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Evaluation of professional footwear and its relationships with the foot structure among clinical nurses

EWA PUSZCZAŁOWSKA-LIZIS[1]*, SABINA LIZIS[1], WIKTORIA DUNAJ[2], JAROSŁAW OMORCZYK[3]

[1] Medical College, Institute of Health Sciences, University of Rzeszów, Rzeszów, Poland.
[2] Non Public Physiotherapy Practice, Physiotherapy Unit, Rzeszów, Poland.
[3] Faculty of Physical Education and Sports, Institute of Sport, University School of Physical Education, Kraków, Poland.

Purpose: This study aimed to evaluate professional footwear comfort, functionality and style as well as their relationships with the foot structure among nurses. *Methods*: We examined 120 clinical nurses aged 40–50 years, occupationally active, wearing specific type of footwear at work for a minimum of 7 h a day, for 5 days prior to the research. The study relied on the CQ-ST podoscope for measurements of foot. Perception of footwear comfort, functionality and style scales were also used in the research. The results were analysed with the use of Mann–Whitney *U*-test and Spearman's rank correlation. *Results*: Statistically significant negative associations were found between right and left foot length and overall comfort of footwear ($p = 0.045$, $p = 0.045$) as well as between right and left foot width and arch height ($p = 0.015$, $p = 0.028$). Heel angle positively correlated with safety ($p = 0.008$, $p = 0.050$), ease of donning and doffing ($p = 0.001$, $p = 0.004$), as well as shoe style ratings ($p = 0.047$). Variables determining shoe comfort were positively correlated with most shoe functionality characteristics as well as with shoe style ($p < 0.05$). *Conclusions*: Tested medical footwear meets the requirements of nurses in terms of comfort, functionality and aesthetics, and the studied features of footwear can be a useful guideline for the selection of shoes for representatives of this professional group. These footwear can be an element of workwear, and even, in the case of women with transverse flat feet – an alternative to ordinary utility shoes. There is a need to consider different widths for the same length size in medical footwear designs.

Key words: *foot bones, foot deformities, flatfoot, hallux valgus, bunion, shoes, nursing*

1. Introduction

Pursuing the nursing profession requires working long hours, often shift work. The profession is dominated by women, whose task is to care for a patient, including observing and recognizing their health needs, as well as nursing problems. It is a profession of public trust and high risk. Those who perform it are under the influence of physical, biological, chemical and psychosocial factors that burden them, which can lead to adverse health effects, accidents, and reduce the effectiveness of work [2], [15], [23]. The multitude of occupational duties and poor dissemination of rules on the permissible values of weights carried or carried on carts, can lead to musculoskeletal overload and dysfunction [5], [25]. The components of the passive and active musculoskeletal systems can become further overloaded as a result of wearing inappropriate footwear that, instead of stabilizing the feet and providing opportunities for recovery, can create the risk of pain and even injury to the lower extremities [8], [16].

Pita-Fernandez et al. [19] and González-Elena et al. [9] stressed that feet are an important foundation of human health. Due to their complex anatomical structure, they have a key influence on posture and locomotion. Adequate foot health determines a person's well-being and quality of life. López-López et al. [13]

* Corresponding author: Ewa Puszczałowska-Lizis, Medical College, Institute of Health Sciences, University of Rzeszów, Rzeszów, Poland. E-mail: ewalizis@poczta.onet.pl
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pointed out the currently observed increase in the frequency of foot pathologies, which is a serious public health problem. According to Cauley [4], Puszczałowska-Lizis et al. [20] and Wilson et al. [27], this largely applies to women's feet, which are delicate structures, both in relation to the size of the bone elements and the strength of active-passive stabilizers. In the perimenopausal period, due to the deficiency of sex hormones, the bones of women's feet are more vulnerable to osteoporotic changes. Therefore, their reaction may differ regarding footwear compared to men.

Therefore, it is important to popularize among nurses properly fitted footwear that stabilizes foot structures well and includes orthotic inserts [7], [26]. Data in the literature indicate that the appropriate thickness and structure of the sole of the shoe can act as a buffer against ground reaction forces, protecting the foot from injury, while the design of the inside of the shoe should support the medial longitudinal arch, reducing the risk of foot fatigue. It is equally important to properly brace and stabilize the forefoot in the shoe, as this can improve the quality and performance of physical work. Flexible sole materials can effectively relieve the pain of prolonged standing, and the softness and breathability of upper surface materials can prevent the development of bacterial foot infections. The shoe should fit the foot properly, otherwise it can be a source of pain and damage [18], [24]. The footwear needs of nurses can be broken into three key points: sensations and symptoms of the worker, the functionality, and the factors that influence footwear choice, such as style. Anderson et al. [1] noted that some workers try to save money while buying work footwear, while they prioritize footwear used after work, including leisure shoes, in which they are willing to invest higher amounts.

