MEASUREMENTS FOR ORTHOPAEDIC SHOES: A STUDY ON ACCURACY AND AGREEMENT OF PROFESSIONALS AND STUDENTS

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Abstract

We aimed at comparing foot measurements of final-year Prosthetics & Orthotics students (ten; having knowledge, but lacking experience), skilled technicians (two; lacking formal education on foot anatomy and disorders, but having lots of experience) and the measures provided by a foot scanner. Both feet of four healthy adult volunteers were measured. Agreement with scanner and within-group agreement were statistically analysed. In general, agreement within both groups was very high, whereby technicians were more synchronised among themselves than students. We also found that technicians appropriately determined EU shoe size as two to three sizes larger than the foot length, which is measured by the scanner and was erroneously reported by the students. Therefore, efforts should be made within undergraduate orthotics and prosthetics education to familiarise the students with practical procedures and requirements of orthopaedic measurements.

INTRODUCTION

Many people, especially elderly, have foot problems. These impact their activities, such as walking and consequently also participation (1). Foot disorders can affect all the more proximal joints of the lower limb (2). There are several reasons for foot problems, such as diabetes, rheumatoid arthritis and different injuries, but also inappropriate shoes. Inappropriate shoes cause foot ulcers in up to 20% of patients with diabetes (3). Over 70% of elderly patients admitted to a general rehabilitation unit have been found to have inappropriate shoes (3).

Many patients with foot problems get orthopaedic shoes. It is important that the measurement is performed by a skilled person who also has appropriate knowledge of foot anatomy and deformities.

The aim of the present study was to compare foot measurements of final-year Prosthetics & Orthotics (P&O) students (having knowledge, but lacking experience), skilled technicians (lacking formal education on foot anatomy and disorders, but having 10 years of experience) and the measures provided by a scanner.

METHODS AND SUBJECTS

Methods

The measurements were performed by two skilled technicians from the Institute for Rehabilitation, Republic of Slovenia, Ljubljana, and ten P&O students from the University College of Health Studies. They were all instructed to perform the measurements for the purpose of producing orthopaedic shoes. Additionally, the subjects' feet were measured by a foot scanner (UCS Inc., Vrhnika, Slovenia), which only measured the dimensions A, B, C and F (see below and figure 1).

Six dimensions were measured (Figure 1):
A. circumference at metatarsal heads (in cm);
B. circumference at midfoot (in cm);
C. circumference at hindfoot (in cm);
D. ankle circumference at malleolar level (in cm);
E. shank circumference at 15 cm (in cm);
F. EU shoe size.

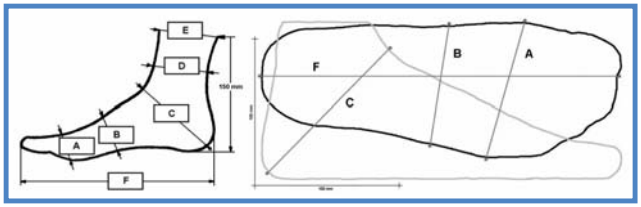

Figure 1: *Foot measures (left) and sample output from the foot scanner (right)*

Mean deviation (MD) was used to assess agreement of the measurers with the scanner measurements. Coefficient of variation (i.e., standard deviation divided by the mean, expressed in %) was used to assess agreement within the two groups of measurers. Intraclass correlation (ICC, using

absolute agreement definition with two-way random effects model) was used to assess overall agreement among the measurers (4). Bland-Altman plots (5) were used to further explore agreement and accuracy of the measurers.

Subjects

Four adult volunteers were measured (three male and one female), aged 28-59 years. All were healthy and none had any foot impairment or deformity. Both feet of each subject were measured.

RESULTS

Descriptive statistics summarising the measurements, agreement with scanner and agreement among each group of measurers are reported in Table 1. Mean CV over all dimensions for the technicians was 1.1% and 1.2% for left and right foot, respectively (and 1.1% over both feet), while for students it was 2.4% and 2.2% (2.3 % overall). Selected bland-Altman plots comparing the technicians and the students against the scanner (Figure 2) illustrate good agreement regarding circumference at hindfoot (top panels) and downward bias of the students and the scanner with respect to the technicians (bottom panels).

