34th Annual International Conference of the IEEE EMBS
San Diego, California USA, 28 August - 1 September, 2012

Biomechanical Assessment of Work Footwear for International Airline Personnel

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***Abstract*— Heel pain is a major musculoskeletal condition and it's commonly experienced by air hostesses due to the time spent standing and walking. A new method of biomechanical assessment was performed in air hostesses and airport staff, while wearing work footwear. The aim of this *pilot study* was to assess the performance and comfort of the work footwear in air hostesses and airport staff by analyzing the pattern of the plantar pressure. A comparative study was carried out in nineteen females in three different conditions: a) barefoot, b) wearing their work footwear and c) wearing a new design of comfortable work footwear. Average pressure, body barycenter, foot barycenters and points of maximum pressure under the foot were collected using the pressure platform EPS/R1 from LorAn Engineering Inc. The results showed high average pressure and lowest contact area under the work footwear; foot biomechanical alterations were also found in the majority of the subjects due to the shape and the design of the shoe. This method of biomechanical evaluation on air hostesses and airport staff have shown that a new design of an ergonomic shoe is required in order to prevent heel pain and biomechanical deformities, with attenuation of heel peak plantar pressure.**

***Index Terms*— Biomechanics, comfort, foot health, hostesses' footwear, plantar pressure distribution.**

I. INTRODUCTION

SHOES perform important functions in daily living, such as creating an interface between feet and ground, as well as giving protection and support to the foot during standing and walking [1]. Inadequate footwear increases foot problems [2], [3]; postural instability [4]; and fall risk [5]. Footwear features affect the standing balance and gait performance. Specifically, high heels or soft insoles cause postural instability [6]. In addition to footwear features, footwear fitness is equally important. However, due that the assessment of footwear fitness is not well standardized, its relationship with physical performance remains unclear. Some researchers have investigated footwear fitness in terms of the length and width difference between the foot and shoe [3], [6]. In these cases, ill-fitting footwear were classified as "too loose" or "too tight", indicating if the footwear was too long or too wide, relative to the foot size.

Wearing inadequate footwear limits mobility and consequently impairs health, independence, and quality of life [6], especially in old women. It seems prudent that older women should avoid high-heeled footwear, which reduces the support base and changes the weight distribution on the plantar surface of the foot, overloading the metatarsophalangeal joints and impairing balance.

This pilot study will consider these aspects in order to define a new footwear design for air hostesses and airport personnel to prevent heel pain and biomechanical deformities with attenuation of heel peak plantar pressure.

II. MATERIAL AND METHODS

A. Subjects

This study was carried out for assessing the shoe comfort using the plantar pressure platform EPS/R1 from LorAn Engineering for evaluating the plantar pressure and postural balance in standing position during barefoot, using the previous shoe model, and the new model, in air hostesses and personnel who walks most of their time during work. The previous model consisted on a work shoe with a heel height of 2 cm and a wooden outsole with thin leather insole. The new model was a work shoe with a similar heel height, a hard rubber outsole, and a leather insole with cushions in the heels and metatarsal heads.

Nineteen volunteers, all females were selected, with (a) age range: 18-60 years, and (b) with a body mass index inferior to 35.

This was a collaborative work between Pontificia Universidad Javeriana/Department of Electronic Engineering/BASPI research group and Avianca Airline, and was consented with all the subjects. This pilot study is the first application of this technology in Colombia, and in a university/enterprise collaborative work.

Fig. 1: Airline personnel.

B. Equipment

The measurement system configuration, was installed at the facilities of Avianca (Bogotá, Colombia), and consists of the pressure distribution platform (LorAn Engineering S.R.L., Italy) with 2304 resistive sensors distributed in a matrix of 48×48 sensors, with a resolution of 1 sensor/cm^2, and

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a sampling frequency of 30Hz; and the software Footchecker 4.0, to measure the Average Pressure (AP); and the location of Body Barycenter (BB), Foot Barycenters (FB), and Points of Maximum Pressure (PML).

C. Protocol

At the beginning of the session, a comprehensive assessment of the status of the shoes was performed. Subjects were asked to be barefoot, with no objects in their pockets, no jewelry or watches to be worn, to avoid changes in the measurement.