The presented facts became a direct reason for undertaking the topic of the study, the aim of which was focused on the evaluation of professional footwear comfort, functionality and style, as well as their relationships with the foot structure among clinical nurses.

The present research aimed to answer the following questions:

1. Does the foot structure features, perception of footwear comfort, functionality and style differentiate nurses experiencing and not experiencing foot problems?
2. What are the relationships of foot features of the tested nurses with their perception of footwear comfort, functionality and style of footwear?
3. What are the relationships of perception of footwear comfort with functionality and style of footwear?

2. Materials and methods

2.1. Study participants

Study pursued in March 2023 involved 120 nurses aged 40–50 ($\bar{x}$ = 45.49 ± 3.80 years), with higher education, employed in randomly selected clinics in the Podkarpackie Province, Poland.

The study included active nurses aged between 40 and 50, with a university education, who gave informed consent to participate in the study, and wore footwear for health care workers of a certain brand (Lukmor, Poland, EU) while working, for five days prior to the research, for minimum of seven hours a day. Pregnant nurses, those with musculoskeletal injuries and surgery in the recent past, and those who refused or declined to participate in the study were excluded.

The average body weight of the studied women was $\bar{x}$ = 66.99 ± 11.78 kg, average body height was $\bar{x}$ = 164.44 ± 6.47 cm, and the BMI was 24.75 ± 3.96. 70 nurses (58% of the group) had a normal body structure, 35 nurses (29% of the group) were overweight, 14 nurses (12% of the group) were obese, and 1 nurse was underweight (1% of the group).

In the interview, 50 nurses (42% of group) reported foot problems, like foot pain, blisters, bunions, corns and calluses, claw toes, ingrown toenails, toenail fungus. Therefore, study subjects were divided into two groups: reported foot problems and not reported foot problems.

2.2. Study protocol

The study relied on the CQ-ST podoscope (Electronic System, Ltd., EU) for measurements of foot in standing, with even distribution of body weight evenly on each lower limb. The width and foot angle were natural, unforced. The calculations included six indices:

1. Foot length – the line between distal points of the forefoot and rearfoot [cm].
2. Foot width – the line between distal points of the metatarsale tibiale (mtt) and the metatarsale fibulare (mtf) points [cm].
3. Clarke's angle – the medial longitudinal arch, MLA – is included between the tangent to the medial foot edge and the line that connect mtt point with the largest recess of the fooprint [°].
4. Heel angle (γ) – is included between two tangents to the foot edges (medial and lateral), which cross over the heel [°].

5. Hallux valgus angle (α) – the Ist toe position – is included between the tangents to the medial foot edge, and to the pad of the Ist toe, marked from the mtt point [°].
6. Angle of the varus deformity of the Vth toe (β) – the Vth toe position – is included between the tangents to the lateral foot edge, and the pad of the Vth toe, marked from the mtf point [°], [20], [21].

Evaluation of footwear comfort, functionality and style were assessed using a visual analogue scale, which was 10 cm long [17].

Nurses rated nine themes of the footwear related to its perceived comfort jointly, both in relation to the right and left foot:

1. Shoe length – length of the shoe.
2. Shoe forefoot width – width of the shoe in the forefoot region.
3. Shoe heel width – width of the shoe in the heel region.
4. Heel height – height at which the hindfoot is raised in relation to the forefoot.
5. Heel cushioning – softness/hardness of the midsole in the heel region.
6. Forefoot cushioning – softness/hardness of the midsole in the forefoot region.
7. Arch height – medial arch height of the insole.
8. Mediolateral control – position of the foot controlled by the shoe.
9. Overall comfort – overall impression of the shoe [6], [17], [21].

Specific terms that clearly delineate extremes were anchored at the ends of the scale with the left marked "not comfortable at all" (0 comfort points), and the right end of scale marked "most comfortable" (10 comfort points).

This is a reliable measure of subjective footwear perception, as ICC = 0.799 [17].

The functionality of the footwear was assessed taking into account the criteria proposed by Anderson et al. [1]. Nurses rated seven themes of the footwear related to its functionality jointly, both in relation to the right and left foot:

1. Grip – adhesion of footwear to the ground, resistance of footwear to sliding on the ground.
2. Durability – resistance of footwear to damage.
3. Safety – protection of feet from injuries caused by heavy or sharp objects, fluid spills, etc.
4. Weight – footwear weight.
5. Breathability – ability to drain evaporating sweat to the outside of the shoe.
6. Ease of donning and doffing – solutions for quick putting on and taking off.
7. Individualiztion – fitting shoes to the foot [1].

