

## GENDER DIFFERENCES IN FOOT SHAPE

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### INTRODUCTION

Knowledge of foot shape is important to design shoes which fit properly. Although many shoes for women are simply scaled down versions of the same shoe for men (Frey, C., 2000), previous studies describe differences between genders particularly at the arch, the lateral side of the foot, the first toe and the ball of the foot. Men have longer and broader feet than women for a given stature (Wunderlich, R.E.; Cavanagh, P.R., 2000), whereby women tend to have a narrower heel in relation to the forefoot and have narrower feet than men in general relative to length (Frey, C., 2000). Besides differences between genders, ethnic origin can also influence foot shape (Hawes, M.R.; Sovak, D. et al., 1994)

New methods provide the opportunity to measure the three-dimensional shape of the foot, which may help analyze the difference between genders more precisely. Moreover it is also an economical method, even for measuring large populations.

### METHODS

Both feet of 423 men (age:  $30 \pm 10$ yr; body mass index:  $23 \pm 2$ kg/m<sup>2</sup>) and 424 women (age:  $28 \pm 10$ yr; body mass index:  $21 \pm 2$ kg/m<sup>2</sup>) were scanned using a three-dimensional foot scanner with a spatial resolution of 1.5 mm (Human Solutions GmbH, Kaiserslautern). For each subject, the values measured for the right and left foot were averaged for further analysis. 90% of the subjects were athletes, 65% runners. Various anatomical landmarks were defined to measure ball length, outside ball length, ball width, ball girth, toe length, toe height, instep length, instep height and heel width. Coherences of the foot length to a given variable were described using the Pearson product-moment correlation (r) and analyzed for both genders. Contingency tables were used to illustrate the distribution of foot length in relation to the given variables for both genders. Significant differences between men and women for the foot lengths 25.00-25.66 cm (Size 38, net value) and 25.67-26.32 cm (Size 39, net value) were detected using Student's t-test. The significance level was set at  $\leq 0.05$ .

### RESULTS

		w	w	w	w	w	m	w	m	w	m	m	m	m
			5.0	6.0	6.5	7.5	6.0	8.5	7.0	9.0	7.5	8.0	8.5	9.0
Ball length (%)	EU	34	35	36	37	38		39		40		41	42	43
	mm	223-230	230-237	237-243	243-250	250-257		257-263		263-270		270-277	277-283	283-290
	162.5	8												
	167.5	84	23											
	172.5	8	64	27	1									
	177.5		12	59	32									
	182.5		1	14	56	31	13		3					
	187.5				10	60	74	30	38		1			
	192.5					9	13	60	49	40	44	8		
	197.5							10	10	47	51	39	7	
	202.5									13	4	47	40	7
	207.5											6	49	36
	212.5												3	43
217.5													14	
All	Col n	25	69	101	96	68	38	30	69	15	95	89	67	28

**Table 1:** Contingency table: Foot length (steps of 6-7 mm) in comparison to ball length (steps of 5 mm). Percentage values of representatives for each foot and ball length in the table (greatest percentage is highlighted), absolute number of subjects at the bottom of each column.

No differences between men and women could be shown regarding length measurements of the foot (i.e. Table 1), whereas in respect to ball and heel width as well as instep height there is a statistically significant difference between genders; women's feet are narrower than men's and have a longer instep height for a given foot size.

Foot length is highly correlated with different length measurements of the foot, whereas the coherence of width and height measurements to foot length is poor, though an increase of foot length cannot be proportionally transfused to measures of width and height of the foot (Table 2).

Variable	r for ♀	r for ♂	Ratio ♀ : ♂	Mean Difference ♀ : ♂	
				Size 38, n=106	Size 39, n=99
Ball Length	0.96	0.95	♀ = ♂	- 0.9 mm	+ 0.7 mm
Outside Ball Length	0.87	0.85	♀ = ♂	- 0.1 mm	- 0.4 mm
Ball Width	0.45	0.25	♀ < ♂	- 5.9 mm <sup>(*)</sup>	- 4.1 mm <sup>(*)</sup>
Ball Girth	0.37	0.13	♀ < ♂	- 13.8 mm <sup>(*)</sup>	- 10.0 mm <sup>(*)</sup>
Toe Length	0.83	0.78	♀ = ♂	- 0.5 mm	- 0.8 mm
Toe Height	0.38	0.34	♀ < ♂	- 0.2 mm <sup>(*)</sup>	- 0.1 mm <sup>(*)</sup>
Instep Length	0.85	0.79	♀ ≤ ♂	- 3.5 mm <sup>(*)</sup>	- 1.3 mm
Instep Height	0.35	0.24	♀ < ♂	- 4.6 mm <sup>(*)</sup>	- 3.8 mm <sup>(*)</sup>
Heel Width	-0.02	0.00	♀ < ♂	- 3.2 mm <sup>(*)</sup>	- 3.1 mm <sup>(*)</sup>

**Table 2:** Pearson product-moment correlation (r) for the given variable and the foot size, differences between gender (♀ = women, ♂ = men) over all, statistically proven for size 38 and 39.

## DISCUSSION

The findings of this study demonstrate differences between gender regarding important anatomical measurements of the foot. Women have narrower feet in the heel and forefoot region and their instep height is also lower than in men. For these measures, lasts for women's shoes cannot only be a downscaled version of those for men's shoes. For the same given shoe size, women need narrower shoes with a smaller instep height in comparison to men.

No distinction between genders could be observed regarding length measurements of the foot, thus no differentiation needs to be made for ball length, toe length, outer ball length and instep length in men's and women's shoes.

The Results refer to dimensions with an emphasis on the plantar plane. Additional measurements of the three dimensional foot shape will be added to complete the analysis. Furthermore, different foot types will be described using factor and cluster analyses, though feet do not only differ between genders but also between different foot types.

## REFERENCES

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