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The Effectiveness of Personalized Custom Insoles on Foot Loading Redistribution during Walking and Running

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Abstract. The objective of this study was to investigate the effectiveness of different hardness of personalized custom insoles on plantar pressure redistribution in healthy young males during walking and running. Six males participated in the walking and running test (age: 24±1.6 years, weight: 67.9±3.6 kg, height: 175.5±4.7 cm). All subjects were instructed to walk and run along a 10m pathway wearing two different hardness insoles (i.e., hard custom insoles (CHI) and soft custom insole (CSI)) and control insole (CI) at their preferred speed. Peak pressure, mean pressure, maximum force, pressure-time integral were collected to analyze using SPSS. The plantar pressure of forefoot and medial midfoot were significantly increased and of lateral forefoot and lateral midfoot were decreased by both kinds of custom insoles in running tests. While the CHI significantly increased plantar pressure of the medial forefoot compared with the CSI and CI both in walking and running tests. The custom insoles showed significantly higher plantar pressure on medial midfoot. But CSI seems better than CHI because of redistributing the plantar pressure by increasing the plantar pressure of whole forefoot. Moreover, CSI showed significantly lower plantar pressure than CI and CHI at lateral midfoot during running test. The CHI causes significant high pressure at medial forefoot (MF), which may raise the risk of forefoot pain.

1 Introduction

The footwear took a blossom development with increasingly people seeking for health and sports. The industry of footwear designing and manufacturing of footwear becomes more complex. Different materials are selected with respect to their functional requirements, especially in sports shoes. Tong et al. reported that comparison of four podiatry clinic materials i.e., SRP-Slow Recovery Poron (extra soft 4790-92), P-Poron (soft 4708-blue), PPF-Poron (soft 6708-blue) plus Plastazote (firm 30 Shore A durometer) and PPS-Poron (soft 4708-blue) plus Plastazote (soft 15 Shore A durometer) used in the fabrication of simple insoles which were able to reduce the pressure and the PPF significantly reduced the foot pressure(Tong et al., 2010). Previous studies also concluded that young men (mean age33 (±11.13) years) and old men (mean age69 (±1.1) years) wearing firm midsole to walk on a narrow beam can keep stability better than soft midsole and less fall from the beam was seen(Robbins et al., 1992, Robbins et al., 1994). Furthermore, they found the relation between sole hardness and plantar pressure. Plantar pressure increases with the growth of shoe sole hardness. However, the wearing comfort has no significant difference among all experimental shoes(Lane et al., 2014). Most current studies focus on the sole hardness of elderly, but healthy or young men have received insufficient focus on this issue. Therefore, this study aimed to explore the plantar pressure redistribution of healthy young people with different hardness insoles, especially during running.

As the improvement of technique and designing of footwear, personalized customization becomes popular in recent years. Custom insoles are produced by various approaches. Tsung et al.

using foot impression casts and a commercial 3D digitizing system made three contoured insoles from three different loading conditions for diabetic patients and normal control subjects to compare the function of three custom insoles on relieving plantar pressure during walking. And they concluded that the insole made from semi-weight loading condition, provided more stable standing posture with lowest plantar pressure among all experiments insoles(Tsung et al., 2004). Then, some studies compared two kinds of custom insoles made from computer aided designing and computer aided manufacturing (CAD-CAM) and foam impression cast approaches. They found both kinds of insoles can redistribute plantar pressure, which decreased plantar pressure on heel and increase plantar pressure on middle arch. There is a difference in plantar pressure at central forefoot between two insoles, which the plantar pressure is lower in insoles made by CAD-CAM method than foam impression cast method(Ki et al., 2008). Moreover, it has been shown that the shape of custom insole played the most crucial role on relieving plantar pressure, then the insole stiffness played the second most important role(Cheung et al., 2008). Meanwhile the other factors, such as arch type, insole thickness, midsole stiffness and thickness are less important. This information is the foundation to enhance the manufacture and designing of custom insole as well as the disciplines for health people choosing footwear. Foot morphology is a distinctive feature from person to person. The insole made from silicone vacuum bag technique can conform to different foot plantar(Caravaggi et al., 2016). This method was also used by several brands in the modern market. However, there are little literature to evaluate the plantar pressure redistribution with combination the personalized shape and different hardness of custom insoles.

The objective of this study was to investigate the effectiveness of personalized custom insoles with different hardness on plantar pressure redistribution during walking and running in healthy young males. We hypothesized that the different hardness insoles would redistribute the plantar pressure, and as a result, the plantar pressure at medial midfoot would be increased. Another objective is to compare whether the soft custom insole or the hard one seems better in plantar pressure redistribution.

