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Short communication

A Case Study of Chinese Bound Feet: Application of Footprint Analysis

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A B S T R A C T

Foot print patterns of the bound feet of a 90-year-old Chinese female were made to obtain insight into the ergonomic consequences of a Chinese custom that caused significant disabilities for many women throughout history. Pressure patterns were evaluated using the techniques applied to standard thumb print analsyis. A digital summary of the pressure patterns were compared to the patterns obtained from a normal subject. The outcomes indicated that the bound foot produced greater plantar tissue pressures than the non-bound foot. These observations help explain the discomfort, gait abnormalities, and disabilities exhibited by many older women with bound feet living in China today. Although foot-binding is no longer practiced, this study offers an ergonomic perspective on a custom practiced in China for centuries.

Key words: *chinese bound feet, foot prints, pressure analysis, ergonomics, history*

Introduction

Footbinding was introduced to China in the 7th century and the tradition continued until the early part of the 20th century. The practice of footbinding was considered a status symbol for wealthy families. Small feet on women were seen as beautiful and only wealthy families could support women unable to perform physical labor. The feet were bound early in life to keep the feet short as they matured to adulthood. Binding started at the age of five or six and was continued throughout a woman's adult life[1].

Binding affected the development of the foot which included the reduction of length, a reshaping of the sole that caused an exaggerated arch, and a reduction of the overall width of the foot[2]. The physical appearance of an adult bound foot is illustrated in Figure 1. A radiograph of a similar bound foot is illustrated in Figure 2. To accommodate the foot deformities, shoes were developed to fit the necessary shape. An example of such a shoe design is illustrated in Figure 3.

There are considerable numbers of older women living in China today whose feet were bound during their childhood. Although many of these women discontinued binding their feet later in adulthood, the foot deformities remain and these women continue to experience significant discomfort limiting their ability to stand or walk for extended periods of time[3]. Therefore, an ergonomic evaluation of Chinese bound feet can provide important insight into the consequences of a cultural practice that will be forgotten when the affected generation of women passes away[4,5]. The purpose of this study was to provide

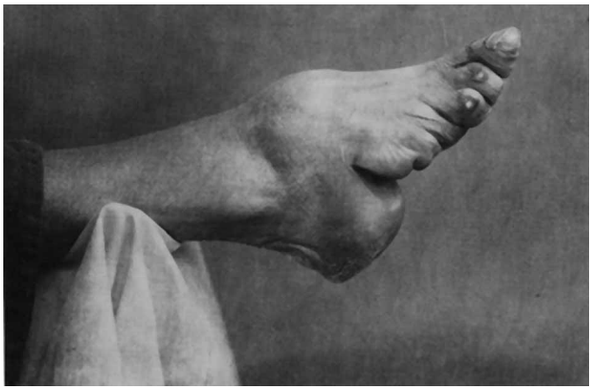

Fig. 1. Illustration of an adult Chinese bound foot. (Source: Reference 1, p.20).

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Fig. 2. Radiograph of an adult Chinese bound foot. (Source: Reference 1, p.135).

Fig. 3. Example of a shoe for Chinese women with bound feet (Source: Reference 2, p.20).

an ergonomic perspective on the unique foot pressure distribution patterns that resulted from the deformation caused by the foot binding practice.

Material and Methods

A healthy 90-year old female with bound feet and her 56-year old daughter with normal feet participated in this case study. The mother weighed 47 kg. and had a stature of 144 cm. The daughter weighed 56 kg. and had a stature of 157 cm. The footbinding deformity of the mother is illustrated in Figure 4.

To obtain the foot pressure patterns, the traditional approach used for thumb print analysis was employed where skin tissue ridges and grooves are identified by color intensity differences. Areas of high pressure (ridges) are displayed as light while low pressure areas (grooves) are displayed as dark. Both women were asked to sit in a comfortable chair. The women then placed both feet into a bowl of water containing red-dye. They were then asked to take four very slow steps forward starting with their right foot. A large piece of white paper was placed on the floor in front of them. The four footprints generated on the white paper (two right foot prints and two left foot prints) were then dried and stored for subsequent digital scanning and analysis. An example of a digitized footprint pattern is illustrated in Figure 5.

Analysis

The foot print analyis was based on the pattern obtained from the first step of the left foot. For each step, the todal body weight was being exerted on one foot only. Since the steps were taken very slowly, we believe that no significant additional dynamic forces were created while the normal gait cycle was maintained. Foot gait cycle starts from the time when the heel of one leg strikes the ground to the time at which the same leg contacts the ground again. There are two phases: stance phase and swing phase. We analyzed the stance phase illustrated in

Fig. 4. Illustration of foot deformity of the 90-year old female participant.

Fig. 5. Illustration of a footprint for the normal (left) foot and a footprint for the bound (left) foot.

Fig. 6. Stance phase of gait.

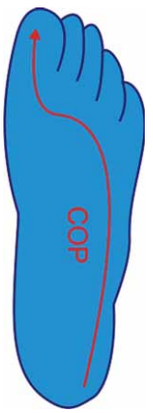

Fig. 7. Trajectory of COP.

Figure 6. When the foot is on the ground, the stance phase of gait begins with the heel touching the ground while the toes do not touch the ground.

I the next phases of motion, the foot contact the ground and the forces on the foot change in direct response to the ground reaction forces that are applied to the body. During walking, the Center of Pressure (COP) travels medially from metatarsal heads to the big toe as illustrated in Figure 7. Such »rolling« dynamics contribute to the development of good foot prints, similar to those obtained in human thumb prints. In this case study, the impact of both the *pressure flow* and the *pressure distribution* are shown.

