Original paper

Foot shape and its relationship with somatic characteristics in pre-school children

Budowa stóp i jej związki z cechami somatycznymi u dzieci w okresie przedszkolnym

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Key words: development of the foot, the medial longitudinal arch, transverse arch, setting of the hallux, setting of the V toe.

Słowa kluczowe: rozwój stopy, wysklepienie podłużne, wysklepienie poprzeczne, ustawienie palucha, ustawienie V palca.

Abstract

Introduction: The preschool period, characterised by high intensity of ontogenetic developmental changes, is considered to be the most important regarding formation of the foot. Getting to know the issue of the foot anatomy in children in this period is the main problem, which is the starting point towards proper prevention, examination, or correction of its deformities.
Aim of the research: To analyse the shape of children's feet and its relationship with chosen somatic characteristics in preschool children.
Material and methods: The study group comprised 80 five-year-old children recruited from randomly selected pre-schools in the Podkarpackie region. A CQ-ST podoscope was used as the research tool. In order to evaluate intersex differences at the average level of the tested variables, we used the Student's *t* test or alternatively the Mann-Whitney *U* test. The relations between tested variables was assessed using Pearson's linear correlation or Spearman's rank correlation.
Results: A low percentage of foot deformities in the children was found. In girls, statistically significant relationships were seen between Clarke's angle in the right foot and body mass index as well as between Wejsflog index in the right foot and body weight and height. In the case of boys, Clarke's angle and Wejsflog index in the left foot correlated with body mass index.
Conclusions: We can therefore assume that most of the surveyed girls and boys had correctly longitudinally and transversely arched feet and toes positioned correctly. Excessive weight was a factor distorting the foot shape in children; it caused a deterioration of longitudinal and transverse arch of the right foot in girls, and left foot flattening occurred in boys.

Streszczenie

Wprowadzenie: Okres przedszkolny, charakteryzujący się dużą intensywnością ontogenetycznych zmian rozwojowych, jest uznawany za najważniejszy z punktu widzenia kształtowania się stopy. Poznanie budowy stóp u dzieci w tym okresie ma podstawowe znaczenie i stanowi punkt wyjścia do podejmowania profilaktyki, badania i korekcji ich deformacji.
Cel pracy: Analiza parametrów budowy stóp i ich związków z wybranymi cechami somatycznymi u dzieci w okresie przedszkolnym.
Materiał i metody: Badaniami objęto 80 dzieci w wieku 5 lat uczęszczających do losowo wybranych przedszkoli na terenie województwa podkarpackiego. Narzędzie badawcze stanowił podoskop CQ-ST. Do oceny międzypłciowych różnic w przeciętnym poziomie badanych zmiennych zastosowano test *t*-Studenta lub alternatywnie test *U* Manna-Whitneya. Analizę związków badanych zmiennych wykonano na podstawie korelacji liniowej Pearsona lub korelacji rang Spearmana.
Wyniki: Odnotowano niski odsetek deformacji stóp u badanych dzieci. U dziewcząt stwierdzono statystycznie istotne związki między kątem Clarke'a stopy prawej a wskaźnikiem masy ciała oraz między wskaźnikiem Wejsfloga stopy prawej a masą i wysokością ciała. W przypadku chłopców kąt Clarke'a i wskaźnik Wejsfloga stopy lewej korelowały ze wskaźnikiem masy ciała.
Wnioski: Większość badanych dziewcząt i chłopców miała prawidłowo wysklepione podłużnie i poprzecznie stopy oraz prawidłowo ustawione palce. Nadmiar masy ciała niekorzystnie wpływał na ukształtowanie stóp, przy czym u dziewcząt powodował pogorszenie wysklepienia podłużnego i poprzecznego stopy prawej, natomiast u chłopców dochodziło do spłaszczenia łuków podłużnych i poprzecznych stopy lewej.