Table 1: *Descriptive statistics summarising the measurements, agreement with scanner and agreement among each group of measurers (MD = mean deviation; CV = coefficient of variation; NA=not available).*

Subject	Dimension	Technicians						Students						Scanner	
		Left Foot			Right Foot			Left Foot			Right Foot			Left	Right
		Mean (Range)	MD	CV	Mean (Range)	MD	CV	Mean (Range)	MD	CV	Mean (Range)	MD	CV	Foot	Foot
1	A	27.0 (27.0-27.0)	1.10	0%	27.3 (27.0-27.5)	0.85	1%	24.7 (23.0-28.5)	-1.25	6%	24.4 (23.5-26.0)	-2.05	3%	25.9	26.4
	B	25.8 (25.5-26.0)	-1.85	1%	26.0 (26.0-26.0)	-1.40	0%	26.3 (25.0-27.5)	-1.35	3%	26.2 (25.5-27.5)	-1.23	2%	27.6	27.4
	C	37.5 (38.0-37.0)	0.20	2%	37.0 (37.5-36.5)	0.20	2%	37.1 (36.0-38.0)	-0.25	2%	36.7 (36.0-37.0)	-0.15	1%	37.3	36.8
	D	24.5 (24.0-25.0)	NA	3%	24.5 (24.0-25.0)	NA	3%	28.2 (26.0-30.0)	NA	4%	28.1 (26.0-30.0)	NA	4%	NA	NA
	E	25.0 (24.5-25.5)	NA	3%	25.0 (24.5-25.5)	NA	3%	25.5 (25.0-27.0)	NA	3%	25.6 (25.0-26.5)	NA	3%	NA	NA
	F	45.0 (45.0-45.0)	2.50	0%	45.0 (45.0-45.0)	3.00	0%	43.2 (42.0-44.0)	0.65	1%	42.7 (42.0-43.5)	0.65	1%	42.5	42.0
2	A	23.0 (23.0-23.0)	-0.40	0%	23.3 (23.0-23.5)	-0.15	2%	22.9 (22.0-24.5)	-0.55	3%	22.9 (22.0-23.5)	-0.50	2%	23.4	23.4
	B	22.5 (22.0-23.0)	-1.40	3%	22.5 (22.0-23.0)	-0.70	3%	23.2 (22.0-24.5)	-0.70	3%	23.3 (22.5-24.5)	0.05	3%	23.9	23.2
	C	32.8 (33.0-32.5)	1.05	1%	32.8 (33.0-32.5)	2.25	1%	32.0 (31.0-34.0)	0.30	3%	31.9 (31.0-33.0)	1.37	2%	31.7	31.7
	D	22.5 (22.0-23.0)	NA	3%	21.8 (21.5-22.0)	NA	2%	23.6 (22.0-25.0)	NA	4%	23.7 (22.0-25.0)	NA	4%	NA	NA
	E	23.0 (23.0-23.0)	NA	0%	22.8 (23.0-22.5)	NA	2%	23.2 (22.5-24.0)	NA	2%	23.1 (22.0-24.0)	NA	3%	NA	NA
	F	39.3 (39.0-39.5)	2.25	1%	39.3 (39.0-39.5)	1.75	1%	38.0 (37.5-39.0)	1.00	1%	38.0 (37.5-38.5)	0.50	1%	37.0	37.5
3	A	28.0 (28.0-28.0)	0.50	0%	27.3 (27.5-27.0)	0.05	1%	26.2 (25.0-27.5)	-1.30	3%	26.2 (24.5-28.0)	-1.05	4%	27.5	27.2
	B	28.8 (28.5-29.0)	-1.65	1%	28.8 (28.5-29.0)	-0.85	1%	28.7 (27.0-30.0)	-1.75	3%	29.2 (28.0-30.5)	-0.45	3%	30.4	29.6
	C	39.5 (40.0-39.0)	0.10	2%	39.0 (39.5-38.5)	0.10	2%	39.3 (39.0-40.0)	-0.15	1%	38.9 (38.0-40.0)	0.00	2%	39.4	38.9
	D	27.0 (27.0-27.0)	NA	0%	27.0 (27.0-27.0)	NA	0%	29.4 (28.0-31.0)	NA	3%	29.6 (28.5-31.0)	NA	2%	NA	NA
	E	28.0 (28.0-28.0)	NA	0%	28.3 (28.5-28.0)	NA	1%	29.1 (27.0-39.0)	NA	12%	28.1 (27.0-29.0)	NA	2%	NA	NA
	F	45.3 (45.5-45.0)	3.25	1%	45.3 (45.5-45.0)	2.75	1%	42.7 (41.5-44.0)	0.70	2%	42.6 (41.0-43.5)	0.05	2%	42.0	42.5
4	A	29.5 (29.0-30.0)	0.70	2%	28.3 (28.5-28.0)	0.25	1%	27.6 (27.0-29.0)	-1.20	2%	27.3 (26.0-29.0)	0.75	4%	28.8	28.0
	B	28.8 (28.5-29.0)	-1.95	1%	28.8 (28.5-29.0)	-1.35	1%	29.2 (28.5-30.5)	-1.50	2%	29.4 (29.0-30.0)	-0.75	1%	30.7	30.1
	C	39.3 (39.5-39.0)	-1.25	1%	39.3 (39.5-39.0)	-0.25	1%	38.8 (38.0-39.0)	-1.75	1%	38.4 (37.0-40.0)	-1.10	2%	40.5	39.5
	D	28.8 (28.0-29.5)	NA	4%	28.3 (27.5-29.0)	NA	4%	29.9 (28.0-32.0)	NA	4%	29.8 (28.0-33.0)	NA	5%	NA	NA
	E	28.8 (28.5-29.0)	NA	1%	28.0 (28.0-28.0)	NA	0%	30.1 (28.5-39.5)	NA	11%	28.1 (27.0-29.0)	NA	3%	NA	NA
	F	45.8 (45.5-46.0)	2.25	1%	45.8 (45.5-46.0)	2.25	1%	42.9 (42.0-44.0)	-0.60	2%	43.3 (42.5-44.5)	-0.25	2%	43.5	43.5
Overall Mean	A	26.9 (23.0-30.0)	0.48	0.6%	26.5 (23.0-28.5)	0.25	1.3%	25.3 (22.0-29.0)	-1.08	3.8%	25.2 (22.0-29.0)	-1.09	3.2%	26.4	26.3
	B	26.4 (22.0-29.0)	-1.71	1.7%	26.5 (22.0-29.0)	-1.08	1.4%	26.8 (22.0-30.5)	-1.33	2.6%	27.0 (22.5-30.5)	-0.60	2.2%	28.2	27.6
	C	37.3 (32.5-40.0)	0.03	1.4%	37.0 (32.5-39.5)	0.58	1.4%	36.8 (31.0-40.0)	-0.46	1.6%	36.5 (31.0-40.0)	0.03	1.8%	37.2	36.4
	D	25.7 (22.0-29.5)	NA	2.4%	25.4 (21.5-29.0)	NA	2.1%	27.8 (22.0-32.0)	NA	3.9%	27.8 (22.0-33.0)	NA	4.1%	NA	NA
	E	26.2 (23.0-29.0)	NA	1.0%	26.0 (22.5-28.5)	NA	1.4%	26.9 (22.5-39.5)	NA	7.1%	26.2 (22.0-29.0)	NA	2.7%	NA	NA
	F	43.8 (39.0-46.0)	2.56	0.6%	43.8 (39.0-46.0)	2.44	0.6%	41.7 (37.5-44.0)	0.44	1.7%	41.6 (37.5-44.5)	0.24	1.3%	41.3	41.4