Results

Using a Medlab® digital imaging system, the paper pressure footprint patterns of both women were scanned. The peak plantar pressure areas are shown in red while the lower pressure areas are shown in green. Figure 8 illustrates such a color printout. The differences in the total areas of red and green, as well as differences in the proportions of red and green, provide an understanding of the foot pressure distributions patterns.

X axis and Y axis scales are in centimeters

Further analysis using 3-D simulation software revealed additional (comparative) information about the two different pressure distribution patterns. An output of a 3-D simulation analysis is illustrated in Figure 9.

Figures 6 and 7 together show that for a normal foot, body weight is distributed primarily over the toes, the meta-tarsal region, as well as over the mid-foot section, while for a bound foot, the pressure is concentrated on the meta-tarsal and mid-foot regions of the foot. Table 1 shows the actual foot pressure values for both test subjects. It must be noted that all contacts, regardless of pressure intensity, were considered to contribute equally to the total plantar contact area.

Discussion and Conclusions

Use of a foot prints to evaluate plantar pressure distributions for bound feet provided insights into the ergonomic consequences of an old Chinese custom. Comparing bound feet with a normal feet revealed helps to understand the chronic discomfort, stunted toe nail growth and skin lesions. Foot ulceration and calluses can be attributable to the localized tissue pressures associated with a deformed foot[6,7]. However, it is not clear how much impact the anatomical deformation of the bound foot itself affects the local tissue blood circulation[8]. Nevertheless, the observed phenomena may be the result of a combination of all these factors[9,10]. Clearly, the on-going well-being of women with bound feet will continue to be

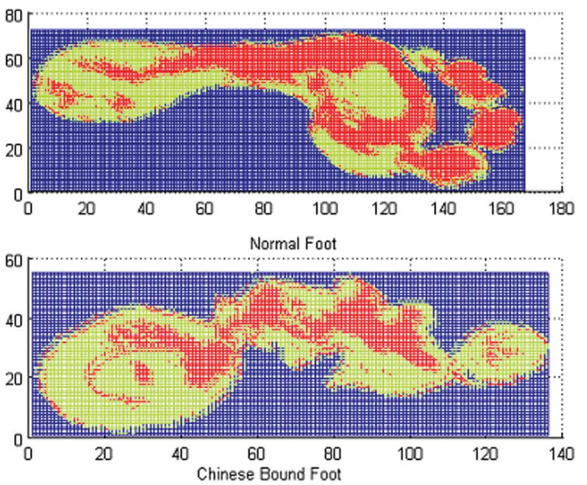

Fig. 8. Pressure distribution patterns for the normal foot (top) and a bound foot (bottom).

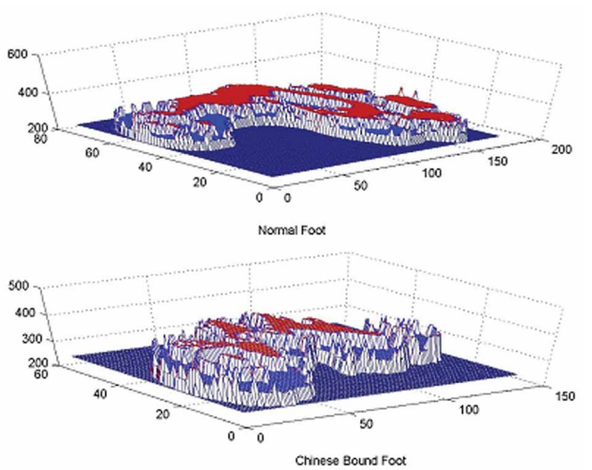

Fig. 9. 3-D simulation to visualize peak pressure distribution patterns for a normal foot (top) and a bound foot (bottom).

TABLE 1
SUMARY OF PARICIPANT CHARACTERISTICS AND RESULTING FOOT PRESSURE VALUES

Foot Condition	Subject Weight (kg)	Subject Height (cm)	Foot Length (cm)	Plantar Contact Area (cm^2)	Foot Pressure (N/cm^2)
Normal Foot	56	157	22	110	5.1
Bound Foot	47	144	18	76	6.2

of interest to health professionals in modern China. While the study illustrated a simple and practical application of a print procedure to document pressure distribution patterns of bound and normal feet, the results help explain the pain and disabilty of women with bound feet in China today. Although the total number of women with bound feet is becoming smaller both inside an outside of China, designers may wish to assist in the development of shoes that may help reduce some of the discomfort experienced by the women with bound feet today.

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PROCJENA DISTRIBUCIJE PLANTARNIH TLAKOVA U SLUČAJU POVEZIVANJA STOPALA U KINI

SAŽETAK

Pribavljeni su uzorci tlakova otiska stopala 90-godišnje Kineskinje s povezanim stopalima i uspoređeni s uzorcima tlakova otiska stopala njezine 56-godišnje kćerke, koja ima normala stopala. Uzorci distribucije tlakova dokumentirani su u oba slučaja. Analiza je otkrila da je povezano stopalo proizvelo sveukupno veći tlak plantarnog tkiva od normalnog (ne – povezanog) stopala. Rezultati pomažu, djelomice, objasniti nelagodu, nepravilnosti držanja i invaliditet koje danas proživljava žena s povezanim stopalima. Namjera je studije dati ergonomski pregled običaja koji još uvijek utječe na zdravlje i dobrobit brojnih starijih žena u suvremenoj Kini.