Specific terms that clearly delineate extremes were anchored at the ends of the scale with the left marked "not functional at all" (0 functionality points), and the right end of scale marked "most functional" (10 functionality points).

Additionally, one more theme of the footwear was assessed, such as "style", which depend on the design, appearance, attractiveness, presence of the shoe on the leg [1]. Left end of the 10-point scale marked "not attractive" (0 style points), and the right end of scale marked "most attractive" (10 comfort points).

The assessment took into account footwear for health care workers of a certain brand (Fig. 1). This footwear were women's white breathable medical leather clogs ORTOMED manufactured by Lukmor, Poland, EU (model of product: WZ-104). The nurses wore this shoes at work for five days prior to the research, for minimum of 7 hours a day. The selection of this footwear model was determined by an economic cost and high quality, especially with respect to health features. Such footwear is characterized by a single-layer sole made of a lightweight polyurethane called EVA (ethylene vinyl acetate), which has anti-slip and anti-electrostatic properties. The functional tread provides very good grip and excellent cushioning for the foot over the entire surface. In addition, the shoes have a molded, replaceable Fusbet orthotic insole, a thermo-cured toe box to protect the toes from injury, a glued and sewn perforated leather upper underneath to allow ventilation and prevent excessive foot perspiration. Instead of a heel counter at the back, the shoes are equipped with an adjustable strap to support the foot. The footwear meets safety standards for protective footwear (PN EN ISO 20347:2012).

Fig. 1. Medical leather clogs ORTOMED used in the research

The shoes belonged to the participants, they purchased them, in a size adjusted to the length of the feet. Before the test, the researchers verified the suitability of the footwear to the tested feet while the subjects were in an even weight-bearing standing po-

sition. The footwear was considered well fitted when the toes could move freely and were not locked in the forefoot, and the heel was placed securely at the heel counter. The nurses' participation in the 5-day shoe test was verified based of their declaration. Moreover, the wear condition was checked during the tests.

The evaluation of footwear comfort, functionality and style was verified by the participants in the presence of the researcher, after being given a detailed information about the assessed themes of the footwear and how to mark the outcomes on a visual analogue scale. If necessary, other explanations were made. Prior examinatoions each nurse was asked to wear the tested shoes and perform tasks simulating clinical nursing work for 15 minutes, including: 5-minute walking, 5-minute standing, and 5-minute sitting.

A research protocol was approved by the Bioethics Review Committee, University of Rzeszów (Approval Reference Number 3/12/2015). The examinations was fully anonymous, and was conducted in conformity to the guidelines of the Helsinki Declaration as revised in 2013. Each subject provided written informed consent to participate, after obtaining detailed explanations about the research, including information about the study aim, data collection procedures, participants' right to withdraw at any point, ass well as anonymity and confidentiality of the data.

2.3. Statistical analysis

Normality of the distribution pertinent features was verified via the Shapiro–Wilk test. The collected research results were analysed with the use of Mann–Whitney *U*-test and Spearman's rank correlation. The strength of associations was determined based on the Stanisz [22] scale:

$R_{XY} = 0$ variables are not associated,
$0 < R_{XY} < 0.1$ little association,
$0.1 \leq R_{XY} < 0.3$ weak association,
$0.3 \leq R_{XY} < 0.5$ average association,
$0.5 \leq R_{XY} < 0.7$ high association,
$0.7 \leq R_{XY} < 0.9$ very high association,
$0.9 \leq R_{XY} < 1$ almost full association [22].

Value of 5% was set as a cut-off for statistical significance. The Statistica application, version 13.3 PL (StatSoft Inc., Tulsa, OK, USA; StatSoft, Kraków, Poland) was used to process all the results obtained.

3. Results

In Table 1, characteristics of foot structure features, footwear comfort, functionality and style of the nurses are presented.

The data collected in Table 2 show that nurses reporting foot problems had wider right ($p = 0.028$) and left ($p = 0.005$) feet than nurses not reporting any foot problems. In addition, those reporting a foot problem had higher right ($p = 0.002$) and left ($p = 0.038$) hallux valgus angle (α) values. There were no differences in the assessment of comfort, functionality and style of the shoes tested by women reporting foot problems, and those not reporting such problems ($p > 0.05$).