Introduction

The human foot is an important static-dynamic part of the motor system and is characterised by different pace of development. During infancy, its plantar part is covered with a fat layer and the muscles of its arch are weak. The main factors shaping a child's foot are the beginnings of locomotion and increasing loading of the lower extremities. The process of arch formation covers primarily the period between the age of 3 and 6 years [1] while longitudinal and transverse arches become explicit at the age of 6 years. The preschool period, characterised by a high intensity of ontogenetic developmental changes, is considered the most important regarding foot formation. It is also a critical period in which increased risk of formation of foot defects occurs, mostly flat feet. Lowering of the foot arch in children and development of static flat foot is the result of muscle weakness and deficiencies in the ligamento-capsular apparatus. Two types of flat feet may develop in preschool children: the first is the type of the early childhood feet that have not undergone the evolution of growth characteristic for their age and have a flattened arch (feet remain fatty, limp, with weak muscles, and continue to be seemingly flat feet); the second type are feet with normal bone structure, but held by weak ligaments and muscles that cannot cope with keeping the skeleton in the right setting [2]. Lin *et al.* [3] analysed the correlations of factors and clinical significance with flexible flatfoot in preschool children aged 2–6 years from Taiwan. The results show that age, height, weight, foot progression angle, occurrence of physical knock-knee, and joint laxity score correlate with flat foot. Children with flat foot compared with children without, performed physical tasks poorly and walked slowly, as determined by gait parameters. Flat foot should not simply be regarded as a problem of static alignment of the ankle and foot complex, but maybe the consequence of a dynamic functional change of the lower extremity. Better understanding of the correlating factors and the clinical relevance of flat foot may prove helpful in deciding on the most appropriate treatment for a particular patient. Evans and Rome [4], based on Cochrane review, affirmed that flat foot has been found normally to reduce with age. The normal findings of flat foot versus children's age lead to the estimate that approximately 45% of preschool children and 15% of older children (average age 10 years) have flat feet. Lizis [1] stresses that preschool age is critical for future health and efficiency of the feet, and the Clarke angle stabilises between the age of 11 and 13 years, when it corresponds to the feet of adults. Understanding the issues concerning the construction of the foot is of key importance; it is the starting point for proper prevention, testing, or correction of deformities. The issue of foot structure and function is undertaken by specialists from many fields of science who characterise developmental changes in a manner specific to a given discipline. A variety of research methods, comparing the results of studies on people at different ages and in different environments, often caused difficulty in unambiguous, accurate diagnosis and prognosis of the feet arch condition and feet capacity. Therefore, divergent results on the prevalence of deformities and the impact of various factors on the delicate structure of the foot can be found in the literature.

Aim of the research

The present paper is an attempt to focus on this issue and aims to analyse the foot shape and its relationship with body composition in 5-year-old children.

Material and methods

We examined 80 children, 5-years-old (40 girls and 40 boys), recruited from randomly selected preschools in the Podkarpackie region in South-Eastern Poland. The inclusion criteria were as follows: age 5 years, attending preschool, understanding the instructions that were necessary for the measurement procedures, and written, informed consent to participate in the study given by the parents or guardians. The exclusion criteria were: a congenital or acquired neurological disease, signs of orthopaedic disease, pathology of the lower limb affecting support and gait, and previous orthopaedic surgery.

The CQ-ST podoscope (manufactured by Elektronik System) was applied as the main research tool. The podoscopic examination of the plantar side of the foot is a development, and improvement, of the well-known plantographic method. In addition to an exact foot print, we obtained information about the foot arching. The study entailed measuring the plantar surfaces of the feet, in a relaxed stance, with the upper limbs hanging alongside the body. Each time, both feet were subjected to examination. The width and foot angle were natural and unforced. Based on

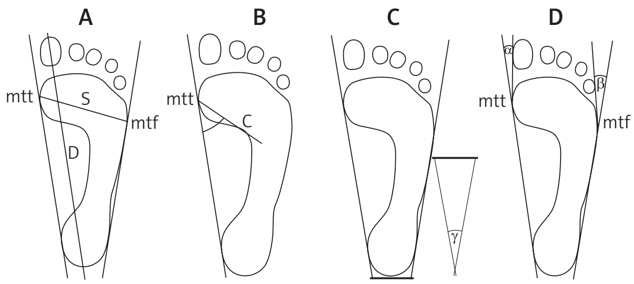

Figure 1. Procedure for determining the feet structure indices: a) foot length (*D*), foot width (*S*) and the Wejsflog (W_{wp}) index; b) Clarke's angle; c) heel angle (γ); d) hallux valgus angle (α) and the angle of the varus deformity of the fifth toe (β)