A preliminary measurement was performed with every subject, to inform them how to position their feet on the platform and to establish the anatomical position of the body. The method for controlling feet position consisted of a 2D guide drawn on the platform.

Subjects stood on and off the platform for each measurement, performing 3 measurements barefoot and with each pair of shoes. A total of 171 measurements were taken. A research assistant observed and guided the accommodation of the subject's feet position (Figure 2).

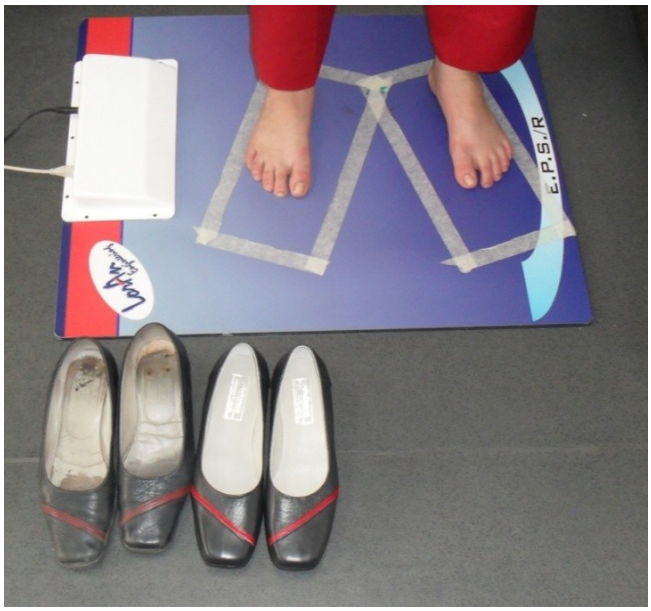


Fig. 2: System measurement

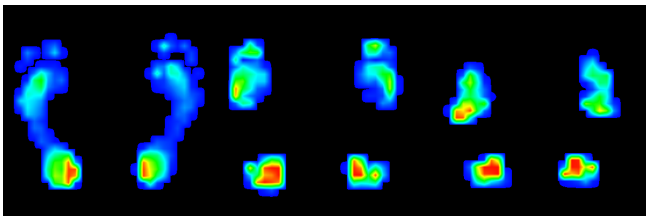
D. Data Analysis

Variables BB, FB and PML are measured and as coordinate pairs (BBx,BBy; FBx,FBy; PMLx,PMLy) and presented in a coordinate system representing their location on the pressure platform.

Background images of a pressure patterns in barefoot, previous model, and new model of work footwear are used as guides for the analysis (figure 3). ©Tableau Public Edition 2012 is used only for graphical presentation purposes.

III. RESULTS

Observing the contact area, both footwear reduce foot space, which is shown in the contact area, and that leads to an increase of plantar pressure. These images were results of measurements in one subject, but all subjects display plantar pressure patterns similar to figure 3. The new model reduces more contact area than the previous model, showing increased pressure at the forefoot.



(a) Barefoot (b) Previous Model (c) New Model

Fig. 3: Patterns of plantar pressure

Average pressure presents the importance of the contact area. Figure 4 shows that the reduction caused by the work footwear, especially the new model, increases the average pressure.

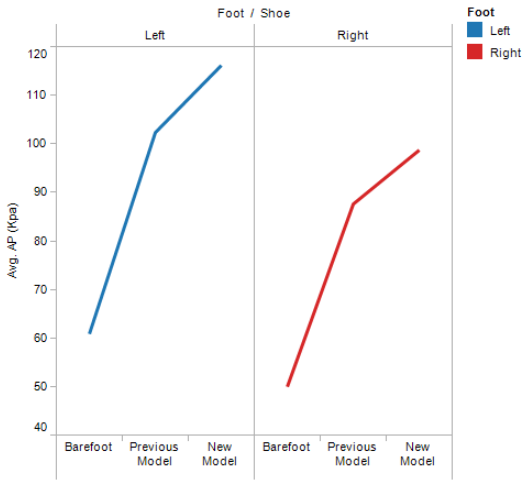
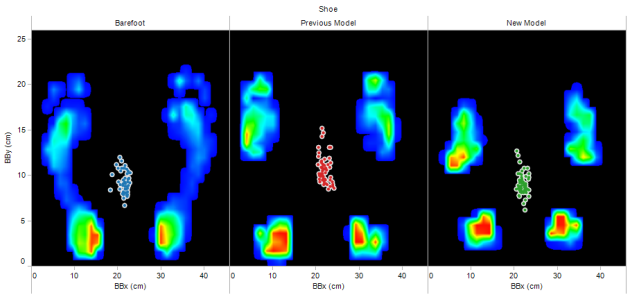


Fig. 4: Average pressure.