Table 1. Characteristics of foot structure features, and variables characterized of footwear comfort, functionality and style of the study subjects

Variable		$\bar{x}$ ± SD	Max–Min	Q_{25}	Me	Q_{75}
Foot structure						
Foot length [cm]	rf	23.01 ± 1.29	27.00–20.60	22.00	23.00	24.00
	lf	23.00 ± 1.23	26.10–20.60	22.00	23.00	24.00
Foot width [cm]	rf	8.93 ± 0.52	10.50–7.60	8.60	8.85	9.30
	lf	9.03 ± 0.56	10.80–7.70	8.70	9.00	9.45
Clarke's angle [°]	rf	38.35 ± 8.37	53.00–8.00	34.50	40.00	45.00
	lf	37.83 ± 8.31	57.00–8.00	34.00	40.00	43.00
Heel angle (γ) [°]	rf	17.13 ± 1.77	22.00–13.00	16.00	17.00	18.00
	lf	17.28 ± 1.92	22.00–13.00	16.00	17.00	18.50
Hallux valgus angle (α) [°]	rf	6.41 ± 5.00	30.00–0.00	3.00	6.00	10.00
	lf	7.15 ± 5.67	27.00–0.00	2.00	7.00	11.00
Angle of the varus deformity of the Vth toe (β) [°]	rf	16.01 ± 5.84	30.00–3.00	12.50	16.00	20.50
	lf	15.43 ± 5.26	30.00–3.00	12.00	15.00	19.00

Table 1 continued

Perception of footwear comfort					
Shoe length [points]	8.26 ± 1.83	10.00–0.00	8.00	9.00	10.00
Shoe forefoot width [points]	8.29 ± 1.83	10.00–0.00	8.00	9.00	10.00
Shoe heel width [points]	7.35 ± 2.35	10.00–0.00	6.00	8.00	9.00
Heel height [points]	7.65 ± 1.60	10.00–1.63	6.75	7.75	9.00
Heel cushioning [points]	7.67 ± 2.28	10.00–1.00	7.00	8.00	9.00
Forefoot cushioning [points]	7.52 ± 2.14	10.00–0.00	7.00	8.00	9.00
Arch height [points]	7.60 ± 2.03	10.00–0.00	6.50	8.00	9.00
Mediolateral control [points]	7.53 ± 2.08	10.00–1.00	7.00	8.00	9.00
Overall comfort [points]	8.00 ± 1.75	10.00–1.00	7.00	8.00	9.00
Functionality of footwear					
Grip [points]	7.95 ± 1.89	10.00–1.00	7.00	8.00	10.00
Durability [points]	7.41 ± 2.15	10.00–1.00	6.00	8.00	9.00
Safety [points]	6.75 ± 2.50	10.00–0.00	5.00	7.00	9.00
Weight [points]	8.17 ± 2.09	10.00–0.00	7.00	9.00	10.00
Breathability [points]	6.81 ± 2.83	10.00–0.00	5.00	8.00	9.00
Ease of donning and doffing [points]	8.68 ± 1.81	10.00–0.00	8.00	9.00	10.00
Individualiztion [points]	7.62 ± 2.25	10.00–0.00	7.00	8.00	9.00
Attractiveness of footwear					
Style [points]	7.80 ± 2.55	10.00–0.00	7.00	9.00	10.00

rf – right foot, lf – left foot, $\bar{x}$ – arithmetic mean value, SD – standard deviation, Max – maximum value, Min – minimum value, Q_{25} – lower quartile, Me – median, Q_{75} – upper quartile.

Table 2. Comparision of foot structure, footwear comfort, functionality and style in nurses reported and not reported foot problems

