

MORPHOLOGICAL ANALYSIS OF THE LATERAL FOOT SHAPE AT DIFFERENT HEEL HEIGHTS

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INTRODUCTION

This work presents a morphological analysis of the evolution of the lateral foot shape with different heel heights. The purpose of the study was to set up a procedure to obtain the shank curve of feet for different heel heights and to develop a mathematical algorithm to calculate this curve for any heel height. This will have applications in the design of shoe components such as soles, lasts, steel shanks, etc., taking into account the foot shape, with the objective of improving comfort in high-heeled shoes.

REVIEW AND THEORY

A significant characteristic of women's shoes is the height of the heel that can reach up to 10 cm. This changes the foot and body posture, modifying the foot plantar pressure distribution, and it has been related to discomfort and foot pain (Nyska, 1996). Midfoot support depends on the match between foot shape and shoe shank shape. A too high or too low shoe shank will modify the midfoot support and it could affect the plantar pressure distribution. Although it is an important parameter for the design of high-heeled shoes, studies about on-foot shank shape have not been found in the literature.

Morphometric tools that allow analyzing of open curves have been applied in this study to obtain a statistical shape of the foot shank for several heel heights. These techniques are of common use in anthropology and biology to study the form of an organism, bones, etc. (Bookstein, 1991). There are some studies related to the foot anatomy, especially the footprint, using morphometric analysis tools for closed contours, such as Elliptic Fourier Analysis (Sforza, 1998) and Medial Axis of an outline (Mochimaru, 1997).

PROCEDURES

A new system based on a digital image was developed to capture the lateral foot shape with different heel heights. Landmarks that referred to anatomical points of the foot were also captured to allow alignment of different feet for further statistical analysis.

Fifteen females with foot size 37 (European size) and age 25 ± 5.25 years participated in this study. A two-dimensional curve of the foot shank and five landmarks were captured and digitized for four heel heights: 25, 35, 55 and 85 mm using the morphometric application tpsDig.

The shank curves of the subjects were aligned for each separate heel height using the Procrustes generalized orthogonal least-squares (GLS) superimposition method. This method fits one landmark configuration over another by minimizing the sum of squared distances between homologous landmarks (Rohlf, 1990).

The aligned curves set for each heel height were digitised to obtain thirty points for each curve. The mean and the percentiles 5, 10, 25, 50, 75, 90 and 95 were obtained for each x coordinate. Interpolated curves were generated for all percentile calculated (Figure 1). Finally, a mathematical application was developed to calculate the shank curve for any heel height by means of a transformation function. One of the heel height curves measured was used for the validation of the mathematical model.

RESULTS AND DISCUSSION

The procedure developed in this work has allowed us to obtain shank curves of women's feet for different heel heights and to assess the change of the lateral foot shape when this height increases.

An application has been developed and validated to calculate foot shank curves defined by any heel height. This application will make it possible to assist the design of shoe components such as soles, lasts, steel shanks, etc., taking into account the foot shape with the objective to improve comfort in high-heeled shoes.

REFERENCES

- Nyska, M. et al. (1996). *Foot & Ankle*, **13**: 662-666.
- Bookstein, F.L. (1991). *Morphometric Tools for Landmark Data*. Cambridge, UK: Cambridge University Press
- Rohlf, F.J. & Slice, D. (1990). *Systematic Zool.*, **39**:40-59.
- Sforza, C. et al (1998). *J Orthop Res*. **16**: 758-765.
- Mochimaru, M. et al (1997). *Ergonomics*, **40**: 450-464.

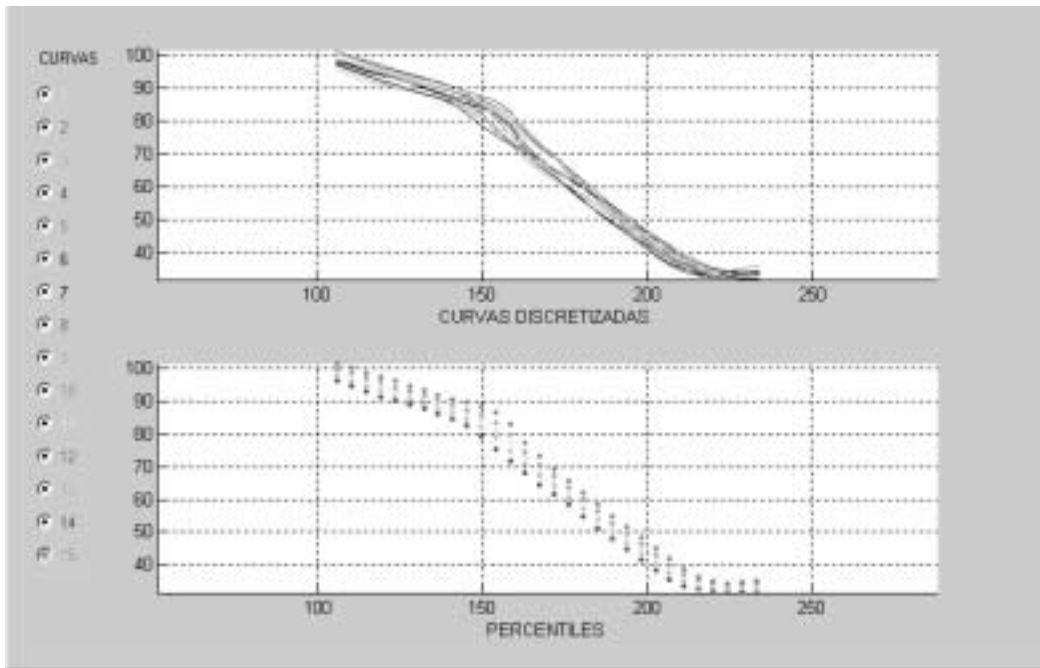


Figure 1: Shank curves of 15 women feet aligned and percentiles for a heel height of 85 mm.

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