

Original Article

# The influence of revised high-heeled shoes on foot pressure and center of pressure during standing in young women

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**Abstract.** [Purpose] Revised high-heeled shoes were developed to minimize foot deformities by reducing excessive load on the forefoot during walking or standing in adult females, who frequently wear standard high-heeled shoes. Specifically, this study aimed to investigate the effects of revised high-heeled shoes on foot pressure distribution and center of pressure distance during standing in adult females. [Subjects and Methods] Twelve healthy adult females were recruited to participate in this study. Foot pressures were obtained under 3 conditions: barefoot, in revised high-heeled shoes, and in standard 7-cm high-heeled shoes. Foot pressure was measured using the Tekscan HR mat scan system. One-way repeated analysis of variance was used to compare the foot pressure distribution and center of pressure distance under these 3 conditions. [Results] The center of pressure distance between the two lower limbs and the fore-rear distribution of foot pressure were significantly different for the 3 conditions. [Conclusion] Our findings support the premise that wearing revised high-heeled shoes seems to provide enhanced physiologic standing posture compared to wearing standard high-heeled shoes.

**Key words:** Revised high-heeled shoes, Centre of pressure, Standing

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## INTRODUCTION

Ideal postural alignment is maintained not only by muscle activity but also by muscular forces interacting with the force of gravity while standing<sup>1)</sup>. Biomechanically, joint positioning while standing requires dynamic postural muscle activity to stabilize body posture against the line of gravity<sup>2)</sup>.

Therefore, the foot pressure distribution associated with joint positioning may reflect the overall postural alignment required to stabilize body posture within the base of support. High-heeled shoes (HHS) disturb the natural function and position of the ankle joint by forcing the foot into plantar flexion, with excessive vertical and shear stress on the medial forefoot<sup>3)</sup>. Recently, many studies have examined the consequences of this positional change in terms of balance, gait, and general well-being. Compared to standard HHS, a preliminary study indicated that the revised HHS placed 9.5% less weight on the forefoot and 10.5% more weight on the rearfoot while standing. About 10% of the rearward weight shift while standing was due to lowering of the heel

angle by 10–15° in the revised HHS design<sup>4)</sup>.

Revised HHS were developed to address the shortcomings of standard HHS. They are intended to normalize physiologic standing posture and walking pattern compared to standard HHS by making use of tunnel technology with excellent shock absorption and a rearward decrease in the wedge angle<sup>4)</sup>. However, it is not clear how much the revised HHS affect foot pressure distribution in response to altered postural alignment, with an approximate 10% rearward weight shift while standing<sup>4)</sup>. Therefore, this study aimed to investigate the effects of revised HHS on the distribution of foot pressure and center of pressure (COP) distance during standing in adult females.

## SUBJECTS AND METHODS

Twelve adult females (age: 18–25 years; height: 165.0 ± 4.8 cm; weight 56.7 ± 5.6 kg) were examined under 3 conditions: (1) barefoot, (2) in standard HHS with 7-cm heels, and (3) in revised HHS with 7-cm heels. All subjects gave informed consent as required by the institutional review board. All data were compared for the 3 conditions. The exclusion criteria were the presence or history of neurological or musculoskeletal disease. In addition, pregnant women or women who had any psychological disorder were excluded. Revised HHS were made using tunnel technology with excellent shock absorption and a rearward decrease of the wedge angle.

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Foot pressure was measured during standing tasks. The measured variables were COP distance from the heel end, and the distribution of left rearfoot, left forefoot, right rearfoot, and right forefoot pressures.

One way repeated analysis of variance (ANOVA) was performed to compare the 3 different conditions for each measurement using the Statistical Package for the Social Sciences version 21.0 (SPSS Inc., Chicago, IL, USA). Bonferroni adjustment was used for multiple comparisons under the 3 conditions, and  $p < 0.05$  was set to indicate the level of statistical significance.

## RESULTS

The left rearfoot pressure was 70.50% when barefoot, 29.50% when wearing revised HHS, and 24.00% when wearing standard HHS; there were significant differences between the 3 conditions. The left forefoot pressure was 29.50% when barefoot, 70.50% in revised HHS, and 76.00% in standard HHS, with significant differences observed between the 3 conditions. The right rearfoot pressure was 69.75% when barefoot, 28.50% when wearing revised HHS, and 23.00% when wearing standard HHS; there were significant differences between the 3 conditions. The right forefoot pressure was 30.25% when barefoot, 71.50% in revised HHS, and 77.00% in standard HHS, with significant differences present between the 3 conditions.

The COP distance was  $5.28 \pm 0.53$  cm when barefoot,  $10.43 \pm 1.75$  cm when wearing revised HHS, and  $12.23 \pm 1.03$  cm when wearing standard HHS; there were significant differences between the 3 conditions in the results of one-way repeated measures ANOVA for the change of COP distance (sum of squares = 329.07, degree of freedom = 2,  $F = 2749.45$ ,  $p < 0.01$ ).

## DISCUSSION

Wearing HHS results in an anterior and medial shift of forces within the foot; forefoot forces increase, and the force concentration, shear stress, and loading rate at the first metatarsal head dramatically increase, while those over the fifth metatarsal head decrease<sup>3, 5-8</sup>. This change in force distribution (as well as the often tight-fitting toe box of HHS) has been linked to forefoot deformities such as hallux valgus<sup>3, 6-10</sup>, and a correlation between heel height and hallux valgus prevalence has been inferred<sup>11</sup>. Other foot conditions linked to HHS include corns and calluses, metatarsalgia, Achilles tendon tightness, plantar fasciitis, and Haglund's deformity, a protrusion on the back of the calcaneus due to increased calcaneal pressure<sup>12</sup>. In this study, we aimed to investigate the effects of revised HHS on the distribution of foot pressure and COP distance during standing in adult females.

HHS induce greater plantar flexion, whereas flat heels induce greater dorsiflexion of the ankle. Therefore, compared to women wearing HHS, those wearing flat shoes use specific muscles more and shift their bodies anteriorly. The distribution of foot pressure moved from the rearfoot to the forefoot as the heel height increased. The peak pressures on the forefoot were 2.3-2.5 times greater than those on the

rearfoot in subjects wearing HHS. Increasing the heel height shifted the distribution of foot pressure toward the forefoot and altered the biomechanics<sup>5</sup>. Our study showed significant differences in the distribution of foot pressure between the 3 conditions, and wearing revised HHS was associated with less pronounced changes than wearing standard HHS. In particular, it seems that the excellent shock absorption and rearward decrease of the wedge angle achieved by using tunnel technology resulted in a more normal, physiologic standing posture and static balance when wearing revised HHS, compared to wearing standard HHS<sup>4</sup>. Thus, the pressure on the rearfoot was higher in the current study, whereas the pressure on the forefoot was lower.

COP can also predict dynamic balance ability<sup>13</sup>. Our study showed significant differences in COP distance changes between the 3 conditions, and these changes were less for revised HHS than for standard HHS. Therefore, revised HHS seem to minimize and restore the displacement of the COP. Our findings support the premise that wearing revised HHS seems to normalize physiologic standing posture more than standard HHS. Further research should be conducted, and the effect of revised HHS on posture should be examined in a larger number of subjects, using kinetics and kinematic methods.

The location of COP between the two lower limbs and the fore-rear distribution of foot pressure were significantly different under the 3 conditions. Our findings support the premise that wearing revised HHS seems to provide enhanced physiologic standing posture compared to standard HHS.

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