2 Method

2.1 Subject

Six male subjects from 23 to 26 years old (24±1.6), volunteered in this study, and their feet were absent of foot deformities or any history of diseases. The average weight of subjects is 67.9(±3.6) kg, average height is 175.5(±4.7) cm. All subjects signed a consent form for participation in this study which was approved by the Research Academic of Grand Health Ethics Committee (RAGH20160318).

2.2 The execution procedure of custom insoles

In this study, each subject has three pairs of insoles: (a) flat, control insoles; (b) personalized, soft custom insoles, and; (c) personalized, hard custom insoles. The control insoles were pre-fabricated in foam with a Shore C of hardness 30 without any contoured shape, which means virtually flat.

The soft and hard custom insoles were personalized and shape-based on each subject's plantar impressions. The plantar impressions were taken under a relaxed stand with body weight evenly distributed on both feet. Each subject was instructed to stand on a machine which has two silicon balloons, and left his or her plantar impressions on it in order to mold insole-shaped moulds.

The materials of soft and hard custom insoles were same and consisted of two layers: the upper layer is in foam; the lower layer is in thermoplastic. All the materials have been widely used in modern markets. Through heating and cooling, the custom insoles were shaped based on each subject's feet mould, and provided fitted and personalized support for the forefoot, midfoot and heel.

The three type insoles as seen in Figure.1 were assessed:

(a) Control insole (Figure.1, a): CI, Shore C 30.

(b) Soft custom insole (Figure.1, b): CSI, Shore A75 thermoplastic at midfoot and heel, full arch support, heel reinforcement.

(c) Hard custom insole (Figure.1, c): CHI, Shore A150 thermoplastic at midfoot and heel, full arch support, heel reinforcement.

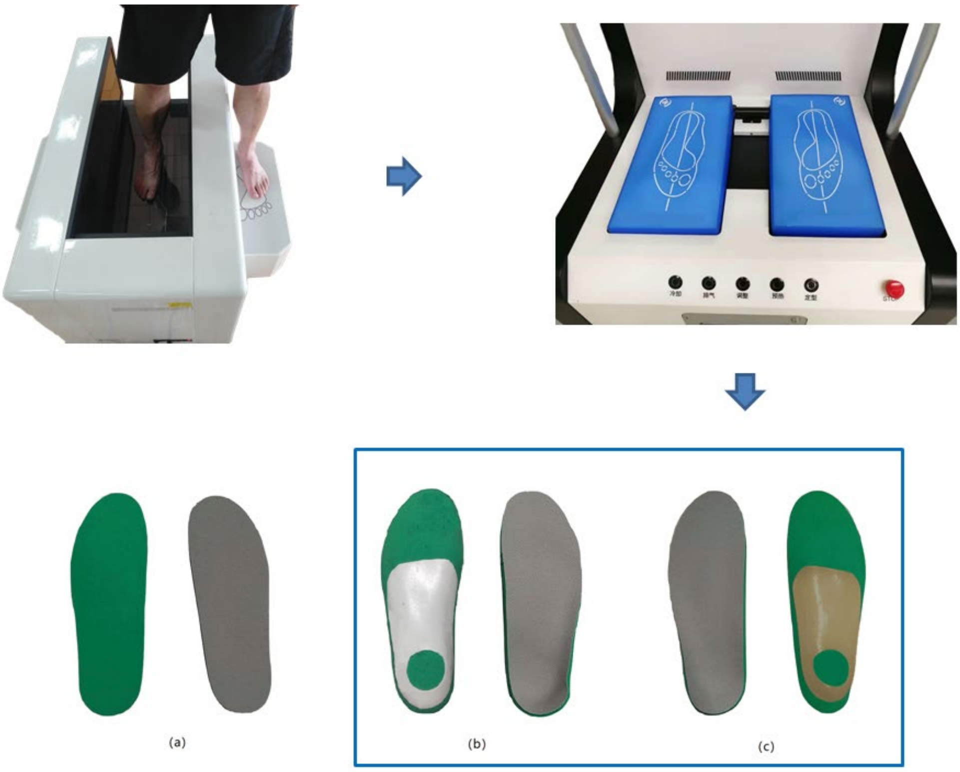

Fig. 1. Illustration of the custom procedure of experimental insoles: a, control insole; b, custom insole with soft material; c, custom insole with hard material

2.3 Protocol

This study was conducted in the sports performance laboratory of the Research Academic of Grand Health in Ningbo University. After a sufficient time to familiar the experimental insole condition, all subjects were instructed to walk and run along a 10m pathway at their preferred speed. Moreover, the running speed had to be hold within in ±5% of the chosen velocity of each subject to minimize the influence of velocity on plantar pressure. Plantar pressures were measured with a sensory insole system (pedar-X®, Novel). 6 successful trials were recorded for each kind of experimental insole per subject.

