

SEXUAL DIMORPHISM IN FOOT SHAPE

R.E. Wunderlich and P.R. Cavanagh

Center for Locomotion Studies, Penn State University, University Park, PA 16802

INTRODUCTION

It is commonly recognized that correct shoe fit is attained by matching shoe shape to foot shape. Appreciation of the sexual dimorphism of foot shape is, therefore, essential to the proper design of women's shoes. Traditionally many women's shoes have been made using a small version of a men's last with all dimensions proportionally scaled according to foot length. However, if women's feet differ in *shape* from men's feet, this is an inappropriate model for a women's shoe last and could lead to improper shoe fit in women. In 1993, the American Orthopaedic Foot and Ankle Society's Women's Shoe Survey (Frey et al., 1993) reported that 88% of the healthy women surveyed were wearing shoes smaller than their feet (1.2 cm average in length), and 80% of the women surveyed had some sort of foot deformity.

METHODS

The U.S. Army foot and leg anthropometric data set (Parham et al., 1992) was used to analyze sexual dimorphism as well as racial differences in foot shape. Univariate t-tests and multivariate discriminant analyses were used to assess the following: 1) significant differences between males and females for each foot and leg dimension, standardized to foot length, 2) the reliability of classification into sex and race classes using the absolute and standardized variable sets, and 3) the relative importance of each variable to the discrimination among sex and race classes.

RESULTS

The results indicate that, for a given stature, males have longer and broader feet than females. After normalization of the measurements by foot length, males and females were found to differ significantly in four calf and six foot shape variables (Table 1). Classification by sex alone using absolute values was correct at least 93% of the time, whereas classification by race alone was correct only 80% of the time, and by race and sex together only 78% of the time. Using the variables standardized to foot length, sex and race together could be classified correctly 71.3% of the time, sex alone 85%, and race alone 81%.

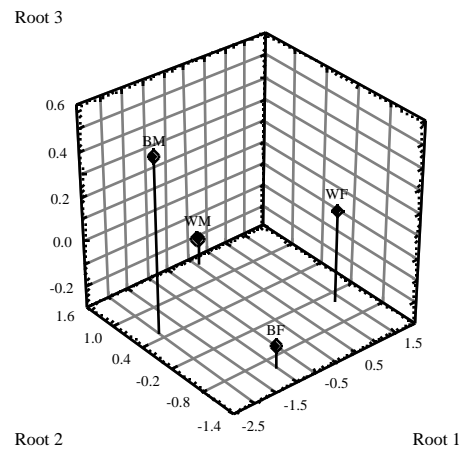
DISCUSSION

These findings have implications for forensic science as well as for footwear. The results indicate that the reliability of identification of isolated foot and lower leg specimens to sex and race categories is high. This study also demonstrates that female feet are not simply scaled-down isometric versions of male feet but rather differ in a number of shape characteristics. A woman's foot has a higher arch, a shallower first toe, a smaller ball of foot circumference, a shorter ankle length, a shorter length of the outside ball of foot, and a smaller instep circumference. The last on which a women's shoe is built should reflect these differences.

Table 1. Foot measurements, normalized by foot length, for which there were significant differences between men and women.

Code	p value	Male mean (foot lengths)	Female mean (foot lengths)	[1-(Female /Male)]* 100	Male value at common foot length (257 mm)	Female value at common foot length (257 mm)	Delta mm (Female- Male)
Females greater than males on the following variables:							
clfhght	<0.001	1.270	1.301	2.38%	326.48	334.26	7.78
plarht	0.001	0.113	0.119	5.04%	28.94	30.53	1.59
ankcir	<0.001	0.830	0.855	2.92%	213.3	219.73	6.43
calfcirc	<0.001	1.372	1.446	5.12%	352.51	371.55	19.04
Males greater than females on the following variables:							
anklht	<0.001	0.471	0.444	-6.08%	121.00	114.06	-6.95
toelht	0.001	0.082	0.080	-2.50%	20.98	20.48	-0.49
bofcirc	<0.001	0.271	0.268	-1.12%	69.66	68.77	-0.89
anklegth	<0.001	0.402	0.396	-1.52%	103.30	101.75	-1.54
oboflg	<0.001	0.617	0.612	-0.82%	158.67	157.24	-1.43
incirc	<0.001	0.970	0.957	-1.36%	249.21	245.92	-3.29

Figure 1. Plot of centroids of first three roots of the canonical variates analysis by sex and race. WM – White males; BM – Black males; WF – White Females; BF – Black Females.



REFERENCES

- Parham K., Gordon C., Bensel C.:** Anthropometry of the foot and lower leg of U.S. Army soldiers: Fort Jackson, S.C. 1992.
- Frey C., Smith J., Sanders M., Horstman H.:** American Orthopaedic Foot and Ankle Society Women's Shoe Survey. *Foot & Ankle*, **14**:78-81, 1993.

This work was supported by a grant from Ryka.