the picture obtained during the scan, the researcher marked by hand specific points in a computer and then, on the basis of those points, the computer calculated the indices describing the longitudinal and transverse arch of the foot and arrangement of the hallux and the fifth toe. All footprints were elaborated by the same person. The following parameters were measured: foot length (*D*), foot width (*S*), Clarke's angle, the Wejsflog (W_{wp}) index, heel angle (γ), hallux valgus angle (α), and the fifth toe varus deformity angle (β). The procedures for calculating the feet structure indices are shown in Figure 1.

Anthropometric measurements of the body mass and height were taken. The body mass was measured with electronic scales, determined to the nearest 0.1 kg. The body height was measured to the nearest 0.1 cm using a Martin-type anthropometer. The obtained data were used to calculate the body mass index (BMI). Basic descriptive statistics of the somatic features in the examined girls and boys are presented in Table 1.

The study was approved by the Ethics Committee of Rzeszow University. The procedures were carried out in accordance with the Declaration of Helsinki. In order to ensure the integrity of the research process, all tests were carried out in the morning, using the same measuring instruments, and operated by the authors. The measurements were carried out in a gym; children wore their gymnastic uniforms without shoes. All participants, their parents, or legal guardians received detailed information concerning the aim and methodology used in the study and gave written consent.

Statistical analysis

Based on the yielded data, the following descriptive statistics were calculated: arithmetical mean value ($\bar{x}$), standard deviation (SD), median (Me), and maximum and minimum values. The normalcy of distribution of particular characteristics was verified by means of the Shapiro-Wilk test. In order to evaluate intersex differences at the average level of the tested variables, we used the Student's *t* test for independent samples or the non-parametric Mann-Whitney *U* test. The relation between two variables with normal distribution was assessed using Pearson's linear correlation (*r*), and Spearman's rank correlation (*R*) was used in the case of nonparametric variables. Results were considered statistically significant if the probability level of the test was lower than the predetermined significance level $p < 0.05$. The Stat Soft Statistica application (version 10.0) was used to process the test results.

Results

Table 2 provides descriptive statistics of selected parameters of the construction of girl's and boy's feet. The length and width of the foot were similar in both sexes. Average values of the Clarke angle were within norms, which, according to Lizis [1] amounts to 24–47° for girls and 25–44° for boys. Also, the γ and α did not deviate from the standards and were similar for the right and left foot. Average of the V toe β in both girls and boys ranged around the upper limit of the norm, which was adopted from 0° to 9° [5]. No statistically significant inter-sex differences were found between the analysed indicators.

Most of the surveyed girls and boys had correctly longitudinally and transversely arched feet and toes positioned correctly. No statistically significant intersex variation in this respect was observed (Table 3).

The data in Table 4 indicate a statistically significant positive relationship between the length and width of the foot of girls and boys as well as body weight and height and BMI. Additionally, the Clarke angle in girls in the right foot showed a negative correlation with BMI ($R = -0.35$; $p = 0.027$*), while the Wejsflog (W_{wp}) index of the right foot correlated negatively with body weight ($R = -0.34$; $p = 0.035$*) and body height ($r = -0.32$; $p = 0.045$*). In the case of the boys, the Clarke angle of the left foot and W_{wp} index of the left foot showed negative correlations with BMI ($R = -0.33$; $p = 0.036$* and $R = -0.38$; $p = 0.016$*).

