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Standing Balance on the Ground —The Influence of Flatfeet and Insoles

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Abstract. [Purpose] The aim of this study was to determine whether insoles change standing balance on the ground in normal and flat-footed subjects. [Subjects] Twenty subjects with flatfeet and 20 subjects with normal feet were included in this study. [Methods] Body sway was evaluated based on the center of pressure while subjects stood on the ground. Body sway was measured during upright standing with the feet 10 cm apart for 30 seconds. The total locus length and the area of body sway were then measured using a zebris system. Measurements were made under three sets of conditions: using BMZ insoles, which supported the cuboid; using Superfeet insoles, which supported the medial longitudinal arch; and with no insoles. [Results] The 3 insole conditions were compared. On level ground, the total locus length for the Superfeet insole was significantly less than those for the BMZ insole and no insole. [Conclusion] On level ground, Superfeet feet insoles were effective in stabilizing standing balance in both flat-footed and normal-footed subjects.
Key words: Flatfoot, Insole, Standing balance

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INTRODUCTION

The arches of the feet, i.e., the medial longitudinal, lateral longitudinal, and transverse arch, are important structures that act as shock absorbers for body weight, and preserve stability during both walking and standing[1)]. Muscles, the plantar fascia, and ligaments support these three arches[2)]. Individuals with flatfeet show not only imperfect foot load transfer[3)] but also hip joint, knee joint, and lumbar region imperfections[4)].

The foot structure is involved in load bearing, leverage, shock absorption, balance, and protection[5)]. If the foot structure is destroyed, as in flatfeet, surgical treatment[6)] and conservative treatment, e.g., physical therapy, exercise, and orthoses, are available. Foot orthosis therapy is frequently prescribed to rebuild partial foot structure[7, 8)].

Although it is reported that the foot orthosis reduces the instability of the center of gravity[9–11)], there are a variety of foot orthoses available. BMZ insoles (BMZ, Japan) are reported to support the arch and improve drifting to the center of gravity.

Unlike existing foot orthoses, BMZ insoles (Fig.1) insoles are said to support not only the medial longitudinal arch but also the lateral longitudinal arch and transverse arch by supporting the cuboid to balance mobility with stability.

BMZ insoles are new types of insoles that have not been researched previously. Furthermore, no study has yet been performed to investigate whether the BMZ insole or an existing foot orthosis (the Superfeet insole) is more effective. Therefore, the purpose of the present study was to examine whether the two types foot orthosis were effective for flatfeet on the basis of measurement of the center of gravity and whether standing balance was influenced by normal feet and flatfeet .

SUBJECTS AND METHODS

Twenty subjects with flatfeet (10 female, 10 male) and 20 subjects with normal feet (10 female, 10 male) were included in this study which was not case contolled. The mean age was 20.1 years (range, 19–23 years), mean height was 164.4 cm (standard deviation (SD), 9.2 cm), mean weight was 56.8 kg (SD, 7.9 kg) and mean shoe size was 25.2 cm

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(SD, 1.1 cm). The ethics committee of Hokkaido Bunkyo University approved all study protocols, and each participant provided written informed consent prior to enrollment.

The medial longitudinal arch height was evaluated using the bony arch index[12] (BAI). The BAI was calculated from the navicular height (h) divided by the foot length (l) (BAI=h/l). A low arch was defined as a BAI of less than 0.21 during a weight-bearing activity, a normal arch was regarded as a BAI between 0.21 and 0.27, and a high arch was regarded as a BAI greater than 0.27.

Body sway was evaluated based on the center of pressure (COP) while the subjects stood on level ground with their open. Body sway was measured during upright standing with the feet 10 cm apart for 30 seconds. The total locus length (TLL) and the area of body sway (ABS) were measured using a zebris FDM-SX system (zebris® Medical GmbH, Isny, Germany).

Measurements were taken under three sets of conditions: using BMZ insoles, which supported the cuboid; using Superfeet insoles (Impact Trading, Yokohama, Japan), which supported the medial longitudinal arch; and with no insoles. The three insole conditions were then compared.

Measurements were taken three times for each condition, and mean values were used for analysis. Reliability was assessed using an intraclass correlation coefficient (ICC, 2,1). Minimal detectable change was calculated using a 95% confidence interval. Statistical analysis was performed by three-way repeated measures ANOVA, and differences among the parameters were checked using the Bonferroni test. A p value of <0.05 was considered the level of significance.

