Health Problems of Civilization
eISSN: 2354-0265, ISSN: 2353-6942

ORIGINAL PAPER

Comparative prevalence of foot deformities in preschool children from the Visegrad Group (V4) countries: a multicenter cross-sectional study

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Puszczalowska-Lizis E, Mikulakova W, Demjanovic Kendrova L, Kynstova H, Jezkova A. Comparative prevalence of foot deformities in preschool children from the Visegrad Group (V4) countries: a multicenter cross-sectional study. Health Prob Civil. https://doi.org/10.29316/hpc/236233

Tables: 5
Figures: 0
References: 25
Submitted: 2026 Jul 27
Accepted: 2026 Sep 9

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Abstract

Background. Early detection and monitoring of pediatric foot deformities are crucial for preventing long-term musculoskeletal complications. This study aimed to analyze the prevalence of foot deformities in six-year-old children from the Visegrad Group (V4) countries.

Material and methods. We evaluated 300 six-year-old children from Poland, Slovakia, and the Czech Republic, including 50 girls and 50 boys from each country. Foot assessments were performed using a CQ-ST podoscope, and data were analyzed using the chi-square test.

Results. The majority of children exhibited normal longitudinal arch height (girls: 62-78%; boys: 44-68%), transverse arches (girls: 56-70%; boys: 42-70%), and hallux alignment (girls: 74-94%; boys: 78-94%). The country of residence significantly influenced deformity prevalence ($p<0.05$). Flatfoot (longitudinal and transverse) and fifth toe varus predominated in Poland. High-arched feet predominated in Slovakia for both sexes and in Czech boys, whereas Czech girls frequently exhibited hallux valgus. Boys' hallux alignment was independent of the country of residence.

Conclusions. Country of residence significantly differentiates foot deformity profiles in V4 preschoolers. These regional variations highlight an urgent need for tailored, national preventive and therapeutic programs, focusing on flatfoot in Poland and high-arched feet in Slovakia.

Keywords: flatfoot, hallux valgus, foot deformities, Europe, child

Introduction

Foot deformities in preschool-children represent a significant health issue due to their impact on musculoskeletal development, posture, and functional capacity. This period is a stage of intensive growth and remodeling of the musculoskeletal system; therefore, early identification of structural and functional foot abnormalities is crucial for prevention and the implementation of appropriate therapeutic interventions. Although many changes observed during early developmental stages are physiological and resolve with maturation, some abnormalities may persist or progress. This can lead to biomechanical disorders of the lower limbs, as well as an increased risk of pain and functional limitations later in life [1-3]. Foot deformities are among the most frequently diagnosed musculoskeletal disorders in children, with flatfoot, planovalgus foot, or valgus foot deformity being the most common [4-6]. The prevalence of foot deformities in children varies across populations, which may result from genetic factors, lifestyle, as well as the diagnostic methods used and the evaluation criteria

adopted [7,8]. Literature also emphasizes the influence of environmental factors, such as the type of footwear worn [9-11]. In recent years, increasing attention has been focused on the impact of a sedentary lifestyle, excessive body weight, and insufficient physical activity on the development of foot deformities in children [12-14].

Central European countries, despite cultural and socioeconomic similarities, differ in the organization of preventive care and screening programs, which may influence the detection and prevalence of diagnosed deformities. The Visegrad Group (V4) countries, comprising Poland, the Czech Republic, Slovakia, and Hungary, represent an interesting area for comparative analyses. Similar geographical and demographic conditions enable the assessment of foot deformity prevalence while simultaneously accounting for variations resulting from local health factors and lifestyles. Although the V4 consists of four nations, this study was conducted within an international research project implemented through a collaboration between institutions from three of these countries: Poland, the Czech Republic, and Slovakia. A comparison of data regarding preschool children from these V4 countries may provide valuable insights into the scale of the problem and highlight directions for preventive and educational initiatives. Furthermore, research involving six-year-old children is particularly critical, as they are at a vital stage of musculoskeletal development. During this period, the foot is already more formed than in earlier years of life, yet it remains subject to intensive changes associated with growth and maturation [15,16]. At this age, children attain school readiness, which is associated with a lifestyle shift, an increase in sedentary time, and a change in physical activity levels [17]. These factors can influence the development of the foot arches and the occurrence of postural defects. The examination of six-year-old children's feet enables the early detection of abnormalities, such as the lowering of the medial longitudinal or transverse arch, valgus foot deformity, or other deformities. Early diagnostics allow for the implementation of appropriate preventive or therapeutic interventions, which can prevent the progression or consolidation of defects and their negative consequences later in life.