Table 1. Somatic parameters of the study subjects

Feature	$\bar{x}$ ± SD	Me	Max.–min.	*t/Z*	*P*-value
Body weight [kg]:					
Girls	21.12 ±5.87	19.85	40.00–12.00	*Z* = –0.40	0.690
Boys	20.78 ±3.91	20.20	33.30–15.10		
Body height [cm]:					
Girls	113.33 ±7.99	113.50	130.00–96.00	*t* = 0.40	0.706
Boys	112.70 ±6.75	114.00	126.00–100.00		
BMI [kg/m²]:					
Girls	16.21 ±2.66	15.35	26.00–13.60	*Z* = –1.21	0.227
Boys	16.29 ±1.87	16.00	21.70–13.30		

Table 2. Comparison of structural features of the feet obtained in groups depending on sex

Feature	Girls (n = 40)			Boys (n = 40)			*t/Z*	*P*-value
	$\bar{x}$ ± SD	Me	Max.–min.	$\bar{x}$ ± SD	Me	Max.–min.		
Foot length [cm]:								
rf	16.68 ±1.16	16.55	19.70–14.40	16.68 ±1.07	16.80	18.60–14.20	t = –0.03	0.976
lf	16.63 ±1.18	16.45	19.80–14.00	16.63 ±1.08	35.00	18.50–14.30	t = 0.01	0.992
Foot width [cm]:								
rf	6.70 ±0.62	6.45	8.20–5.20	6.46 ±0.53	6.50	7.60–5.40	t = 0.06	0.954
lf	6.44 ±0.58	6.50	7.70–5.40	6.48 ±0.53	6.55	7.60–5.20	t = –0.36	0.717
Clarke's angle [°]:								
rf	34.43 ±10.14	35.50	53.00–17.00	33.58 ±12.11	37.50	51.00–10.00	Z = 0.03	0.977
lf	33.20 ±10.46	35.00	50.00–13.00	33.38 ±12.72	37.50	58.00–13.00	Z = 0.33	0.743
Wejsflog (W_{wp}) index:								
rf	2.60 ±0.16	2.58	2.90–2.32	2.59 ±0.15	2.58	2.95–2.22	t = 0.18	0.856
lf	2.59 ±0.15	2.58	3.00–2.35	2.57 ±0.13	2.56	2.85–2.33	t = 0.67	0.505
Heel angle (γ) [°]:								
rf	17.00 ±2.26	17.50	22.00–12.00	17.20 ±2.21	18.00	22.00–11.00	Z = –0.45	0.655
lf	16.90 ±2.07	17.00	21.00–11.00	17.13 ±2.10	18.00	22.00–12.00	Z = –0.61	0.544
Hallux valgus angle (α) [°]:								
rf	2.72 ±3.77	0.00	12.00–0.00	3.33 ±4.27	0.00	14.00–0.00	Z = –0.51	0.607
lf	2.75 ±3.75	0.00	13.00–0.00	3.45 ±3.95	2.50	16.00–0.00	Z = –0.56	0.392
The V toe varus deformity angle (β) [°]:								
rf	10.90 ±5.01	9.00	22.00–0.00	10.75 ±7.49	12.50	22.00–0.00	Z = –0.29	0.771
lf	8.97 ±6.34	9.00	22.00–0.00	10.63 ±5.62	9.50	20.00–0.00	Z = –1.39	0.163

rf – right foot, lf – left foot.

Discussion

The issue of shaping of children's feet has been undertaken many times in the past, and analysis of the results led the authors to different conclusions. Mickle *et al.* [6], based on analysis of Arch Index value in children (mean age: 4.2 ±0.6 years) who were recruited from 10 randomly selected preschools from the Illawarra region of New South Wales, Australia, found that the preschool boys displayed significantly flatter feet than the girls. Although there were no between-gender differences in structural foot dimensions, the boys had a significantly thicker midfoot fat pad than the girls by approximately 0.4 and 0.5 mm on both the right and left feet, respectively. The authors conclude that the increased incidence of flat-footedness in boys compared with girls of the same age seems to be caused by a thicker plantar fat pad in the medial midfoot in boys. This suggests that the development of the medial longitudinal arch may progress at a slower rate in boys than in girls, and that intervention for a flexible flat foot, particularly for young boys, may be unnecessary.