Variable		Reported foot problems (n = 50)			Not reported foot problems (n = 70)			Z	p
		$\bar{x}$ ± SD	Max–Min	Me	$\bar{x}$ ± SD	Max–Min	Me		
Foot structure									
Foot length	rf	23.25 ± 1.31	26.10–20.80	23.00	22.84 ± 1.26	27.00–20.60	22.80	1.73	0.084
	lf	23.24 ± 1.31	26.10–20.80	23.00	22.82 ± 1.15	25.00–20.60	22.80	1.73	0.084
Foot width	rf	9.06 ± 0.52	10.50–8.10	9.00	8.83 ± 0.51	10.00–7.60	8.80	2.20	0.028*
	lf	9.22 ± 0.57	10.80–8.20	9.15	8.90 ± 0.51	9.80–7.70	8.80	2.79	0.005*
Clarke's angle	rf	37.24 ± 7.95	47.00–12.00	40.00	39.14 ± 8.63	53.00–8.00	40.00	–1.56	0.119
	lf	36.56 ± 7.81	47.00–12.00	40.00	38.74 ± 8.58	57.00–8.00	40.00	–1.58	0.113
γ angle	rf	16.98 ± 1.90	22.00–13.00	17.00	17.24 ± 1.67	21.00–14.00	17.00	–0.86	0.392
	lf	17.08 ± 2.13	22.00–13.00	17.00	17.43 ± 1.76	22.00–14.00	17.00	–1.10	0.271
α angle	rf	8.24 ± 5.93	30.00–0.00	8.00	5.10 ± 3.74	13.00–0.00	6.00	3.12	0.002*
	lf	8.66 ± 6.53	27.00–0.00	8.00	6.07 ± 4.72	17.00–0.00	6.00	2.07	0.038*
β angle	rf	16.06 ± 6.21	30.00–3.00	16.00	15.97 ± 5.61	28.00–4.00	16.00	0.01	0.989
	lf	15.44 ± 5.93	30.00–3.00	15.00	15.41 ± 4.77	26.00–4.00	16.00	–0.28	0.777
Perception of footwear comfort									
Shoe length		8.34 ± 1.66	10.00–2.00	9.00	8.20 ± 1.95	10.00–0.00	9.00	0.11	0.909
Shoe forefoot width		8.28 ± 1.64	10.00–2.00	8.50	8.30 ± 1.96	10.00–0.00	9.00	–0.52	0.603
Shoe heel width		7.28 ± 2.24	10.00–2.00	7.00	7.40 ± 2.43	10.00–0.00	8.00	–0.64	0.523
Heel height		7.80 ± 1.50	10.00–2.50	7.70	7.89 ± 1.77	10.00–0.30	8.10	–0.81	0.418
Heel cushioning		7.68 ± 2.18	10.00–2.00	8.00	7.67 ± 2.36	10.00–1.00	8.00	–0.27	0.789
Forefoot cushioning		7.42 ± 2.23	10.00–2.00	8.00	7.60 ± 2.08	10.00–0.00	8.00	–0.36	0.719
Arch height		7.56 ± 1.92	10.00–2.00	8.00	7.63 ± 2.12	10.00–0.00	8.00	–0.43	0.664
Medio-lateral control		7.44 ± 2.05	10.00–2.00	8.00	7.59 ± 2.11	10.00–1.00	8.00	–0.52	0.604
Overall comfort		7.98 ± 1.60	10.00–2.00	8.00	8.01 ± 1.86	10.00–1.00	8.00	–0.46	0.645

Table 2 continued

Functionality of footwear								
Grip	7.94 ± 1.78	10.00–2.00	8.00	7.96 ± 1.97	10.00–1.00	8.00	–0.30	0.763
Durability	7.52 ± 2.10	10.00–1.00	8.00	7.33 ± 2.19	10.00–1.00	8.00	0.40	0.692
Safety	6.36 ± 2.48	10.00–1.00	6.50	7.03 ± 2.50	10.00–0.00	7.00	–1.51	0.131
Weight	8.00 ± 2.08	10.00–2.00	9.00	8.29 ± 2.11	10.00–0.00	9.00	–0.88	0.377
Breathability	6.90 ± 2.75	10.00–0.00	8.00	6.74 ± 2.90	10.00–0.00	8.00	0.26	0.796
Ease of donning and doffing	8.62 ± 1.87	10.00–2.00	9.00	8.71 ± 1.77	10.00–0.00	9.00	–0.11	0.915
Individualiztion	7.44 ± 2.31	10.00–0.00	8.00	7.75 ± 2.20	10.00–0.00	8.00	–0.82	0.410
Attractiveness of footwear								
Style	7.78 ± 2.32	10.00–0.00	8.00	7.81 ± 2.71	10.00–0.00	9.00	–0.52	0.600

rf – right foot, lf – left foot, $\bar{x}$ – arithmetic mean value, SD – standard deviation, Max – maximum value, Min – minimum value, Me – median, Z – value of the Mann–Whitney *U*-test statistics; *p* – probability value.

* $p < 0.05$.

Table 3. Relationships of foot structure features with perception of footwear comfort