Aim of the work

The aim of this study was to analyze the prevalence of foot deformities in six-year-old children from the V4 countries and to compare the results among the respective nations. This work could contribute to a better understanding of the prevalence of foot deformities in this age group and provide a baseline for planning effective preventive strategies and early intervention.

Material and methods

A total of 300 six-year-old children (150 girls and 150 boys) were enrolled in this cross-sectional comparative study, which was carried out between February and May 2026. Participants were recruited from randomly selected preschools in Poland, Slovakia, and the Czech Republic, yielding a balanced sample of 50 girls and 50 boys from each country. An *a priori* sample size calculation was performed using G*Power software (version 3.1). Assuming a significance level of 0.05, a statistical power of 80%, and six comparison groups, the minimum required sample size was 216 participants. The final sample comprised 300 children (50 participants in each group), ensuring adequate statistical power for all planned analyses.

Eligibility for participation was determined according to strict inclusion and exclusion criteria. The inclusion criteria comprised: (1) chronological age of six years at the time of examination; (2) cognitive ability to comprehend and follow verbal instructions necessary for the assessment procedures; (3) written informed consent obtained from a parent or legal guardian; and (4) the child's verbal assent and willingness to cooperate. The exclusion criteria were defined to eliminate factors that could confound foot morphology assessments or alter plantar weight-bearing patterns during podoscopic examination. Participants were excluded if they presented with: (1) diagnosed congenital or acquired structural foot deformities (e.g. clubfoot, vertical talus); (2) history of lower limb fractures, major joint trauma, or orthopedic surgery; (3) systemic neurological, metabolic, or musculoskeletal disorders affecting gait, balance, or posture (e.g. cerebral palsy, developmental coordination disorder); (4) clinically significant lower limb length discrepancy (>1 cm); (5) acute dermatological conditions, painful skin lesions, or open wounds on the plantar surface of the feet that would impede natural weight-bearing or full contact with the podoscope plate; or (6) persistent uncooperative behavior or inability to maintain a stable, independent bilateral standing position during the implementation of the research protocols.

The mean body weight of girls varied across countries, recorded at 21.94±2.52 kg in Poland, 21.15±4.41 kg in Slovakia, and 21.53±4.04 kg in the Czech Republic. The mean body height was 118.48±3.94 cm in Poland, 117.88±5.63 cm in Slovakia, and 115.09±4.74 cm in the Czech Republic, while the corresponding mean Body Mass Index (BMI) values were 15.67±1.67, 15.12±2.35, and 16.31±2.61, respectively. For boys, the mean body weight was recorded at 23.21±2.41 kg in Poland, 21.73±4.08 kg in Slovakia, and 23.08±5.59 kg in the Czech Republic. Concurrently, the mean body height for boys was 120.24±4.31 cm, 120.20±4.97 cm, and 118.52±4.55 cm, resulting in mean BMI scores of 16.54±2.13,

14.93±1.96, and 16.29±2.89, respectively. The comprehensive distribution of body weight status based on BMI categories is presented in Table 1.

Table 1. Body weight status based on BMI by country (V4)

Body weight status	Poland	Slovakia	Czech Republic	Pearson's chi-square test
	n (%)			
Girls				
Underweight	4 (8.0)	12 (24.0)	3 (6.0)	χ^2 (6)=15.14 p=0.019*
Normal weight	37 (64.0)	28 (56.0)	38 (76.0)	
Overweight	8 (16.0)	6 (12.0)	3 (6.0)	
Obesity	1 (2.0)	4 (8.0)	6 (12.0)	
Boys				
Underweight	0 (0.0)	14 (28.0)	4 (8.0)	χ^2(6)=34.88 p<0.001*
Normal weight	38 (76.0)	28 (56.0)	34 (68.0)	
Overweight	12 (24.0)	6 (12.0)	3 (6.0)	
Obesity	0 (0.0)	2 (4.0)	9 (18.0)	

Notes: n – number of subjects; % – percentage of subjects; χ^2 – chi-square test statistic; p – probability value; *p<0.05.