Jankowicz-Szymańska and Pociecha [7] did not observe inter-sex variation of the longitudinal feet arch evaluated with Clarke angle in 5-year-old girls and boys from randomly selected kindergartens in Tarnow, Poland. Their study also did not show statistically significant differences in the longitudinal arch in the right and left foot. Prętkiewicz-Abacjew and Opanowska [2] observed inter-sex differentiation in terms of the prevalence of different types of longitudinal foot arch in preschool-age children from the Tri-City, Poland. In the group of 5-year-olds longitudinal flat feet were significantly more frequent in boys than in girls. The authors reported a small percentage of transverse hollow feet. Chen *et al.* [8] demonstrated a significant association of age, gender, obesity status, joint laxity, and the W-sitting habit with the bilateral flatfoot in preschool-aged children. Age and obesity status, by contrast, were not significantly influential in the unilateral flatfoot group. Vergara-Amador *et al.* [9],

Table 3. Number of subjects with various types of longitudinal and transverse arch and setting of the hallux and the V toe among girls and boys

Variable		Girls	Boys	χ^2
		n		
The medial longitudinal arch (MLA) based on the Clarke's angle:				
rf	Flat foot	7	12	$\chi^2(2) = 2.14$; $p = 0.342$
	Normal foot	27	21	
	High arched foot	6	7	
lf	Flat foot	10	15	$\chi^2(2) = 2.51$; $p = 0.286$
	Normal foot	23	16	
	High arched foot	7	9	
Transverse arch based on the heel angle (γ):				
rf	Flat foot	6	8	$\chi^2(2) = 0.35$; $p = 0.837$
	Normal foot	30	28	
	High arched foot	4	4	
lf	Flat foot	5	7	$\chi^2(2) = 0.40$; $p = 0.820$
	Normal foot	32	30	
	High arched foot	3	3	
Setting of the hallux based on the hallux valgus angle (α):				
rf	Normal setting	39	38	$\chi^2(1) = 0.35$; $p = 0.556$
	Hallux valgus	1	2	
lf	Normal setting	39	39	$\chi^2(1) = 0.00$; $p = 1.000$
	Hallux valgus	1	1	
Setting of the V toe based on the V toe varus deformity angle (β):				
rf	Normal setting	25	18	$\chi^2(1) = 2.46$; $p = 0.116$
	The V toe varus deformity	15	22	
lf	Normal setting	26	19	$\chi^2(1) = 2.49$; $p = 0.115$
	The V toe varus deformity	14	21	

rf – right foot, lf – left foot.

based on studies in children from several schools in Bogota, Central Columbia and Barranquilla, Northern Columbia, highlighted the impact of social, cultural, and racial factors on the development of flat feet. The authors pointed to the link between age and the incidence of flat feet. In the group of 3–5-year-old children the proportion of flat feet was higher compared to children aged 6–7 years. Accordingly, the authors suggest no need for flat feet therapy in children under 6-years-old. There was also a higher proportion of flat feet in boys.

In the study by Pfeiffer *et al.* [10] the prevalence of flexible flat foot in the group of 3–6-year-old children was 44%. The prevalence of flat foot decreases significantly with age: in the group of 3-year-old children 54% showed a flat foot, whereas in the group of 6-year-old children only 24% had a flat foot. Boys had a significant greater tendency for flat foot than girls: the prevalence of flat foot in boys was 52% and 36% in girls. Thirteen per cent of the children were overweight or obese. Significant differences in the prevalence of flat foot between overweight, obese, and normal-weight children were observed. Echarri and Forriol [11] based on the footprints of Congolese children studied with Chippaux-Smirak Index, Staheli's index of the arch, and Clarke's angle showed that the proportion of flat feet decreased with age. The authors reported 70% prevalence for flat feet in children 3–4 years of age and of 40% between 5 and 8 years of age. Boys had a greater tendency for flat feet. According to the three parameters studied there was a greater proportion of flat feet in the urban environment. Arizmendi *et al.* [12], in a Mexican population in Morelia, reported 31.9% prevalence of flat feet in preschool children and 8.8% in school children. In our study, the majority of boys and girls had properly longitudinally arched feet.

