

Effect of revised high-heeled shoes on foot pressure and static balance during standing

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Abstract. [Purpose] The purpose of this study was to investigate the effects of revised high-heeled shoes on the foot pressure ratio and static balance during standing. [Subjects and Methods] A single-subject design was used, 15 healthy women wearing revised high-heeled shoes and general high-heeled shoes in a random order. The foot pressure ratio and static balance scores during standing were measured using a SpaceBalance 3D system. [Results] Forefoot and rearfoot pressures were significantly different between the 2 types of high-heeled shoes. Under the 3 conditions tested, the static balance score was higher for the revised high-heeled shoes than for the general high-heeled shoes, but this difference was not statistically significant. [Conclusion] Revised high-heeled shoes are preferable to general high-heeled shoes, as they result in normalization of normalized foot pressure and a positive effect on static balance.

Key words: Revised high-heeled shoes, Foot pressure, Static balance

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INTRODUCTION

High-heeled shoes (HHSs) are defined as shoes in which the heel is higher than the forepart. HHSs often also include a narrow toe box, rigid heel cap, and curved plantar region, all of which interfere with natural foot motion. HHSs have been worn for several centuries¹⁾, and despite numerous cautions against their use, they remain extremely popular. Surveys suggest that 37% and 69% of women wear them in their daily lives, representing a huge proportion of the female population²⁾.

The use of HHSs cause abnormal postural alignment, particularly in the lower limbs and spine³⁾. Thus, increased forward head posture, lumbar hyperlordosis, pelvic anteversion, and valgus knees. Standing in HHSs causes immediate and temporary postural changes because of forward shifting of the center of gravity³⁾. When HHSs are removed, the body goes back to its original alignment. However, previous studies⁴⁾ indicated that the permanence of postural changes with excessive use of HHSs.

Additionally, wearing HHSs has been associated with an

increased potential for slips and falls because the consequent changes in local sensation around the ankle may affect posture balance in women⁵⁾. If the heel height is >5 cm, women tire easily because it is more difficult for the feet to balance the body weight⁵⁾.

Revised HHSs were developed to address the weaknesses of general HHSs. They attempt to provide a more normal physiologic standing posture and static balance than general HHSs by making use of tunnel technology with excellent shock absorption and a rearward decrease in the wedge angle. The purpose of this study was to investigate the effects of revised HHSs on the foot pressure ratio and static balance during standing.

SUBJECTS AND METHODS

The subjects were 15 young women (21.7 ± 2.1 years; 161.2 ± 5.8 cm; 50.4 ± 5.6 kg) in one of two conditions: (1) wearing general HHSs with a heel height 7 cm, or (2) wearing revised HHSs with a heel height 7 cm. All data were compared only within groups between study conditions. All participants gave informed consent as required by the Institutional Review Board. Exclusion criteria were past or present neurological or musculoskeletal diseases, contractures of the lower limbs, and significant weakness of the quadriceps muscles that would preclude full knee extension while sitting. In addition, pregnant women or women with any psychological problems were excluded. In order to get familiar with the test shoes, subjects were allowed to

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wear several different sizes, and were allowed to familiarize themselves with the walk around.

Foot pressure ratio and static balance were measured during standing tasks using a SpaceBalance 3D system (CyberMedic Corp., Iksan, Republic of Korea). The SpaceBalance 3D system was equipped with 2 wireless force plates (foot placement: 20 cm from heel to heel and 24 cm from toe to toe) that recorded the weight distribution of 4 zones (front, back, left, and right), and a sensor located in the front measured plate inclination. During measurements, the subjects looked at a monitor and did not move their feet. The foot pressure ratio was calculated as the ratio between the front and back pressures and, expressed as a percentage (%). Static balance was evaluated under 3 conditions (eyes open, eyes closed, screen blocked), and the balance posture ratio (BPR) score was calculated by multiplying by a weight (A= 100%, B= 80%, C= 60%, D= 40%, and E=20%) to zone (A–E) ratio.

Data analysis was performed using SPSS version 21.0 (IBM Corporation, Armonk, NY, USA). The Kolmogorov-Smirnov test was used to assess the normality assumption. After verifying that the data were normally distributed, all analyses were conducted using parametric tests. The independent t-test was used to compare the data between the revised HHSs and general HHSs. Null hypotheses of no difference were rejected if p-values were <0.05.

RESULTS

The forefoot pressure ratio was 51.5% for the revised HHSs and 62.0% for the general HHSs, and the differences between the HHS conditions were significant. The rearfoot pressure ratio was 48.5% for the revised HHSs and 38.0% for the general HHSs, and the differences between the HHS conditions were significant. The static balance score was higher for the revised HHSs than for the general HHSs under all 3 conditions. However, the differences between the two types of HHS were not statistically significant (Table 1).

DISCUSSION

Standing while wearing HHSs causes forward weight shifting due to the change in the plantar pressure and in the location of the center of gravity (CG)³. Wearing HHSs first provoke elevation of the calcaneus bone⁶. Changing the forward displacement of the CG, resulting in postural imbalance and promoting adaptive postural adjustments for balance recovery^{3, 6}. This occurs because of the adaptability of the postural system, which meets the demands of the excessive or attenuated postural muscle activities against gravity. So that, either by increasing the heel height, or decreasing the base of support, results in joint pain, muscle shortening, and forefoot deformities³.

Revised HHSs were developed to address the weaknesses of general HHSs, and the purpose of this study was to investigate the effects of revised HHSs on the foot pressure ratio and static balance during standing.

When wearing general HHSs, the pronounced misalignment of the ankle in plantar flexion and increased plantar pressure in the forefoot area promote overload of

Table 1. Comparison between the general and revised high heeled shoes (HHSs)

Variable	Revised HHSs	General HHSs
Forefoot (%)	51.5 ± 4.9	62.0 ± 7.3*
Rearfoot (%)	48.5 ± 4.4	38.0 ± 5.8*
Eyes open (score)	90.7 ± 5.2	88.7 ± 4.9
Eyes closed (score)	88.2 ± 6.8	85.1 ± 6.2
Screen blocked (score)	88.2 ± 7.1	87.0 ± 6.0

*p<0.05

the forefoot⁷. Schwartz et al. demonstrated that at a 5-cm heel height, pressure under the forefoot increases and heel pressure decreases⁸. Consequently, the ankle joint axis moves anteriorly, and the line of gravity moves posteriorly toward the ankle joint^{9, 10}. Moreover, Van der Leeden et al. established a relationship between joint damage and increased forefoot pressure¹¹. In the same way, a reduction in the weight bearing area in HHSs can result in pain¹². Furthermore, the thinner the shoe heels, the greater the instability of the ankle, the overall imbalance, and the postural impairment³. This suggests that an anterior weight transfer mechanism occurs with the use of HHSs. However, habitual wearing of HHSs seems to lead to greater strength through the range of ankle joint plantar flexion, compensating for the loss of control^{13–15}.

Our study demonstrated that revised HHSs produce significantly higher rearfoot pressure and lower forefoot pressure than general HHSs. Additionally, revised HHSs have a greater positive effect than general HHSs on static balance. Revised HHSs seem to normalize physiologic standing posture and static balance by making use of tunnel technology with excellent shock absorption and a rearward decrease in the wedge angle. In conclusion, this study showed that in comparison with general HHSs, revised HHSs produce higher pressure on the rearfoot, lower pressure on the forefoot, and improved balance control.

The only limitation of this study is that the alteration during standing for the revised HHSs was not based on a sufficient variety of methods. Further research should be conducted to determine the effects of the use of revised HHSs on posture with a larger number of subjects and a variety of methods.

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