Foot morphology was assessed using a podoscopic method. To ensure methodological consistency across all participating V4 countries, the exact same device model – the CQ-ST podoscope (Elektronik System, Czernica, Poland) – was utilized at every research site. During the examination, each child stood barefoot on the podoscope platform in a relaxed upright position, with the head aligned in the Frankfurt plane, the upper limbs hanging freely alongside the trunk, and the feet positioned hip-width apart. Body weight was distributed evenly between both feet. The following foot indices were assessed: foot length, foot width, Clarke's angle, heel angle γ, hallux valgus angle (α), fifth toe varus angle (β) [18]. The medial longitudinal arch was evaluated using Clarke's angle, with normal values defined as 29-49° for girls and 20-44° for boys. The transverse arch was assessed based on the heel angle, where values between 15° and 18° were considered normal. Hallux alignment was determined using the hallux valgus angle, with the reference range for normal alignment set at 0-9°. Similarly, the alignment of the fifth toe was evaluated using the angle of the varus deformity of the fifth toe, with values from 0° to 9° regarded as normal [19].

Body weight was measured to the nearest 0.1 kg and body height to the nearest 0.1 cm. To maintain strict methodological standardization across all participating centers, the exact same model of a medical column scale with an integrated telescopic stadiometer (Charder Medical, Taichung, Taiwan) was utilized in each country. Based on these measurements, BMI was calculated for each child as body weight [kg] divided by the square of body height [m], and

weight status categories were determined based on the World Health Organization (WHO) growth charts [20].

All the assessments were conducted in full-time preschool facilities in rooms designated for physical activity, with the children's teachers present throughout the examination. The children typically attended preschool on weekdays between 7:00 a.m. and 4:30 p.m., although attendance times varied individually. To ensure consistency of the measurement procedure, all examinations were performed in the morning, between 8:00 and 11:00 a.m. Prior to data collection, parents or legal guardians were informed about the examination schedule and instructed to ensure that their children refrained from vigorous physical activity during the 12 hours preceding the assessment. Compliance with this recommendation was confirmed by a written declaration signed by the parents or legal guardians. All the measurements were performed by the study investigators using the same calibrated instruments. During the examinations, the children wore only their underwear. Shoes and socks were removed for the podoscopic assessment.

Dependencies between categorical variables were examined using the chi-square test. Statistical analyses and prevalence rates were stratified by sex to account for well-documented sexual dimorphism in pediatric foot morphology and development. Previous literature indicates that preschool boys and girls exhibit differences in the maturation rate of the medial longitudinal arch [18,19]. Furthermore, a sex-specific approach was strictly required to ensure the accurate application of the WHO growth references for evaluating children's weight status categories [20]. Statistical significance was set at $p<0.05$. All the statistical analyses were performed using Statistica software, version 13.3 (TIBCO Software Inc., Palo Alto, CA, USA; StatSoft Poland Sp. z o.o., Kraków, Poland).

Results

Table 2 outlines the descriptive statistics of specific foot morphology features among girls from the studied V4 countries.

Table 2. Foot morphology characteristics among girls from the studied V4 countries

Variable	Poland		Slovakia		Czech Republic	
	$\bar{x}$ ±SD	Me	$\bar{x}$ ±SD	Me	$\bar{x}$ ±SD	Me
Foot length [cm] right foot	17.65±0.81	17.60	18.89±1.35	18.45	18.13±1.16	18.20
Foot length [cm] left foot	17.62±0.82	17.60	18.89±1.33	18.45	18.14±1.18	18.25
Foot width [cm] right foot	6.87±0.45	6.80	7.01±0.37	7.00	7.25±0.44	7.20
Foot width [cm] left foot	6.88±0.47	6.85	7.02±0.33	7.00	7.31±0.43	7.30
Clarke's angle [°] right foot	36.58±11.05	36.50	45.86±7.93	45.00	39.18±8.96	41.00
Clarke's angle [°] left foot	34.64±11.41	34.00	45.56±8.40	45.00	38.64±8.76	41.00
Heel angle γ [°] right foot	16.90±1.87	17.00	15.30±2.20	15.00	15.92±2.55	16.00
Heel angle γ [°] left foot	16.84±1.89	16.00	15.54±2.59	15.50	16.02±2.48	16.50
Hallux valgus angle α [°] right foot	3.96±3.49	4.00	4.48±4.62	3.00	5.00±5.25	3.00
Hallux valgus angle α [°] left foot	3.60±3.41	2.00	5.24±5.15	4.00	5.00±5.12	3.50
Fifth toe varus angle β [°] right foot	13.30±6.01	15.00	8.32±5.08	7.00	8.14±6.76	8.00
Fifth toe varus angle β [°] left foot	14.58±4.73	15.00	8.94±5.09	9.00	7.64±6.11	8.00