The analysis of literature indicates that most authors are focused on evaluation of the longitudinal foot arch, and less frequently on the transverse arch and toes setting. Demczuk-Włodarczyk [5] claims that transverse flat foot becomes visible from the age of three in the case of the left foot, both when it is unloaded and loaded with weight, while in the right foot at first when it is loaded, and at the age of 5 years in unloaded condition. In boys, transverse flat feet become visible in both feet from the age of 4 years, but only in loaded conditions. In the unloaded conditions, it is visible in the right foot at the age of 5 years, and in the left foot at the age of 6 years. A increase in the percentage of transverse flat feet is observed during progressive development. Our research showed that most 5-year-olds had normal transverse foot arches.

The issue of the incidence of irregularities in the toe setting raises some controversies. According to some authors, hallux valgus starts to form during adolescence, and others clearly emphasise that it happens much earlier, often already in childhood. Most authors agree that both hallux valgus and other toe deformities are not genetic, but result from abnormal reactions with footwear [13–15]. The research by Klein *et al.* [16] covering a group of 858 pre-school children from an Austrian province showed that only 23.9% of feet presented a straight position of the great toe. In addition, 808 children wore too small shoes and 812 had inadequate outdoor footwear. The authors claimed that there is a significant relationship between the hallux angle in children and footwear that is too short in length. On the basis of our own re-

Table 4. Correlations between foot structure parameters and the chosen morphological features in examined girls and boys

Feature		Body weight	Body height	BMI
Girls:				
Foot length	rf	R = 0.81; p = 0.000*	r = 0.83; p = 0.000*	R = 0.43; p = 0.006*
	lf	R = 0.83; p = 0.000*	r = 0.86; p = 0.000*	R = 0.43; p = 0.005*
Foot width	rf	R = 0.76; p = 0.000*	r = 0.79; p = 0.000*	R = 0.45; p = 0.004*
	lf	R = 0.67; p = 0.000*	r = 0.72; p = 0.000*	R = 0.36; p = 0.023*
Clarke's angle	rf	R = –0.24; p = 0.143	r = –0.07; p = 0.690	R = –0.35; p = 0.027*
	lf	R = –0.15; p = 0.349	R = –0.03; p = 0.875	R = –0.29; p = 0.071
Wejsflog (W_{wp}) index	rf	R = –0.34; p = 0.035*	r = –0.32; p = 0.045*	R = –0.26; p = 0.109
	lf	R = –0.09; p = 0.570	r = –0.07; p = 0.655	R = –0.08; p = 0.610
γ angle	rf	R = 0.25; p = 0.116	R = 0.21; p = 0.191	R = 0.19; p = 0.253
	lf	R = –0.04; p = 0.919	R = –0.09; p = 0.570	R = 0.04; p = 0.789
α angle	rf	R = 0.22; p = 0.182	R = 0.20; p = 0.226	R = 0.12; p = 0.475
	lf	R = –0.02; p = 0.896	R = –0.04; p = 0.825	R = –0.02; p = 0.879
β angle	rf	R = 0.06; p = 0.699	R = 0.07; p = 0.657	R = –0.02; p = 0.914
	lf	R = 0.01; p = 0.961	r = –0.01; p = 0.959	R = 0.05; p = 0.767
Boys:				
Foot length	rf	r = 0.62; p = 0.000*	r = 0.83; p = 0.000*	R = 0.17; p = 0.307
	lf	r = 0.63; p = 0.000*	r = 0.83; p = 0.000*	R = 0.22; p = 0.176
Foot width	rf	r = 0.53; p = 0.000*	r = 0.55; p = 0.000*	R = 0.34; p = 0.032*
	lf	r = 0.58; p = 0.000*	r = 0.61; p = 0.000*	R = 0.36; p = 0.022*
Clarke's angle	rf	R = –0.10; p = 0.511	R = 0.16; p = 0.319	R = –0.28; p = 0.076
	lf	R = –0.14; p = 0.381	R = 0.11; p = 0.505	R = –0.33; p = 0.036*
Wejsflog (W_{wp}) index	rf	r = –0.05; p = 0.774	r = 0.16; p = 0.331	R = –0.30; p = 0.056
	lf	r = –0.13; p = 0.436	r = 0.09; p = 0.592	R = –0.38; p = 0.016*
γ angle	rf	R = 0.25; p = 0.113	R = 0.13; p = 0.415	R = 0.25; p = 0.127
	lf	r = –0.13; p = 0.434	r = 0.06; p = 0.711	R = –0.14; p = 0.399
α angle	rf	R = 0.15; p = 0.364	R = 0.05; p = 0.767	R = 0.17; p = 0.305
	lf	R = 0.01; p = 0.930	R = –0.09; p = 0.575	R = 0.18; p = 0.268
β angle	rf	R = 0.06; p = 0.712	R = –0.07; p = 0.677	R = 0.13; p = 0.432
	lf	R = 0.03; p = 0.873	R = 0.01; p = 0.961	R = –0.07; p = 0.688