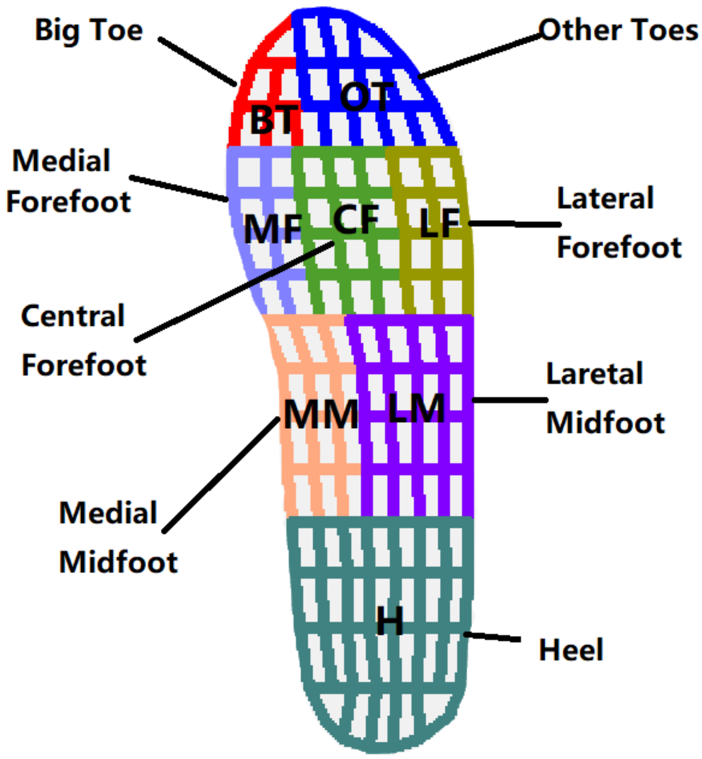

Fig. 2. Partition of foot plantar for plantar pressure measurement

2.4 Data analysis

The data was acquired from the dominate foot of every subject, in this study all subjects dominated in the right foot. And the stabile step at middle of the trial was considered to be chosen for analysis. Peak pressure, mean pressure, maximum force, pressure-time integral were collected to analyze using SPSS Statistical Package. The foot plantar was divided into eight regions (as shown in figure 2): BT (big toe), OT (other toes), MF (medial forefoot), CF (central forefoot), LF (lateral forefoot), MM (medial midfoot), LM (lateral midfoot), H (heel). After checking the normality of the variables, a one-way test was performed for the data followed by a post hoc test corrected for multiple comparisons to detect the effect of three insole conditions. The significance level was set as 5% ($p<0.05$).

3 Result

As shown in figure 3-a and 3-c, the CSI and CHI caused a significant higher mean pressure at MM ($p=0.002$, $p=0$) and H ($p=0.015$, $p=0.008$), and maximum force ($p=0.001$, $p=0$) at MM than the CI during walking. Meanwhile, both the custom insoles caused a decreased pressure-time integral at CF ($p=0$, $p=0.018$) regions.