Variable		Shoe length	Shoe forefoot width	Shoe heel width	Heel height	Heel cushioning	Forefoot cushioning	Arch height	Medio--lateral control	Overall comfort
		R *p*								
Foot length	rf	–0.08 0.369	–0.07 0.424	–0.18 0.053	–0.15 0.114	–0.00 0.983	–0.08 0.379	–0.08 0.361	–0.10 0.264	–0.19 0.043*
	lf	–0.08 0.388	–0.07 0.464	–0.17 0.064	–0.15 0.107	–0.00 0.972	–0.08 0.394	–0.08 0.366	–0.09 0.308	–0.18 0.045*
Foot width	rf	–0.00 0.967	–0.09 0.354	–0.16 0.092	–0.04 0.632	–0.01 0.933	0.00 0.993	–0.22 0.015*	–0.08 0.368	–0.13 0.147
	lf	–0.05 0.601	–0.10 0.280	–0.15 0.094	–0.07 0.470	0.01 0.942	–0.00 0.968	–0.20 0.028*	–0.09 0.328	–0.11 0.237
Clarke's angle	rf	–0.08 0.371	–0.05 0.580	–0.03 0.729	–0.06 0.503	–0.05 0.613	–0.00 0.989	0.02 0.868	–0.02 0.844	0.01 0.924
	lf	–0.08 0.404	–0.08 0.388	–0.03 0.719	–0.09 0.336	–0.07 0.459	0.00 1.000	0.02 0.824	–0.02 0.787	–0.04 0.682
γ angle	rf	0.02 0.845	0.00 0.995	–0.03 0.719	–0.03 0.736	0.01 0.954	0.14 0.116	–0.02 0.805	0.01 0.895	0.04 0.674
	lf	–0.02 0.833	–0.04 0.651	–0.05 0.573	–0.00 0.974	–0.01 0.951	0.11 0.238	–0.10 0.264	–0.04 0.675	–0.00 0.987
α angle	rf	0.07 0.421	0.06 0.505	0.06 0.490	–0.06 0.541	–0.03 0.720	0.00 0.991	0.03 0.773	0.10 0.298	0.11 0.222
	lf	–0.07 0.441	–0.03 0.715	–0.12 0.197	–0.16 0.079	–0.02 0.869	–0.08 0.395	–0.04 0.675	–0.06 0.539	0.01 0.892
β angle	rf	0.07 0.429	–0.03 0.761	–0.08 0.387	0.01 0.908	0.10 0.282	0.11 0.226	0.08 0.390	0.08 0.362	0.02 0.847
	lf	0.09 0.350	0.00 0.960	–0.07 0.435	–0.07 0.422	0.07 0.424	0.11 0.218	0.08 0.358	0.13 0.167	0.05 0.558

rf – right foot, lf – left foot, *R* – Spearman rank correlation coefficient, *p* – probability value.

* $p < 0.05$.

Data collected in Table 3 indicate statistically significant weak negative associations between right and left foot length and overall comfort of footwear (respectively $R = –0.19$; $p = 0.045$ and $R = –0.18$; $p = 0.045$), as well as between right and left foot width and arch height (respectively $R = –0.22$; $p = 0.015$ and $R = –0.20$; $p = 0.028$).

The data collected in Table 4 show statistically significant positive weak and average associations of heel angle (γ) of the right and left foot regarding safety ($R = 0.24$; $p = 0.008$ and $R = 0.17$; $p = 0.050$), as well as ease of donning and doffing ($R = 0.32$; $p = 0.001$, $R = 0.26$; $p = 0.004$). Heel angle (γ) also positively weak correlated with shoe style ratings ($R = 0.18$; $p = 0.047$).

Table 4. Relationships of foot structure features with functionality and style of footwear

Variable		Grip	Durability	Safety	Weight	Breathability	Ease of donning and doffing	Individu-aliztion	Style
		R *p*							
Foot length	rf	–0.07 0.420	–0.01 0.874	–0.18 0.053	–0.06 0.538	–0.09 0.337	–0.15 0.097	–0.08 0.377	–0.10 0.298
	lf	–0.06 0.494	–0.00 0.975	–0.17 0.060	–0.06 0.538	–0.08 0.371	–0.15 0.096	–0.07 0.416	–0.10 0.286
Foot width	rf	–0.01 0.945	–0.04 0.643	–0.04 0.636	–0.00 0.989	0.01 0.909	0.07 0.462	–0.01 0.917	–0.04 0.655
	lf	0.01 0.914	–0.03 0.705	0.01 0.897	0.03 0.726	0.04 0.698	0.08 0.379	0.04 0.695	–0.01 0.938
Clarke's angle	rf	0.05 0.576	0.09 0.303	0.07 0.449	0.04 0.703	–0.07 0.434	–0.03 0.782	–0.01 0.890	0.13 0.155
	lf	0.04 0.647	0.08 0.386	0.11 0.245	–0.02 0.835	–0.08 0.363	–0.03 0.746	0.01 0.901	0.09 0.321
γ angle	rf	0.12 0.194	–0.02 0.796	0.24 0.008*	0.07 0.456	0.08 0.396	0.32 0.001*	0.02 0.805	0.18 0.047*
	lf	0.13 0.157	0.05 0.619	0.17 0.050*	0.06 0.489	0.08 0.388	0.26 0.004*	0.01 0.874	0.15 0.099
α angle	rf	0.06 0.529	0.02 0.800	0.09 0.309	0.10 0.291	0.08 0.377	0.16 0.087	0.09 0.303	–0.01 0.951
	lf	–0.16 0.087	–0.11 0.241	–0.12 0.205	–0.01 0.956	–0.08 0.366	0.10 0.263	–0.14 0.141	–0.05 0.607
β angle	rf	0.09 0.331	0.05 0.558	0.13 0.172	0.07 0.476	–0.09 0.341	0.02 0.799	0.06 0.519	0.06 0.496
	lf	0.15 0.093	0.09 0.355	0.14 0.140	0.08 0.364	0.08 0.382	0.02 0.870	0.11 0.251	0.04 0.671

rf – right foot, lf – left foot, *R* – Spearman rank correlation coefficient, *p* – probability value.
* $p < 0.05$.