*rf – right foot, lf – left foot, *p < 0.05.*

search we found that toe deformities are not common in children aged 5 years. The values of α did not deviate from the norms and was similar in case of the right and left foot. The average of the V toe β in both girls and boys approximated the upper limit of the norm.

Another important issue is the influence of the morphological features of the construction of children's feet. Mickle *et al.* [17] observed lower longitudinal arch in obese children relative to their non-overweight peers. The authors attempted to determine whether the longitudinal flat feet in obese and overweight preschoolers is attributable to the presence of a thicker midfoot plantar fat pad or a lowering of the longitudinal arch. Based on the conducted study, they recognised that lower plantar arch height found in the overweight/obese children suggests that the flatter feet characteristic of overweight/obese preschool children may be caused by structural changes in their foot anatomy. Riddiford-Harland *et al.* [18] considered whether the feet in obese children are flat or fat. The authors' findings indicate that obese children had significantly greater medial midfoot fat pad thickness relative to the leaner children during both non-weight bearing and weight bearing. The obese children also displayed a lowered medial longitudinal arch height when compared to their leaner counterparts. The authors conclude that obese children had significantly fatter and flatter feet compared to normal weight children. The functional and clinical relevance of the increased fatness and flatness values for the obese children remains unknown. In turn, Evans and Karimi [19] seemed to strongly exclude the relationship between body weight and flat feet determined with FPI index. Also, Mikołajczyk and Jankowicz-Szymańska [20] did not observe statistically significant correlations between BMI and Clarke angle in preschool girls and boys. The opinions of the above cited authors are in disagreement with Matsuda *et al.* [21], who examined the relationship between age, sex, body build, and foot load in preschool children. The authors pointed out the uneven load distribution in feet and explained asymmetries with lateralisation of supporting and manipulating functions in the lower extremities. They linked foot deformities more with weight and physique than with age and gender. They found that taller children with higher BMI are more prone to flat feet than children whose weight-height ratios are within accepted standards. Demczuk-Włodarczyk [5] stressed that a massive type of body build interferes with the structure of the foot in children during development. The evaluation of the relationship between the longitudinal and transverse feet arches with the type of body build showed the most frequent defects in massive boys and massive and slender girls. Our research showed that excessive weight adversely affects feet shaping; in girls the increase in weight-height rates reduces longitudinal and transverse arch of the right foot, and in boys the left foot flattens. These differences may result from the level of sexual dimorphism and type of physical activity in early childhood, which may have an impact on the dynamics of shaping limb preferences in manipulative and stabilisation function. Girls are encouraged to take part in more static play in a small space, for example playing "home" with dolls, while boys choose fun requiring more intensive effort and larger area. Jumping and kicking involve the left lower limb more in the supporting function, and the right one for manipulation. In this situation distribution of more weight on the left side occurs in boys. The left foot is loaded more and therefore, in the case of excessive body weight, it may be more susceptible to flattening. However, this issue requires separate studies.

Summing up our own research and the reports of other authors, the need for constant screening of the condition of feet and care for their proper development have to be highlighted, especially in children during developmental plasticity. Creating the right conditions for the development of the feet, teaching correct motor habits allows a reduction in the correction only in cases where it is necessary.

Conclusions

Most of the surveyed girls and boys had correctly longitudinally and transversely arched feet and toes positioned correctly. Excessive weight was a factor distorting the foot shape in children; it caused a deterioration of longitudinal and transverse arch of the right foot in girls, and left foot flattening occurred in boys.

Conflict of interest

The authors declare no conflict of interest.

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