Fig. 1. Superfeet (left) and BMZ insoles (right). The Superfeet insole supports the medial longitudinal arch, the BMZ insole supports the cuboid.

RESULTS

ICCs increased to above 0.8 ($p<0.05$). The TLL values with no insoles, with Superfeet insoles, and with BMZ insoles were 353.2±52.2 mm, 342.4±61.6 mm and 346.6±62.1 mm, respectively, in subjects with normal feet. In subjects with flatfeet, they were 456.0±55.5 mm, 428.1±53.5 mm, and 436.2±71.3 mm, respectively (Table 1).

On level ground, significant differences were found in TLL according to insole conditions in both flat-footed and normal-arched subjects, with the TLL values for Superfeet insoles being significantly lower than those for BMZ insoles and no insoles ($p<0.05$). Further, the values for the normal-arched feet group were significantly lower than those for the flat-footed group ($p<0.05$).

The ABS values with no insoles, with Superfeet insoles, and with BMZ insoles were 72.7±31.0 mm^2, 71.5±38.6 mm^2, and 82.4±51.1 mm^2, respectively, in subjects with normal-arched feet. In subjects with flatfeet, they were 103.3±56.5 mm^2, 91.1±40.0 mm^2, and with BMZ 99.8±52.8 mm^2, respectively (Table 2). On level ground, no significant difference in ABS value was found for any insole condition between subjects with flatfeet and those with normal-arched feet. However, the values for the normal-arched feet group were significantly lower than those for the flat-footed group ($p<0.05$).

DISCUSSION

We measured TLL and ABS for subjects with no insoles, Superfeet insoles, and BMZ insoles on level ground. The Superfeet insoles supported the medial longitudinal arch; however, the BMZ insoles, which are designed to support the cuboid, could provide stability to the lateral part of the foot.

The TLL values for subjects with Superfeet insoles were significantly lower than those for subjects with BMZ insoles and no insoles under all insole conditions. One pre-

Table 1. Total locus length$^{\#}$ (mm)

Category	No insole	Superfeet$^{\#}$	BMZ
Normal-arched feet group*	353.2±52.2	342.4±61.6	346.6±62.1
Flat-footed group	456.0±55.5	428.1±53.5	436.2±71.3

Values are expressed as means ± SD. *p< 0.05 (category), $^{\#}$p< 0.05 (type of insole)

Table 2. Area of body sway$^{\#}$ (mm^2)

Category	No insole	Superfeet	BMZ
Normal-arched feet group*	72.7±31.0	71.5±38.6	82.4±51.1
Flat-footed group	103.3±56.5	91.1±40.0	99.8±52.8

Values are expressed as means ±SD. * p< 0.05 (category) vious study reported better postural control in young subjects wearing plastic-textured insoles[13], but another did not observe improvement of balance in male athletes with two different foot orthoses[14]. Although there are many types of insole, consensus concerning which insoles are better has not been obtained. In this study, two different insoles were compared: the Superfeet insoles, which supported the medial longitudinal arch, and BMZ insoles, which have a structure designed to support the cuboid.

On level ground, Superfeet insoles were effective in stabilizing standing balance in both flat-footed and normal-arched subjects. Our study suggests that support of the medial longitudinal arch is important when standing. However, in daily life, individuals encounter not only level ground but also slopes of various degrees of tilt. Further study is needed to clarify the results when standing on uneven ground and while walking. The reason why the BMZ insoles were not effective maybe that BMZ insoles provide a rather low amount of support to the medial longitudinal arch. The medial longitudinal arch seems essential to stabilize postual sway, which standing still. However instability while standing on the ground might be better for initiation of dynamic motions such as walking or running. This is the first evidence of BMZ insoles on the ground. We measured TLL and ABS under static conditions while the subjects were standing still on the ground. Active condition such as walking or running might be needed to evaluate the effects of BMZ insoles.

This is the first evidence concerning BMZ insoles in subjects standing still on the ground. BMZ insoles represent a new concept in insoles in that they support the lateral part of the foot, and investigation of other types of environments such as uneven terrain, walking or running would be needed to determine if this insole is effective.

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