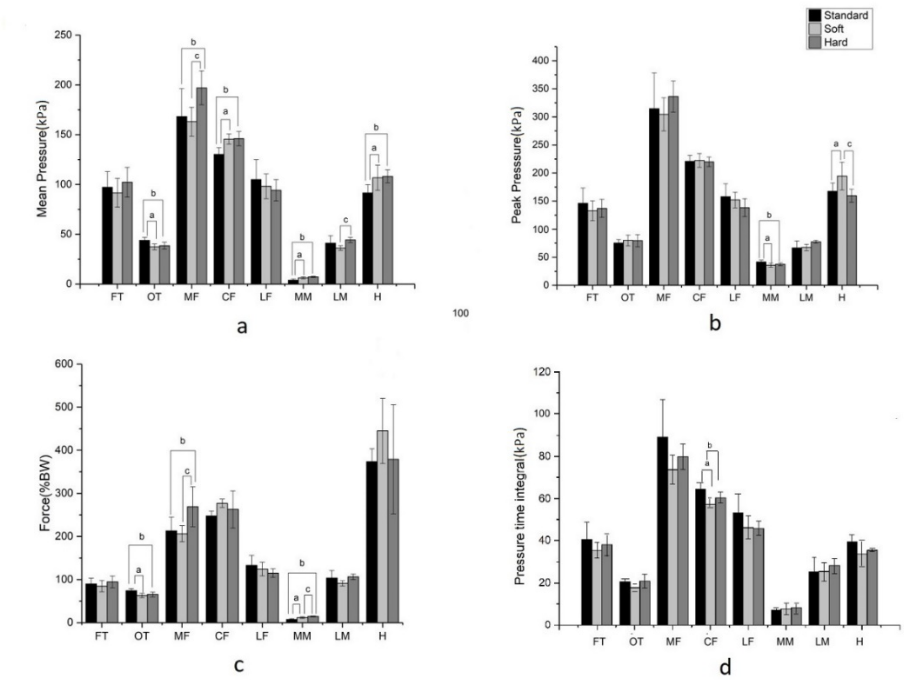

Fig. 3. The mean pressure, peak pressure, maximum force and pressure-time integral of subjects for each insole condition during walking. [a] denotes statistically significant difference between standard insole and soft insole ($p<0.05$), [b] denotes statistically significant difference between standard insole and hard insole ($p<0.05$), [c] denotes statistically significant difference between standard insole and hard insole ($p<0.05$)

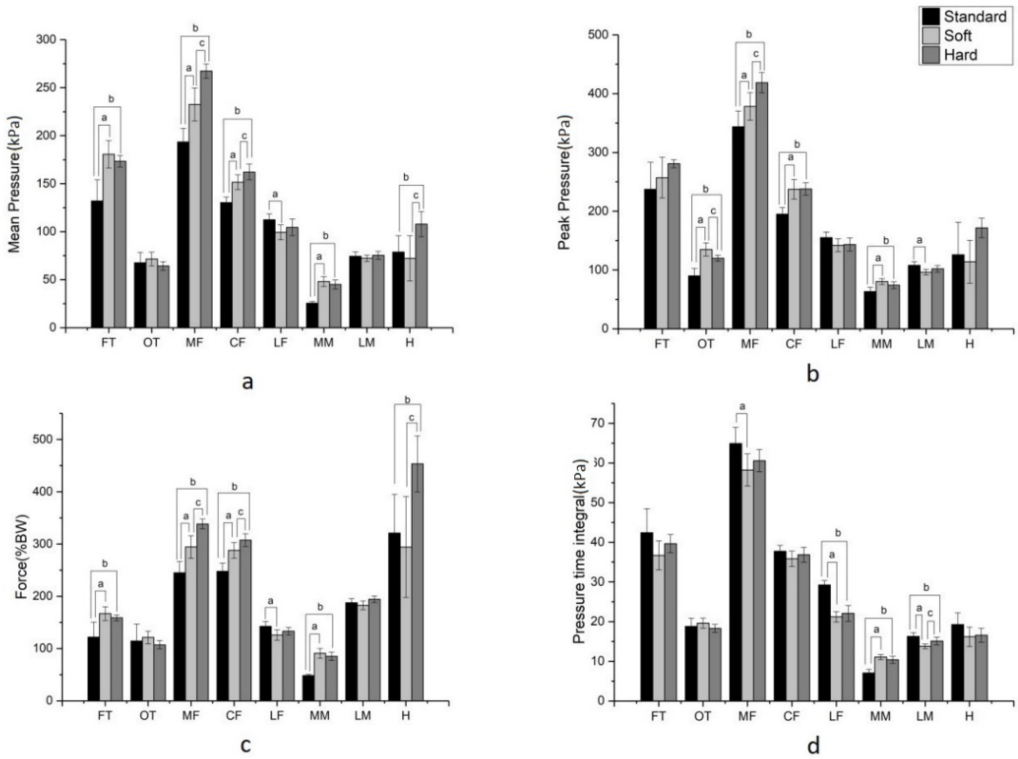

Fig. 4. The mean pressure, peak pressure, maximum force and pressure-time integral of subjects for each insole condition during running. [a] denotes statistically significant difference between standard insole and soft insole ($p<0.05$), [b] denotes statistically significant difference between standard insole and hard insole ($p<0.05$), [c] denotes statistically significant difference between standard insole and hard insole ($p<0.05$)

Comparing with the CI during running, custom insoles (CSI and CHI), as seen in figure 4-a, showed significantly higher mean plantar pressure at BT (p=0, p=0), MF (p=0, p=0), CF (p=0, p=0) and MM (p=0, p=0) regions; significant higher peak pressure (Figure 4-b) at OT (p=0, p=0), MF (p=0.019, p=0), CF (p=0, p=0) and MM (p=0, p=0.007) regions ; increased maximum force (Figure 4-c) at BT (p=0, p=0), MF (p=0, p =0), CF (p=0, p =0) and MM (p=0, p=0) regions. However, both CSI and CHI in figure 4-d showed significantly lower pressure-time integral at LF (p=0, p=0) and LM (p=0, p=0.029) regions during running.

