XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

PLANTAR PRESSURE ANALYSIS OF INSERTS IN HIGH HEELED SHOES

[1]Abraham Perez-Cortes, [2]Alejandra A. Silva-Moreno, [3]Michelin Alvarez-Camacho, [2]Manuel Hernandez-Trejo, [4]Fernando Sotelo-Barroso
[1] Biomedical Engineering, Iberoamericana University, Mexico City, Mexico
[2]CIATEC, A.C., Omega 201, Fracc. Ind. Delta, 37545 León, Guanajuato, México
[3]National Rehabilitation Institute (INR), Mexico City, Mexico [4]University of Guanajuato.
Email: asilva@ciatec.mx

SUMMARY
High heeled shoes generate an increase in plantar pressure of the forefoot area. In order to increase comfort by redistributing these high pressure points, shoemakers and manufacturers are interested in developing a shoe insole insert that could be included during the manufacture of their product. In this work, six shoe inserts were design-tested within a high heeled shoe designed to accommodate shoe inserts. Tekscan equipment was used to assess pressure distribution and contact area in forefoot, hindfoot, and hallux. Results show that a better pressure distribution response was observed in a total length design that combined comfortable and viscoelastic materials, compared with a control of the studied regions. The results shows that the use of an appropriate shoe design and inserts makes possible to obtain a comfortable and esthetically pleasant shoe.

INTRODUCTION
Previous studies have evaluated the effect of shoe inserts, such as heel cup, arch support, metatarsal pad, and total contact insert; subjects perceived comfort and foot pressure distribution on using high heeled shoes[1] In that study, total contact inserts were designed to end at the distal border of the metatarsal heads due to insufficient room at the toe box to accommodate a longer insert without a feeling of tightness. Nevertheless, the results showed a pressure reduction of 24% under the metatarsal heads.

We hypothesized that the use of total foot-length inserts utilized within a shoe designed with sufficient room in the toe box, will result in a shoe with better pressure distribution. Therefore, the purpose of this work was to assess plantar pressure from forefoot, hallux, and hindfoot employing renewed designed total contact inserts within a new designed high-toe-box shoe with an increase in the 6-mm-high shoe last, and with a 7-cm (2.75-inch) heel.

METHODS
Thirty healthy volunteers were invited to participate in an informative meeting. Inclusion criteria included ages between 18 and 50 years an habitual use of high heeled shoes, while exclusion criteria comprised Body mass index (BMI) >26 and a history of physical trauma during the past 4 years. The study subjects were informed of the methodology and they gave their consent by means of a signed letter for participation in the study.

A footwear with the following characteristic were developed and manufactured: fashionable last; 7 cm high heel dress shoe; sizing 24 cm; EE½ American ball width, and an increase of the internal space of the last about 6mm to receive the inter insole (figure 1).

Figure 1. Shoe last and prototype footwear

Six different inserts were designed with the following characteristics:

I1: Control insert, with a 4.6-mm thickness of 24-point sulfate cardboard and a goatskin lining.
I2: Blue Poron insert 2.9-mm in thickness with a hardness of 28°, a 3-mm adjustment insert, and a 0.8-mm goatskin lining total thickness of 6.7 mm.
I3: Plastazote insert 3.76-mm in thickness with 30° hardness, a 2-mm adjustment insert, and a 0.8-mm lining, with a total thickness of 6.56 mm.
I4: Synthetic Latex insert 3.4-mm thick with 27° hardness, 2-mm adjustment insert, and a 0.08-mm lining, for a total thickness of 6.2 mm.
I5: Kidney-shaped metatarsal button insert, with a maximum height of 9 mm, of Latex, and a 3.15-mm-thick sulfate-cardboard adjustment insert.
I6: Insert with a Latex arch support and a 3.15-mm-thick sulphate-cardboard adjustment insert.
F-Scan in-shoe pressure/force system analysis was used to obtain plantar-pressure distribution data generated in forefoot, hallux, and hindfoot zones for each of the three subjects selected.

In order to obtain the pressure registries, each participant walked a distance of 3.5 m on a carpet, which allowed them to take between six and seven steps at a 1.4m/s rate. Each test was repeated three times. The participants performed a total of 72 tests (3 subjects × 8 inserts × 3 tests).

We used the Student t test to compare the PPPs, in order to evaluate whether there is a difference between the control insert (I1) and the inserts for pressure distribution; with the data obtained from I2, I3, and I4, the effectiveness of the material were evaluated; in inserts I5 and I6, the effectiveness of the orthopedic element were evaluated.