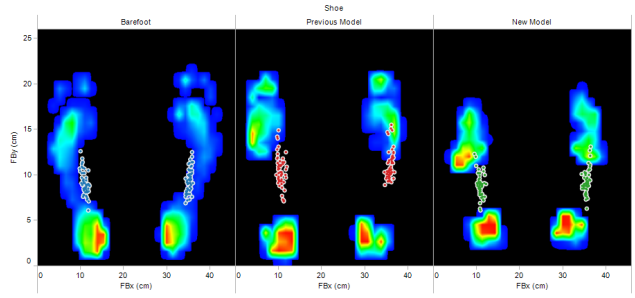
Subjects in barefoot presented an average pressure of 60.78 KPa, the previous model of footwear 102.2 KPa, and the new model 116.1 KPa.

Body barycenter and foot barycenters are located at the midfoot in barefoot. Wearing the previous model, barycenters move to upper midfoot and forefoot. The new model locate the barycenters at a position similar to barefoot (Figure 5).

The subjects in barefoot presents points of maximum pressure at the metatarsal heads and the heels. Using the work footwear, increases the number of points of maximum pressure at the heels, but the pressure at the metatarsal heads also increases. This also occurs with the new model of footwear, but at the metatarsal heads there are no points of maximum pressure, now presenting them at the midfoot (Figure 6).



(a) Body Barycenters



(b) Foot Barycenters

Fig. 5: Barycenters

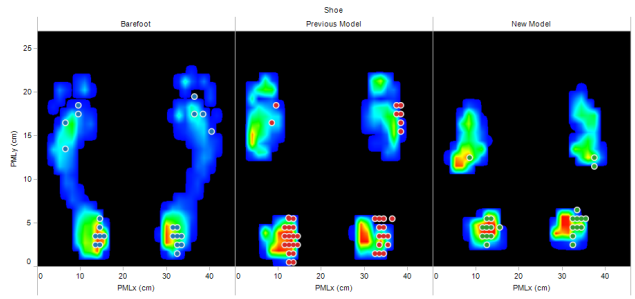


Fig. 6: Points of Maximum Pressure.

IV. DISCUSSION

The analysis of the data collected by the pressure platform shows a lesser contact area and an increase of plantar pressure, due to the reduction of foot space inside the footwear. The reduction of foot space is the main cause of biomechanical alterations like hallux valgus, claw toes, and hammer toes. The increase in plantar pressure leads to a comfort problem with the new model of work footwear used by the personnel at Avianca, although the cushions may reduce the sensation.

The location of the barycenters moves to the upper Y-axis, meaning that body support increases at the forefoot, with the previous footwear. The new model locate the barycenters at a similar location to barefoot, which means that the new model may corrects the balance of the subjects, allowing them to have a better posture at work.

The points of maximum pressure concentrate at the heel in all three cases (barefoot, previous model and new model). At the forefoot, due to the design of the work footwear, the pressure increases, showing points of maximum pressure concentrated among the fifth metatarsal head, making this zone vulnerable to discomfort, and developing hyperkeratosis.

V. CONCLUSION

With this *pilot study* is demonstrated that, although the new model of work footwear helps to the posture of the hostesses and personnel at the airline, the reduction of contact area may cause discomfort and health issues. A complete study in larger population is necessary to assess the effects of the work footwear and to develop a new model of work footwear, based on plantar pressure distribution, and customizable, to ensure that keeps the feet healthy.

ACKNOWLEDGMENT

BASPI Research Group acknowledges the efforts of personnel at Avianca in Bogotá, Colombia, for their help in recruiting subjects for this study, and expresses our gratitude to all study participants.

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