three-way repeated measures ANOVA and the differences among the parameters were subjected to the Bonferroni test. A p-value<0.05 was considered statistically significant.

All study protocols were approved by the ethics committee of Hokkaido Bunkyo University (number 02007), and each participant provided written informed consent before enrollment.



Fig. 1. Participant stood on a sideward slope, and the Zebris system was used to measure total length of the locus and body sway area.

RESULTS

In individuals with normal feet, the TLL values were $1,038.2 \pm 231.0$ mm (no insoles), $1,090.0 \pm 345.0$ mm (Superfeet insoles), and $1,001.4 \pm 240.3$ mm (BMZ insoles). In individuals with flat feet, they were $1,150.9 \pm 308.4$ mm, $1,168.5 \pm 434.1$ mm, and $1,069.8 \pm 287.0$ mm, respectively (Table 1). The TLL values significantly differed based on the three insole conditions in flat-footed and normal-footed individuals. Moreover, TLL values for the BMZ insoles group were significantly lower than those for Superfeet insoles and no insoles group ($p < 0.05$). There were no significances for flat-footed and normal-footed individuals. In individuals with normal feet, the BSA values were 108.6 ± 70.4 mm² (no insoles), 118.6 ± 109.1 mm² (Superfeet insoles), and 107.0 ± 76.1 mm² (BMZ insoles). In individuals with flat feet, they were 139.1 ± 70.2 mm², 131.2 ± 88.6 mm², and with BMZ 133.0 ± 71.5 mm², respectively (Table 2). The BSA values did not significantly differ based on the three insole conditions in flat-footed and normal-footed individuals.

DISCUSSION

We measured the TLL and BSA on a sideward slope in individuals wearing either Superfeet or BMZ insoles or no insoles and found that TLL values differed significantly based on the type of insoles used in normal-footed and flat-footed individuals; however, the BSA values did not.

Insoles have various shapes. In this study, the BMZ and Superfeet insoles were chosen as they support the cuboid and sustentaculum tali, respectively. BMZ insoles were better at postural sway stabilization than Superfeet insoles. There were no significant differences between flat-footed and normal-footed individuals. BSA was not significantly different between flat-footed and normal-footed individuals, probably because all the individuals were healthy (no pain or disability) and could stand still on the sideward slope, and because the task was not difficult.

TLL is the total distance traveled by the COP, whereas BSA is the total area surrounded by the COP for the spatial range of the standing point¹¹. On the sideward slope, TLL values for the BMZ insoles group were significantly lower than those for the Superfeet and no insole groups, and BSA did not significantly differ based on the insole condition. This suggests that BMZ insoles significantly improve the postural sway on the sideward slope.

BMZ insoles support the cuboid and stabilize the lateral part of the foot. In contrast, Superfeet insoles support the hind legs and the sustentaculum tali, without stabilizing the lateral part of the foot. When the insoles provide arch support, activities of the tibialis anterior, soleus, gastrocnemius medialis, gastrocnemius lateralis, and peroneus longus facilitate arch retention and alignment correction¹². The arch of the foot is retained by the insole even when standing for a long time⁵.

In this study, the sway of the COP was measured when the left leg was on the left side slope and the right leg was in the upper position. In this standing position, the left foot is inverted and the right foot is everted. The displacement of the COP to the left may cause eversion of the foot¹³. By supporting the outside of the foot centering on the cuboid bone, BMZ insoles are thought to reduce the inversion of the left foot, bringing it closer to the midline. In contrast, Superfeet insoles have a shape that supports the inside of the foot, facilitating the inversion of the left foot. On level ground, Superfeet insoles were more effective than BMZ or no insoles⁹. However, on sideward slopes, BMZ insoles effectively stabilized postural sway in both normal-footed and flat-footed individuals.

This study had some limitations. First, the shape of the insole needs to be changed to maintain the stability of the foot when the inclination of the floor surface and the joint angle of the foot are different when standing. Second, only body sway was measured; therefore, the angles of each joint of the lower limbs are unknown, and we plan to include this aspect in our future studies. Overall, the cuboid support insole was found to stabilize postural sway on a side slope.

Table 1. Total lengths of the locus (mm)

Category	No insole	Superfeet	BMZ*
Normal-footed group	$1,038.2 \pm 231.0$	$1,090.0 \pm 345.0$	$1,001.4 \pm 240.3$
Flat-footed group	$1,150.9 \pm 308.4$	$1,168.5 \pm 434.1$	$1,069.8 \pm 287.0$

Values are expressed as means \pm SD. * $p < 0.05$ (type of insole).

Table 2. Body sway area (mm²)

Category	No insole	Superfeet	BMZ
Normal-footed group	108.6 ± 70.4	118.6 ± 109.1	107.0 ± 76.1
Flat-footed group	139.1 ± 70.2	131.2 ± 88.6	133.0 ± 71.5

Values are expressed as means \pm SD.

Conflict of interest

There are no conflicts of interest.

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