Notes: $\bar{x}$ – arithmetic mean; SD – standard deviation; Me – median.

Table 3 details the descriptive statistics of specific foot morphology features among boys from the examined V4 countries.

Table 3. Foot morphology characteristics among boys from the studied V4 countries

Variable	Poland		Slovakia		Czech Republic	
	$\bar{x}$ ±SD	Me	$\bar{x}$ ±SD	Me	$\bar{x}$ ±SD	Me
Foot length [cm] right foot	17.70±0.91	17.60	19.19±1.46	19.30	18.61±1.08	18.55
Foot length [cm] left foot	17.70±0.90	17.70	19.15±1.51	19.30	18.65±1.05	18.70
Foot width [cm] right foot	7.06±0.47	7.10	7.11±0.37	7.15	7.44±0.58	7.50
Foot width [cm] left foot	7.11±0.47	7.10	7.10±0.37	7.20	7.43±0.60	7.50
Clarke's angle [°] right foot	28.34±11.31	29.50	43.98±10.08	44.50	37.98±9.36	39.00
Clarke's angle [°] left foot	26.02±11.03	26.50	42.06±10.87	43.50	37.04±9.69	38.00
Heel angle γ [°] right foot	17.24±1.70	17.00	14.80±2.50	14.50	15.94±3.09	16.50

Heel angle γ [°] left foot	17.04±1.78	17.00	14.88±2.59	15.00	15.86±3.01	17.00
Hallux valgus angle α [°] right foot	3.72±3.73	3.50	3.48±3.71	2.00	4.84±5.49	2.50
Hallux valgus angle α [°] left foot	4.08±3.42	4.00	3.74±3.92	2.50	4.68±5.28	3.00
Fifth toe varus angle β [°] right foot	13.40±5.74	14.00	7.96±5.05	6.00	8.44±5.62	10.00
Fifth toe varus angle β [°] left foot	13.34±5.18	13.00	7.08±4.39	6.50	8.14±5.19	10.00

Notes: $\bar{x}$ – arithmetic mean; SD – standard deviation; Me – median.

According to Table 4, most of the examined girls presented with a normal longitudinal arch height in both the right (66-74%) and left (62-78%) feet. Statistically significant dependencies were found between the prevalence of longitudinal foot deformities and the participants' country of residence (right foot: $\chi^2(4)=24.55$, $p<0.001$; left foot: $\chi^2(4)=24.01$, $p<0.001$). Girls from Poland and the Czech Republic were more likely to have longitudinally flat right and left feet, whereas girls from Slovakia more frequently exhibited longitudinally hollow (high-arched) right and left feet. The majority of the examined girls exhibited normal transverse arching, ranging from 56% to 70% for the right foot and 56% to 68% for the left foot. Furthermore, statistically significant dependencies were observed between the prevalence of both right and left transverse foot arch deformities and the country of residence (right foot: $\chi^2(4)=17.44$, $p=0.002$; left foot: $\chi^2(4)=10.92$, $p=0.027$). Girls from Poland were more likely to have transversely flat right and left feet, whereas girls from Slovakia and the Czech Republic more frequently exhibited transversely high-arched right and left feet. The majority of the examined girls exhibited normal hallux alignment, ranging from 76% to 94% for the right foot and 74% to 94% for the left foot. Furthermore, statistically significant dependencies were found between the prevalence of both right and left hallux valgus and the country of residence (right foot: $\chi^2(2)=7.03$, $p=0.030$; left foot: $\chi^2(2)=12.65$, $p=0.002$). Hallux valgus was more common among girls from the Czech Republic than among those from Poland and Slovakia. Statistically significant dependencies were also found between the prevalence of fifth toe varus deformity in both the right ($\chi^2(2)=14.96$, $p<0.001$) and left foot ($\chi^2(2)=28.74$, $p<0.001$) and the country of residence. This specific deformity occurred with a higher frequency among girls from Poland than among their peers from Slovakia and the Czech Republic.