Table 5. Relationships perception of footwear comfort with functionality and style of footwear

Variable	Grip	Durability	Safety	Weight	Breathability	Ease of donning and doffing	Individualization	Style
	R *p*							
Shoe length	0.54 <0.001*	0.35 <0.001*	0.18 0.054	0.33 <0.001*	0.41 <0.001*	0.34 <0.001*	0.51 <0.001*	0.36 <0.001*
Shoe Forefoot width	0.50 <0.001*	0.46 <0.001*	0.14 0.131	0.43 <0.001*	0.45 <0.001*	0.45 <0.001*	0.49 <0.001*	0.44 <0.001*
Shoe heel width	0.53 <0.001*	0.38 <0.001*	0.27 0.003*	0.46 <0.001*	0.33 <0.001*	0.41 <0.001*	0.42 <0.001	0.41 <0.001*
Heel height	0.39 <0.001*	0.30 <0.001*	0.20 0.034*	0.35 <0.001*	0.33 <0.001*	0.45 <0.001*	0.42 <0.001*	0.34 <0.001*
Heel cushioning	0.51 <0.001*	0.35 <0.001*	0.24 0.007*	0.40 <0.001*	0.43 <0.001*	0.38 <0.001*	0.54 <0.001*	0.40 <0.001*
Forefoot cushioning	0.53 <0.001*	0.50 <0.001*	0.24 0.007*	0.50 <0.001*	0.53 <0.001*	0.44 <0.001*	0.65 <0.001*	0.51 <0.001*
Arch height	0.50 <0.001*	0.40 <0.001*	0.15 0.092	0.40 <0.001*	0.46 <0.001*	0.37 <0.001*	0.56 <0.001*	0.37 <0.001*
Medio-lateral control	0.60 <0.001*	0.44 <0.001*	0.28 0.002*	0.38 <0.001*	0.35 <0.001*	0.35 <0.001*	0.55 <0.001*	0.36 <0.001*
Overall comfort	0.56 <0.001*	0.46 <0.001*	0.29 0.001*	0.39 <0.001*	0.52 <0.001*	0.50 <0.001	0.69 <0.001*	0.44 <0.001*

R – Spearman rank correlation coefficient, *p* – probability value.
* $p < 0.05$.

The data collected in Table 5 show statistically significant positive weak and average associations of variables determining shoe comfort, with most shoe functionality characteristics, as well as with shoe style ($p < 0.05$). As the subjective evaluation of footwear comfort increased, the evaluation of footwear functionality and style increased. Only the relationships between the footwear's role in foot protection and ratings of shoe length, front width and medial height were not demonstrated ($p > 0.05$).

4. Discussion

In our study, nurses reporting foot problems were diagnosed with wider feet and higher hallux valgus angle values. This is reasonable and indicates that some of the reported problems, especially foot pain, may be due to lowered transverse arches and deformities in the metatarsophalangeal joint of the toe. We also found that there were no differences in the assessment of comfort, functionality and style of the shoes tested by women reporting foot problems and those not reporting such problems. The data obtained suggest that the footwear tested was selected appropriately, otherwise inappropriate selection of footwear could differentiate the evaluation of its comfort and functionality in the two groups of women. This is suggested by the results López-López et al. [13], obtained in a population of seniors from A Coruña (Galicia, Spain), where the comfort rating of those with foot problems was lower compared to those without foot problems, and was associated precisely with inappropriate footwear selection. In contrast, in another study, López-López et al. [12] showed that in a situation of inappropriate footwear selection, foot problems differentiated the evaluation of footwear functionality, especially in terms of stability and wearability. It is noteworthy that in our study, we found relatively high average comfort score in both groups, which suggest that the shoes tested are tailored for people with foot problems, and the perception of their comfort is high enough to be recommended to nurses. Hurst et al. [11] even concluded, as a result of their study of podiatric patients from a United Kingdom private podiatry clinic, that medical-grade footwear is more suitable than a regular everyday shoe when treating digital lesions associated with pressure, and can be an alternative to regular utility shoes.

