Gait & Posture 58 (2017) 94–97

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Adding an arch support to a heel lift improves stability and comfort during gait

Xianyi Zhang[a,b], Bo Li[a,*], Kun Hu[c], Qiufeng Wan[a], Yuhao Ding[a], Benedicte Vanwanseele[b]

[a] Key Laboratory of Leather Chemistry and Engineering of Ministry of Education, Sichuan University, Chengdu, PR China
[b] Department of Kinesiology, KU Leuven, Leuven, Belgium
[c] Guangdong Huizhou Quality & Measuring Supervision Testing Institute, Huizhou, PR China

ARTICLE INFO

Keywords:
Heel lift
Arch support
Center of pressure
Comfort

ABSTRACT

Heel lifts have been widely used as a conservative treatment for some musculoskeletal problems and complaints. However, the heel rise caused by heel lifts may also affect the plantar pressure distribution and stability during walking. This study aimed to test whether adding an arch support to a heel lift would improve its stability and comfort through comparing the center of pressure (COP) during walking and subjective ratings between heel lifts with and without an arch support. Fifteen healthy male participants were asked to walk along an 8 m walkway while wearing high-cut footwear with the control heel lifts and the heel lifts with an arch support. A Footscan pressure plate was used to measure the COP during walking. Subjective ratings including medial-lateral control, dynamic foot/shoe fitting and overall comfort were assessed for each participant. The results showed that compared to the control condition, the COP trajectory was medially shifted during stance phase of gait in the arch support condition. The maximum displacements and velocity of medial-lateral COP in the forefoot contact phase were smaller in the arch support condition than in the control condition. Adding an arch support to a heel lift also significantly improved the subjective ratings in terms of the medial-lateral control, dynamic foot/shoe fitting and overall comfort. The findings of this study suggest that adding an arch support to a heel lift could improve its stability and comfort during walking.

1. Introduction

In-shoe heel lifts are used as a conservative treatment in many cases of lower extremity disorders, e.g. Achilles tendon disorders [1], heel pain [2], lower back pain [3] and leg length discrepancy [4]. Especially in Achilles tendon disorders, heel lifts can decrease the tensile forces in the triceps surae by inducing plantar flexion at the ankle joint [1]. The increased heel height also shortens the distance between the calcaneus and metatarsals, thereby reducing strain in the plantar aponeurosis [2]. As elevating the rearfoot may alter muscle activation during gait, heel lifts have been used for relieving low back pain [3]. In-shoe heel lifts are also adopted as a leg length adjustment device for leg length discrepancy [4].

Despite perceived benefits of heel lifts, their properties, e.g. materials and shape, may have an influence on the effectiveness. Researchers have shown concerns in increases of plantar pressure under the forefoot and decreases of balance due to conventional heel lifts [5–7]. As the rearfoot is elevated by the heel lifts, the plantar pressure transfers from the rearfoot to the forefoot, which may increase the development of ulcer in diabetic population [8]. Moreover, heel lifts raise the body's center of mass, consequently decreasing the stability during ambulation. Increases in the heel lift height also coincide with an increase in the displacement and velocity of the center of pressure (COP) during walking [6]. Previous studies have shown that the material of heel lifts also have an influence on the plantar pressure distribution and balance control [5,6].

In order to reduce the side effects of conventional heel lifts, improvements on the design are required. To reduce the peak pressure under forefoot and midfoot, an insole with an arch support has been commonly adopted to improve plantar pressure distribution [7,9]. In addition to redistributing plantar pressure, the arch support has been used to improve balance through supporting the medial longitudinal arch to control foot pronation during running [10]. Studies on the elderly also suggest that an arch support improves balance control during gait [11]. Moreover, an arch support provides external support to the longitudinal arch, consequently reducing the stress in the plantar aponeurosis [2]. Therefore, adding an arch support might minimize the adverse effect of a heel lift by redistributing plantar pressure and supporting the medial longitudinal arch.

The authors previously proposed an optimized design of heel lifts

* Corresponding author.
E-mail address: Lib@scu.edu.cn (B. Li).

http://dx.doi.org/10.1016/j.gaitpost.2017.07.110
Received 4 March 2017; Received in revised form 28 June 2017; Accepted 20 July 2017

and assessed its effects on plantar pressure distribution and medial-lateral stability during walking. This optimized heel lift, which consisted of an arch support, reduced the peak plantar pressure and force-time integral [9]. However, the comparison in our previous study was made between flat shoes with and without the optimized heel lifts. Therefore, it is difficult to assess the added value of our new design compared to the conventional heel lifts. In addition, the effect of the new design on balance control was not examined. Hence, the role of an arch support in improving the stability of heel lifts during walking remains unclear. Therefore, the main purpose of this study was to assess the added effect of an arch support in heel lifts on stability control during walking by analyzing detailed COP variables and subjective ratings. We hypothesized that a heel lift with an arch support would improve the stability and comfort, compared to a heel lift without an arch support.