RESULTS AND DISCUSSION

For the participants the general ball width was 224.3 mm (±11.64 mm) in right foot and 224.6 mm (±11.24 mm) in left foot.

In Figure 2, the PPP shows the forefoot, hallux, and hindfoot zone, utilizing the I2, I3, and I4 inserts. The results demonstrate that in the forefoot zone as well as in the hallux, the three materials presented significant pressure reductions with respect to the control insert (I1). The I3 insert presented the lowest pressures with 654.72 (kPa) (SD, ±23.78 kPa) in forefoot and 217.6 kPa (SD, ±97.5 kPa) in hallux. The hindfoot zone did not present a significant reduction in pressure with any material.

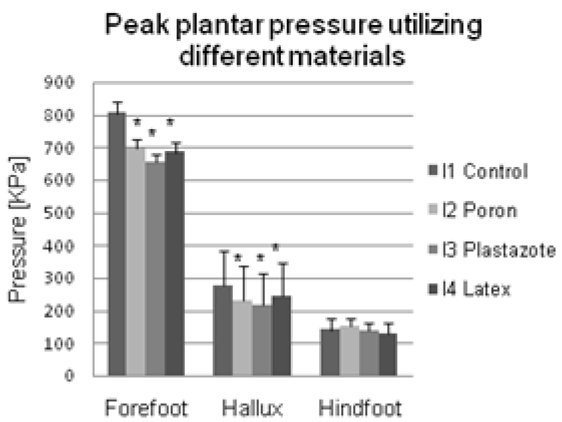

Figure 2. Peak plantar pressures in three regions of the foot.* $p < 0.05$ with respect to I1.

For the orthopedic elements (inserts I5 and I6) Figure 3. The results show that only the arch support presented a significant pressure reduction in the forefoot zone, with respect to the control insert (I1).From the figure, it can be observed that in the hallux as well as in the hindfoot area, there was a significant increase in plantar pressure.

In the manufacturing process of a shoe with extra space in the toe box, the simplest choice for absorbing pressure is an insert manufactured in a sole material with constant thickness. After evaluating three of the most commonly materials utilized in the manufacture of inserts (I2,I3,I4), we observed that the simple Plaztazote insert (I3) significantly achieved distribution of the high plantar pressures generated in the forefoot zone by 18.8% and in the 1st metatarsal by 21.65%. However, it is expected that this material will lose its initial properties within a period of time of 24-48 h of use and exhibit poor impact absorption, as it presents closed porosity (octagonally formed pore), which limits recovery and durability [2].

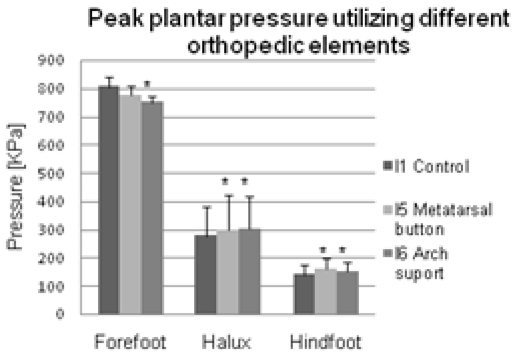

Figure 3. Peak plantar pressures in three regions of the foot. * $p < 0.05$ with respect to I1.

The metatarsal button did not present changes in the forefoot zone with respect to the control insert; in addition, it caused a certain discomfort in each of the participants; these results are similar to the response observed in the Yung-Hui Lee study. The arch support presented a better behavior and achieved a 6.86% reduction of forefoot PPP.

CONCLUSIONS

In this study, we compared the effectiveness of six inserts for the distribution of PPPs during walking with a specially manufactured high heel dress shoe; made with fashionable last with an increment of the internal space of about 6mm to receive the inter insole and a 7-cm high heel. The results shows possible improvement in comfort during the walk cycle.
It is possible to manufacture a shoe that is comfortable and esthetically pleasant in which a complete 7-mm-thick total-contact insert can be introduced, as was achieved

ACKNOWLEDGEMENTS

This study was partially supported by Consejo Nacional de Ciencia y Tecnologia protect number 161135 and CONCYTEG (Guanajuato State Council of Science and Technology). Thanks to the design group of CIATEC for the construction of the shoes.

REFERENCES

1. Yung-Hui, L., Wei-Hsien, H. *Appl Ergo*. **36**, 355-362, 2005.
2. Leber, C., Evanski, P.M. *Prosthet Orthot Int.* **10**(3),135-138, 1986.