An interesting issue is the relationship between foot features and perception of footwear comfort. Our study showed that as foot length increased, the perception of overall shoe comfort decreased. This may be due to the differences between the actual size and the estimated size, dictated by the fact that the nurses surveyed, while trying to properly select shoes for width, had to make a choice of longer footwear at the same time, resulting in a reduced sense of overall comfort. The issue of proper shoe selection is of significant importance. Data in the literature indicate that commonly the most important measure of footwear fit is foot length. It is believed that in order to achieve a good shoe fit, it is necessary to take into account the so-called "functional allowance" equal to one centimeter of the distance from the end of the longest toe to the tip of the shoe. Vrdoljak et al. [28] and Herbaut et al. [10] pointed, that the length of the foot is a crucial dimension in selecting the most appropriate size of footwear. Meanwhile, our results suggest the need to consider different widths for the same length size in medical shoe designs.

We found that as the width of the foot increased, the perception of shoe comfort in terms of medial height decreased. This may be due to the fact that widening of the forefoot increases the area of its contact with the shoe, hence the accompanying decrease in the perception of its comfort in this foot trait. Our results are consistent with the findings of Anderson et al. [1], who also noted that individuals with a widened forefoot have problems with proper shoe fit.

The relationship of foot characteristics to assessments of footwear functionality and style is also an unexplored issue. Our study showed correlations of heel angle with safety, ease of donning and doffing, as well as footwear style. The flatter the transverse feet angle, the higher the footwear functionality rating in terms of foot protection, ease of putting on and off, as well as the higher style rating. The results suggest that the tested shoes meet the requirements of female users with specific deformities in terms of functionality and their style expectations. It is widely recognized that for people with transverse flat feet, putting on shoes is a problem, as well as they are often forced to give up attractive footwear. This is justified especially since Hurst et al. [11] stressed that „street shoes" often don't fit well, and cause pressure on the digits and alter function, which may leading to structural changes and tissue breakdowns/ulceration. Branthwaite et al. [3] conclude that wearing a footwear with a reduced toe box volume and shape causes by constriction of the toes which are associated with the development of joint pathologies and forefoot lesions. According to Louwerens et al. [14], shoes which do not have the capacity to accommodate the forefoot will alter the dynamics of the transverse foot arch, restricting the metatarsal splay of the forefoot.

We found that as the subjective evaluation of footwear comfort increased, so did the evaluation of its functionality and style. Therefore, it can be concluded that requirements for footwear comfort follow expectations for the best possible functionality and aesthetic qualities. This suggests that comfortable footwear assists in stabilizing the foot, while also playing a protective role against external factors and damage. On the other hand, the appearance of a shoe can determine opinions about its function, performance and quality in terms of ergonomics. Nurses expect footwear that provides stability, cushioning, traction and protection while being attractive. Anderson et al. [1] came to different conclusions through a study of representatives of other professional groups. In case of cooks and veterinarians, the style of work footwear was secondary to its comfort and functionality. The authors believe that this approach gives manufacturers more freedom in the design of work footwear. In contrast, in the choice of footwear used after work, attractiveness was a primary concern over comfort.

To the author's knowledge, the present research is the first multi-faceted assessment of the subjective evaluation of footwear comfort, functionality and style, as well as their relationships with the foot structure among nurses. They suggest that the tested medical footwear meets the requirements of nurses in terms of comfort, functionality and aesthetics, and the studied features of footwear can be a useful guideline for the selection of shoes for representatives of this professional group. The tested footwear can be an element of workwear, and even, in the case of women with transverse flat feet – an alternative to ordinary utility shoes. The Authors believe that in that sense their findings may offer a certain application potential. Highly homogeneous character of the study population, i.e., women aged 40–50 years, representative occupationally active female population, and specific type of tested footwear for health care professionals, worn at work, stands for overall credibility of the findings. Our research concerns one professional group, which may be considered a limitation. Very encouraging results obtained in the present study, require further research into this subject to investigate the issues, related to the aesthetic acceptability and functionality of footwear dedicated also to other professional groups.

5. Conclusions

Nurses with foot problems were characterized by wider feet and greater Ist toe valgus. The evaluation of shoe comfort and functionality did not differentiate between the women studied.

There were relationships between foot length and overall comfort of footwear, as well as between foot width and arch height. As foot length increased, the perception of overall comfort of footwear decreased. This may be due to differences between the real size and the estimated size, which would suggest the need to consider different widths for the same length size in medical footwear designs.

There were relationships of heel angle with safety, ease of donning and doffing as well as footwear style. The flatter the transverse feet, the higher the footwear's functionality rating in terms of foot protection, ease of putting on and off, as well as a higher style rating. This suggests that the shoes tested meet the requirements of female users with specific deformities in terms of functionality and their expectations in terms of attractiveness.

As the subjective evaluation of the shoes' comfort increases, the evaluation of their functionality and style increases. This indicates that requirements for shoe comfort follow expectations for the best possible functionality and aesthetic qualities.

Competing interests

The authors declares that they have no competing interests.

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