Significant differences were found between CSI and CHI. As for Two types of custom made insoles, CHI showed higher mean pressure than CSI at MF, CF and H (p=0, p=0.012, p=0.004) during running and at MF (p=0.012) during walking. In particular, CSI showed even lower mean pressure than CHI at LM (p=0.11) during walking.

Furthermore, CSI had smaller pressure-time integral at MF than CI (P=0.007), and CSI also had smaller pressure-time integral at LM than CI and CHI (p=0, p=0,018) during running.

4 Discussion

The aim of this study was to investigate the effectiveness of soft and hard custom insoles on plantar pressure redistribution during walking and running. It shows that custom insoles could significantly increase the plantar pressure on MM region, which exhibited same result as previous finding(Lee et al., 2012).

This investigation also found that maximum force and mean pressure of MM were significantly increased while wearing CHI and CSI during walking, which showed lower maximum force, mean pressure at other toes (OT) than CI. These two findings demonstrated that both CHI and CSI increased plantar pressure at foot arch and relieved plantar pressure at OT, which indicated that the redistribution of plantar pressure on foot plantar may be caused by two types of custom made insoles. These findings are consistent with previous study(Chen et al., 2003), which found custom insole could provide appropriate support to show a more average redistribution of plantar pressure over whole foot and altered the pressure of other regions and arch.

As shown in the result during running test, while wearing CHI and CSI MM region exhibited an increased pressure-time integral, but LM and LF regions exhibited a decreased pressure-time integral. This phenomenon may be explained by the sufficient support on foot arch by custom insoles, meaning maybe larger contact area at MM region and longer roll over time against the support surface. The joint effect with the longer pressure time and increased pressure result in the increase in pressure time integral at MM region(Tsung, Zhang, Mak and Wong, 2004), but the pressure-time integrals of LF and LM were significantly decreased when running with CHI and CSI. These finding demonstrated that CHI and CSI can reduce the plantar pressure of foot on the lateral side (LF and LM) and increase in MM. It has been reported that the elderly with forefoot pain have high plantar pressure on lateral forefoot(Menz et al., 2013, Waldecker, 2002), therefore, the previous studies also proved that the custom made insole can reduce the pressure-time integral on LF and LM. Custom insoles can effectively relieving pain, but whether these custom insoles used in this study can relieve forefoot pain still need further investigation(Gijonnogueron et al., 2013, Hirschmuller et al., 2009, Witana et al., 2009).

It should be noticed that in this study plantar pressure of MF and CF were significantly increased during walking and running with custom insoles (CHI and CSI). Especially in contrast to CI during running, the maximum force, peak pressure and mean pressure at MF region of CHI were increased 38%, 21%, 38% respectively. The maximum force, peak pressure and mean pressure of CF while wearing CHI were increased 25%, 21%, 24% respectively. Previous studies have reported that the peak pressure of heel, midfoot and forefoot can be increased along with the increasing of sole hardness. It has also suggested that wearing hard sole can enhance stability and balance during walking (Menant et al., 2008, Menant et al., 2008, Robbins, Gouw and McClaran, 1992).

Meanwhile, this study investigated which custom insole (CHI and CSI) could better redistribute plantar pressure and bring as less negative influence on foot function as possible. It shows that the plantar pressure of CHI was significantly higher than CSI at MF during walking and running. Additionally, hard custom made insole (CHI) showed higher pressure-time integral on MF as well as significantly higher maximum force, mean pressure on H than soft custom made insole (CSI). Because of same material used to cast these two types of experimental insole, hardness might be the primary reason of increasing the plantar pressure. But, no significant difference of pressure-time integral showed on MM region between CHI and CSI. This is an important finding indicated that without significant difference of redistribution plantar pressure on MM region, CHI was significantly increased the plantar pressure on forefoot (MF) compared to CSI.

In this study, we tested the effectiveness of different hardness custom insoles for redistributing plantar pressure during walking and running in health young man. Three types of insoles were compared the effect of hardness on plantar pressure redistribution. The result exhibited that the custom insoles (CSI and CHI) could significantly increase the plantar pressure on midfoot of both medial and lateral sides (MM and LM). However, the CHI significantly increased the forefoot (MF and CF) pressure, this may potentially raise the risk of forefoot pain.

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