2. Methods

2.1. Participants

An a priori sample size calculation was performed based on our previous published data. With a power of 80% and an α level of 0.05, a minimum sample size of 14 participants was required. A total of fifteen healthy male adults were recruited in this study. Ethics approval was granted by the Medical Ethics Committee of West China College of Public Health of Sichuan University and written informed consent was provided by each participant. The average age of the participants was 22.4 years (SD 1.2), average mass 59.1 kg (SD 7.3), and average height 169.7 cm (SD 5.1). All participants had the same shoe size for the convenience of the COP analyses. None of the participants had any lower extremity injuries for the last 6 months prior to testing. All participants had normal arches, with the arch index (AI) being $0.21 < AI < 0.26$ [12]. The arch index was calculated by the Footscan analysis software (RSscan International, Belgium) based on the dynamic pressure data that was recorded by a Footscan pressure plate.

2.2. Materials and apparatus

A 1 m Footscan® pressure plate (RSscan International, Belgium) was used to record COP coordinates at a measurement frequency of 250 Hz. Displacement of COP in the medial-lateral direction was defined with respect to the x-axis, perpendicular to the longitudinal foot axis. This longitudinal foot axis was defined as the line from mid-heel to forefoot, between metatarsal head 2 and 3. An Infoot 3D foot scanning system (I-Ware Laboratory Co., Ltd, Osaka, Japan) was used to capture foot dimensions. High-cut canvas footwear with a flat outsole was selected for our experiment.

2.3. Heel lift design and manufacture

The design of heel lifts followed the methods described in our previous study [9]. The foot plantar contour was captured by an Infoot 3D foot scanning system while participants were standing in a neutral position, with a pair of flat heel lifts of 25 mm height under their feet. The designed heel lift was extended from the heel to the posterior side of the metatarsophalangeal joint, with a height of 25 mm, and made of EVA with shore hardness of A 32. A heel cup matching the contoured heel, which is often adopted in custom-made foot orthosis, was added to the heel lift as it improves heel fitting and plantar pressure distribution under the rearfoot [13,14]. An arch support was designed to resist depression of the medial longitudinal arch during weight bearing activities.

Based on the three-dimensional data of the foot, two models of heel lifts, one with an arch support and the other without an arch support, were designed in the Delcam Powershape CAD software. Other features of these heel lifts were identical. An engraving machine was used to manufacture these heel lifts.

2.4. Procedures

Participants were given time to get familiarized with the shoe and heel lifts. Then they were asked to walk along an 8 m walkway with an integrated 1 m Footscan pressure plate, at their self-selected speed. Five successful walking trials of each participant were recorded for the two testing conditions, i.e. heel lifts with and without an arch support.

A visual analogue scale (VAS) was used to assess medial-lateral control, dynamic foot/shoe fitting and overall comfort after each condition. The medial-lateral control was rated as how stable the participant felt during walking in the sideways direction. Dynamic foot/shoe fitting was defined as the fitting between foot and shoe during walking. The scale ranged from 0 point to 10 point, with the left end labeled 'completely unstable' for medial-lateral control, 'ill fitting' for dynamic foot/shoe fitting, and 'completely uncomfortable' for overall comfort; and the right end labeled 'completely stable' for medial-lateral control, 'perfect fitting' for dynamic foot/shoe fitting, and 'completely comfortable' for overall comfort.

2.5. Data analysis

The displacement and velocity of the medial-lateral COP (ML-COP) were calculated to assess the medial-lateral stability. The stance phase was divided into four phases: the initial contact phase, the forefoot contact phase, the foot flat phase and the forefoot push-off phase. The displacement and velocity in the medial-lateral COP, especially during the forefoot contact phase and the foot flat phase, are associated with foot stability [6]. Moreover, the contact between the arch support and the foot begins at initial forefoot contact phase and terminates at the initial forefoot push-off phase. Therefore, COP variables during the forefoot contact phase and the foot flat phase were analyzed in this study. The forefoot contact phase was the period from the first metatarsal contact until all metatarsal head areas made contact with the pressure plate. The foot flat phase followed the forefoot contact phase and ended when the heel was off the ground. The range of the COP excursion and velocity was calculated as the absolute difference between the largest and smallest x-coordinate and velocity of the COP respectively during the corresponding phase. The x- and y coordinates were calculated with polynomial interpolation in Matlab version 2009b (Mathworks Inc.) [15].

All COP measures were normally distributed, while the subjective ratings were not normally distributed. Therefore, a paired samples *t*-test and a nonparametric test (Wilcoxon signed-rank test) were performed to analyze the effect of the arch support on the COP variables and subjective ratings, respectively. Statistical analyses were performed using SPSS version 22 statistical analysis software (SPSS Science, Chicago, Illinois). Significant differences between the two conditions were considered if $p < 0.05$.

3. Results

The trajectories of COP in two heel lifts conditions are shown in Fig. 1. The overall COP trajectory was medially shifted in the arch support condition compared to the control. The largest difference in the mean COP displacement was observed during forefoot contact phase. There were no significant differences in the self-selected walking speeds between two conditions ($p = 0.35$), with 3.30 ± 0.37 km/h in the control condition and 3.25 ± 0.34 km/h in the arch support condition.

Comparison of the ML-COP displacement and velocity between the arch support condition and the control are shown in Table 1. Compared to the control, the mean and maximum displacements of ML-COP during the forefoot contact phase in the arch support condition were reduced by 2.3 cm ($p = 0.030$) and 2.8 cm ($p = 0.009$), respectively.