Table 4. Distribution of foot structural characteristics and deformities among girls by the studied V4 countries

Morphological structure of the foot	Clinical assessment	Poland	Slovakia	Czech Republic	Pearson's chi-square test
		n (%)			
Right foot					
Medial longitudinal arch	**Normal foot**	35 (70.0)	33 (66.0)	37 (74.0)	$\chi^2(4)=24.55$ $p<0.001$*
	Flat foot	12 (24.0)	1 (2.00)	10 (20.0)	
	High arched foot	3 (6.0)	16 (32.0)	3 (6.0)	
Transverse arch	**Normal foot**	35 (70.0)	28 (56.0)	32 (64.0)	$\chi^2(4)=17.44$ $p=0.002$*
	Flat foot	12 (24.0)	3 (6.0)	5 (10.0)	
	High arched foot	3 (6.0)	19 (38.0)	13 (26.0)	
Hallux alignment	**Normal setting**	47 (94.0)	45 (90.0)	38 (76.0)	$\chi^2(2)=7.03$ $p=0.030$*
	Hallux valgus	3 (6.0)	5 (10.0)	12 (24.0)	
Fifth toe alignment	**Normal setting**	15 (30.0)	31 (62.0)	27 (54.0)	$\chi^2(2)=14.96$ $p<0.001$*
	Fifth toe varus	35 (70.0)	18 (36.0)	23 (46.0)	
Left foot					
Medial longitudinal arch	**Normal foot**	31 (62.0)	32 (64.0)	39 (78.0)	$\chi^2(4)=24.01$ $p<0.001$*
	Flat foot	14 (8.0)	2 (4.0)	9 (18.0)	
	High arched foot	5 (10.0)	16 (32.0)	2 (4.0)	
Transverse arch	**Normal foot**	34 (68.0)	28 (56.0)	32 (64.0)	$\chi^2(4)=10.92$ $p=0.027$*
	Flat foot	13 (26.0)	5 (10.0)	5 (10.0)	
	High arched foot	3 (6.0)	17 (34.0)	13 (26.0)	
Hallux alignment	**Normal setting**	47 (94.0)	41 (82.0)	37 (74.0)	$\chi^2(2)=12.65$ $p=0.002$*
	Hallux valgus	3 (6.0)	9 (18.0)	13 (26.0)	
Fifth toe alignment	**Normal setting**	8 (16.0)	32 (64.0)	34 (68.0)	$\chi^2(2)=28.74$ $p<0.001$*
	Fifth toe varus	42 (84.0)	18 (36.0)	16 (32.0)	

Notes: n – number of subjects; % – percentage of subjects; χ^2 – chi-square test statistic; p – probability value; *$p<0.05$.

The data presented in Table 5 indicate that the majority of the examined boys exhibited normal longitudinal arching, ranging from 44% to 64% for the right foot and 60% to 68% for the left foot. Furthermore, statistically significant dependencies were observed between the prevalence of both right and left longitudinal foot arch deformities and the country of residence (right foot: $\chi^2(4)=29.04$, $p<0.001$; left foot: $\chi^2(4)=26.24$, $p<0.001$). Boys from Poland were more likely to have longitudinally flat right and left feet, whereas boys from Slovakia and the Czech Republic more frequently exhibited longitudinally high-arched right and left feet. The majority of the examined boys exhibited normal transverse arching, ranging from 42% to 64% for the right foot and 44% to 70% for the left foot. Furthermore, statistically significant dependencies were observed between the prevalence of both right and left transverse foot arch deformities and the country of residence (right foot: $\chi^2(4)=22.88$, $p<0.001$; left foot: $\chi^2(4)=24.15$, $p<0.001$). Boys from Poland were more likely to have transversely flat right and left feet, whereas boys

from Slovakia and the Czech Republic more frequently exhibited transversely high-arched right and left feet. The majority of the examined boys exhibited normal hallux alignment, ranging from 78% to 94% for the right foot and 80% to 94% for the left foot. No statistically significant dependencies were found between the country of residence and the prevalence of hallux valgus in either the right or left foot. However, statistically significant dependencies were observed between the prevalence of fifth toe varus deformity in both the right ($\chi^2(2)=13.07$, $p=0.001$) and left foot ($\chi^2(2)=17.70$, $p<0.001$) and the country of residence. Similar to the female cohort, this specific deformity occurred with a higher frequency among boys from Poland than among their peers from Slovakia and the Czech Republic.