In general, agreement within both groups was very high (ICC computed over all dimensions was 0.996 and 0.975 for technicians and students, respectively, and 0.972 for the pooled sample).

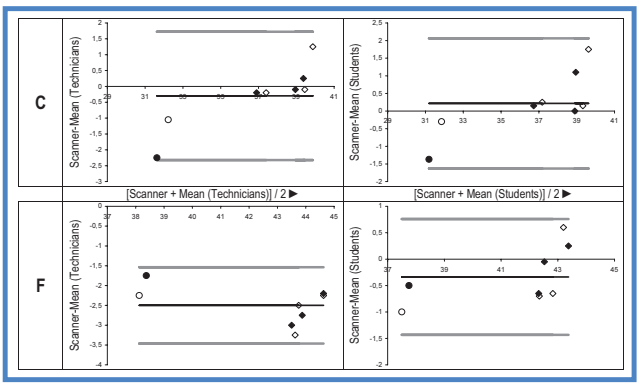

Figure 2: *Bland-Altman plots for comparing technicians (left panels) and students (right panels) with scanner (thin black line = mean difference, thick grey lines = mean difference ± 2SD; circles = female, diamonds = male subjects; open symbols = left, filled symbols = right foot)*

DISCUSSION

It is encouraging that in general, agreement within both groups was very high. As expected, the technicians were more synchronised among themselves than were the students. Students' measurements tended to follow the foot scanner "mechanically" on all dimensions, which is not desirable for the purposes of producing orthopaedic shoes, especially regarding shoe size. The technicians appropriately determined EU shoe size as two to three sizes larger than the foot length, which is measured by the scanner and was also erroneously reported by the students.

CONCLUSION

In undergraduate orthotics and prosthetics education, attention should be paid on practical experience. In particular, the students should be familiarised with the procedures and requirements of actual orthopaedic shoe measurements.

References:

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