The Outsole Pressure Distribution Character during High-heeled Walking
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Abstract
This study analyzed the foot loading on the outsole area while walking in high-heeled shoes. Twelve healthy female volunteers have participated in the test with the heel height of the shoe varied from 0cm, 4.5cm and 8.5cm. The results of this study shows that increasing heel height could increase the peak pressure value in the outsole’s forefoot and heel area. The force-time integral value indicates the heel region is in the reverse direction comparing to the peak pressure, this reflects the impulse in the heel region is decreased when the heel height increased, and the outsole’s high peak pressure of heel was majorly caused by the heel contact area. The high-heeled shoes would make incontrovertible fashion comeback, but the distinctively effect to the foot kinetics should be noticed.

Keywords: Outsole pressure; high-heeled shoes; walking;

1. Introduction

High-heeled shoes, which made female look elegant and sexy, always become a popular choice among women. Although this fashion is intended to be uncomfortable, few women plan to give up their high heels. Biomechanical studies showed that walking in high-heeled shoes may alter lower-extremity joint function [1], raise the peak pressure in the forefoot [2], and change the load distribution on the media foot region [3]. Among all the biomechanical experimental methods, pressure measurement is considered as a practical method to evaluate the effects of the design attributes of footwear and could provide crucial data in the management of foot problems [4-6]. However, most previous researches on the pressure data were

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focused on the insole plantar pressure, the information about shoe’s outsole was quite limited. The purpose of this study is to experimentally characterize the high-heeled pressure data between the outsole and ground.

2. Methods

Twelve healthy female subjects have volunteered to participate in this biomechanical test and data collection. The average age of the subjects was 22 years (range 20-25), average weight was 49 kg (range 45-53), and average height was 161 cm (range 158-165). The subjects’ feet were clinically checked to ensure that there was no recent injury phenomenon. All participants were high-heeled shoes regular wearers with more than two years history. The high-heeled shoes used in this study were commercially available items with similar construction and sole materials. The main difference among these shoes (Fig.1) was the height of the heel designated as: a flat, a low(4.5cm), a high heel (8.5cm).

The outsole pressure data was measured through the Novel e-med system (Novel GMBH, Munich, Germany), which is an automated, digitized pressure platform that analyzes pressure, force, and area data along the contact surface during static or dynamic movement. The resolution of this system is 0.25 sensors/cm², and the sensor area of the platform measures 475mm×320 mm, with a total of 6080 sensors, and a pressure range of 10–1270 KPa. The subjects were asked to walk in a straight line for about 20 meters with each new type of shoes at their own pace before the test. After habituating to the heel height, participants randomly selected shoes and walked for a distance of 20m three times. The platform was employed in the middle of the walking way. Data analysis was conducted with Novel Database Pro software package. Statistical data analysis was conducted in the statistical software package SPSS (version 13.0). Analysis of variance (ANOVA) was employed to study the effects of heel height, and Turkey’s HSD test was used for post hoc comparison with the level of statistical significance was set at the 5% level.

Fig.1. Shoes of three different heel heights used in the study. From left to right: a flat, a low, and a high heel.

3. Results

Fig.2 shows the typical peak pressure distribution of outsole with flat and high heel shoes during normal walking. It clearly displays that the outsole pressure distribution pattern has changed a lot when the heel height increased, especially in the heel and mid-foot region. Comparing to the flat shoes, peak
pressure of high-heeled shoes was highly elevated in heel and forefoot regions, but mid-foot’s pressure was disappeared.

Fig. 2. Peak pressure distribution pattern in flat shoes (a) and high heel shoes (b) during walking.
Fig. 3 illustrates the comparison of peak pressure in three major foot regions during walking under different heel height. It is clearly shows that peak pressure of heel, medial forefoot (MF) and lateral forefoot (LF) were significantly increased in heightened heel shoes comparing to wearing the flat heel height shoes. Peak pressure in high heel shoes also significantly larger than the value in low heel shoes where was appeared in heel and MF areas. The largest increasing value of peak pressure between flat and low heel conditions was appeared in heel region, which was up to 467%.

Meanwhile, force-time integral value during walking in MF and LF are significantly increased in heightened heel shoes comparing to the flat heel height condition. However, this value is significantly decreased in heel region as the heel increased. Only in MF region that the force-time integral value exists significant difference between the low and the high heel height conditions. In addition, this value is quite close in the heel region between the low and the high heel shoes conditions.

Fig. 3. Comparisons of peak pressure in different foot regions with different heel height. (Significant change *P < 0.05)

Fig. 4. Comparisons of force-time integral in different foot regions with different heel height. (Significant change *P < 0.05)
4. Discussion

The results of this study shows that increasing heel height could increase the peak pressure value in the outsole’s forefoot and heel area. Previous studies in high-heeled gait reported that the heel height could elevate the plantar peak pressure in the forefoot, but the heel region plantar pressure was reduced [6, 7]. The different between the plantar pressure and outsole pressure is caused by the shoe’s structure. Because of the most of the high-heeled shoes’ design in the heel region was very small contact area with ground which is the major reason increasing the outsole’s peak pressure during walking. According to the force-time integral value, the heel region is in the reverse direction comparing to the peak pressure, this is able to explain the impulse in the heel region is decreased when the heel height increased. Also, it agrees with the former explanation of the outsole’s high heel peak pressure was majorly caused by the heel contact area.

Another interesting finding is that the pressure of mid-foot area of the outsole was disappeared during high-heeled walking. This may be one reason relates to some foot problems under high-heeled walking [8, 9]. As the outsole contact area reduced in the high-heeled shoes, this indicates clearly impairing the balance ability, increase the likelihood of accident injury. Although the high-heeled shoes would make incontrovertible fashion comeback, the distinctively effect to the foot kinetics should be highly noticed. The high pressure of heel in the high-heeled shoes’ could cause damage easily to the shoes’ heel structure, which should be paid important attention in the footwear design process. The contact area effect of high-heeled outsole to the foot kinetics could be investigated in future studies.

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References