Table 5. Distribution of foot structural characteristics and deformities among boys by the studied V4 countries

Morphological structure of the foot	Clinical assessment	Poland	Slovakia	Czech Republic	Pearson's chi-square test
		n (%)			
Right foot					
Medial longitudinal arch	**Normal foot**	32 (64.0)	22 (44.0)	31 (62.0)	$\chi^2(4)=29.04$ $p<0.001$*
	Flat foot	14 (28.0)	3 (6.0)	3 (6.0)	
	High arched foot	4 (8.0)	25 (50.0)	16 (32.0)	
Transverse arch	**Normal foot**	32 (64.0)	21 (42.0)	25 (50.0)	$\chi^2(4)=22.88$ $p<0.001$*
	Flat foot	14 (28.0)	4 (8.0)	8 (16.0)	
	High arched foot	4 (8.0)	25 (50.0)	17 (34.0)	
Hallux alignment	**Normal setting**	47 (94,0)	46 (92.0)	39 (78.0)	$\chi^2(2)=4.96$ $p=0.084$
	Hallux valgus	5(10.0)	4 (8.0)	11 (22.0)	
Fifth toe alignment	**Normal setting**	14 (28.0)	32 (64.0)	24 (48.0)	$\chi^2(2)=13.07$ $p=0.001$*
	Fifth toe varus	36 (72.0)	18 (36.0)	26 (52.0)	
Left foot					
Medial longitudinal arch	**Normal foot**	32 (64.0)	30 (60.0)	34 (68.0)	$\chi^2(4)=26.24$ $p<0.001$*
	Flat foot	15 (30.0)	2 (4.0)	3 (6.0)	
	High arched foot	3 (6.0)	18 (36.0)	13 (26.0)	
Transverse arch	**Normal foot**	35 (70.0)	22 (44.0)	22 (44.0)	$\chi^2(4)=24.15$ $p<0.001$*
	Flat foot	12 (24.0)	4 (8.0)	8 (16.0)	
	High arched foot	3 (6.0)	24 (48.0)	20 (40.0)	
Hallux alignment	**Normal setting**	47 (94.0)	46 (92.0)	40 (80.0)	$\chi^2(2)=5.71$ $p=0.058$
	Hallux valgus	3 (6.0)	4 (8.0)	10 (20.0)	
Fifth toe alignment	**Normal setting**	13 (26.0)	34 (68.0)	24 (48.0)	$\chi^2(2)=17.70$ $p<0.001$*
	Fifth toe varus	37 (74.0)	16 (32.0)	26 (52.0)	

Notes: n – number of subjects; % – percentage of subjects; χ^2 – chi-square test statistic; p – probability value; *$p<0.05$.

Discussion

The present study demonstrated that normal foot morphology predominated in both girls and boys across the three Central European countries, as the majority of participants exhibited normal longitudinal and transverse arches and normal hallux alignment. Nevertheless, significant differences in the prevalence of foot deformities were identified according to the country of residence, suggesting that geographical and population-related factors may contribute to variations in foot structure during childhood. One of the most consistent findings of the present study was the higher prevalence of both longitudinal and transverse flatfoot among Polish children, whereas children from Slovakia and the Czech Republic more frequently presented high-arched feet. Although foot morphology is known to be influenced by age, sex, body composition, and genetic predisposition, environmental factors also play an important role in shaping the developing foot. Differences in habitual physical activity, footwear characteristics, time spent barefoot, terrain, socioeconomic conditions, and lifestyle may partly explain the observed inter-country variation. Bari et al. [21] and Bafor and Chibuzom [22] pointed that regular barefoot activity and greater exposure to uneven natural surfaces may promote physiological foot development, whereas prolonged use of rigid or poorly fitted footwear and reduced physical activity may contribute to abnormal arch development. Because these variables were not evaluated in the present study, the underlying mechanisms remain speculative and warrant further investigation.

The findings also revealed sex-specific differences in hallux alignment. Among girls, hallux valgus was significantly more prevalent in the Czech Republic, whereas no association between country of residence and hallux valgus was observed in boys. This discrepancy may reflect differences in footwear habits, biological maturation, ligamentous laxity, or other sex-specific biomechanical factors that become apparent during growth. According to Yokozuka and Okazaki [23], Hughes et al. [24], and Ettinger et al. [25], hallux valgus is more common in females, even from adolescence, and has been associated with both hereditary predisposition and external factors, particularly footwear. Therefore, the authors' own research indicated that the absence of significant differences among boys may suggest that environmental influences affecting hallux alignment are either less pronounced or occur later in development.

Another important observation was the consistently higher prevalence of fifth toe varus deformity among Polish children of both sexes. Compared with hallux valgus, fifth toe deformities have received considerably less scientific attention despite their potential clinical significance. Such deformities may result from inappropriate footwear, congenital anatomical

variation, or altered forefoot loading during gait. The consistency of this finding in both girls and boys suggests that common environmental or behavioral factors may be involved, although further studies incorporating footwear assessment and plantar pressure analysis are required to verify this hypothesis.

The observed differences between neighboring countries indicate that even geographically and culturally similar populations cannot be considered homogeneous with respect to foot morphology. This finding highlights the importance of considering regional characteristics when establishing normative reference values and designing preventive or screening programs for pediatric foot disorders. It also suggests that country-specific public health strategies addressing footwear education, physical activity, and early musculoskeletal screening may be justified.

Several limitations should be acknowledged. First, the cross-sectional design precludes conclusions regarding causal relationships between country of residence and foot morphology. Second, potentially important determinants such as BMI, physical activity level, footwear habits, socioeconomic status, ethnicity, and time spent barefoot were not included in the analysis. Third, although the participants were recruited from three neighboring countries, the results may not be generalizable to other populations with different environmental or cultural characteristics. Despite these limitations, the study possesses several strengths. It included a relatively large sample of preschool-aged children from three Central European countries examined using the same standardized methodology, allowing direct comparison of foot morphology between populations. These findings contribute to the limited comparative evidence regarding geographical variation in pediatric foot characteristics and may provide a basis for future longitudinal and multicenter studies investigating the determinants of normal and pathological foot development.

Conclusions

The majority of the examined girls and boys presented with normal longitudinal and transverse foot arches, as well as normal hallux alignment, indicating that a normal foot morphology predominated in the studied population. The country of residence emerged as a significant determinant of the prevalence of both longitudinal and transverse foot arch deformities in both sexes. Specifically, children from Poland more frequently exhibited longitudinal and transverse flatfoot, whereas those from Slovakia and the Czech Republic more often presented with high-arched feet, suggesting a potential influence of environmental,

lifestyle, or population-specific factors on pediatric foot development. Among girls, the prevalence of hallux valgus varied significantly according to the country of residence, with the highest frequency observed in the Czech Republic, whereas no such dependency was established for boys. In contrast, fifth toe varus deformity was significantly more prevalent among both girls and boys from Poland than among their counterparts from Slovakia and the Czech Republic.

Disclosures and acknowledgements

The authors declare no conflicts of interest with respect to the research, authorship, and/or publication of this article.

This research was conducted within the project no. 22510071 “Foot care education program for preschool aged children from the V4 countries”. The project is co-financed by the Governments of the Czech Republic, Hungary, Poland and Slovakia through Visegrad Grants from International Visegrad Fund. The mission of the fund is to advance ideas for sustainable regional cooperation in Central Europe.

The study protocol adhered strictly to the ethical principles of the Declaration of Helsinki, with its later amendments, and received approval from the the Bioethics Committee of the University of Rzeszów (Resolution No. 9/12/2025). Participation was entirely voluntary, requiring written proxy consent from parents or legal guardians alongside the verbal assent of the children. Both the participants and their parents or legal guardians were informed about the study objectives, procedures, and ethical principles, as well as their right to withdraw from the study at any time without any consequences.

Artificial intelligence (AI) was not used in the creation of the manuscript.

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