© Wydawnictwo UR 2019
ISSN 2544-1361 (online); ISSN 2544-2406
doi: 10.15584/ejcem.2019.1.6

http://www.ejcem.ur.edu.pl/en/
European Journal of Clinical and Experimental Medicine
Eur J Clin Exp Med 2019; 17 (1): 33–37

ORIGINAL PAPER

Agnieszka Jankowicz-Szymańska [1 (ABCDEF)], Katarzyna Wódka [1 (BCDF)],
Edyta Mikołajczyk [2 (FG)]

Is valgus foot always flat? The longitudinal arch of the foot and hindfoot valgus in 10–12 year-olds

[1] Institute of Health Sciences, State Higher Vocational School, Tarnow, Poland
[2] Department of Physiotherapy, University of Physical Education, Krakow, Poland

ABSTRACT
Introduction. Flat foot is still a controversial topic. As of yet, there are no unified definitions of this deformation.
Aim. To assess the correlation between the longitudinal arch of the foot and hindfoot valgus in school-age children.
Material and methods. A total of 362 pupils, 183 girls aged 10.96 ± 0.78 yrs and 179 boys aged 10.89 ± 0.78 yrs, participated in the study. Their height and weight were measured and their Body Mass Index (BMI) weight status was categorized. The Arch Index (AI) was used to assess the longitudinal arch of the foot. Hindfoot valgus was measured by a goniometer and defined as the angular deviation between the tibial anatomical axis and the calcaneus longitudinal axis.
Results. About 1/3 of the participants had hollow feet and about a fifth of them had flat feet. No correlations between the longitudinal arch of the foot and the hindfoot valgus were discovered; however, a correlation between excessive weight and the longitudinal flat foot was revealed. No correlations between BMI and hindfoot malalignment were found.
Conclusion. Hindfoot valgus was prevalent in a considerable proportion of boys and girls with the flat, normal and hollow foot. Therapeutic correction of valgus feet should be varied and should depend on the quality of the longitudinal arch of the foot.
Keywords. flat foot, hindfoot valgus, school children

Introduction

The ability to maintain good posture is not inborn. Children, acquiring new locomotor skills, gradually manage control over their body and develop their postural pattern. The lower limb alignment undergoes especially dynamic development. In infants and toddlers, flat feet are a common and normal condition until about age ten.[1,2] During that time, due to the impact of negative external or internal stimuli, foot deformities may develop. Observations of the relationship between the status of body mass and the quality of the arching of the feet indicate a greater incidence of flat feet in children with excessive body mass.[3] Knees valgus are also associated with incorrect foot shape.[4] Foot deformities are very common. Most pediatric orthopedic consultations concern flat feet.[5]

From the point of view of biomechanics, flat feet are a complex deformity. They are caused by ligamentous laxity and lack of muscle control.[6] This study aimed to assess correlations between the longitudinal arch of

Corresponding author: Agnieszka Jankowicz-Szymańska, e-mail: jankowiczszymanska@gmail.com

Participation of co-authors: A – Author of the concept and objectives of paper; B – collection of data; C – implementation of research; D – elaborate, analysis and interpretation of data; E – statistical analysis; F – preparation of a manuscript; G – working out the literature; H – obtaining funds

Received: 3.11.2018 | Accepted: 20.12.2018
Publication date: March 2019

Jankowicz-Szymańska A, Wódka K, Mikołajczyk E. *Is valgus foot always flat? The longitudinal arch of the foot and hindfoot valgus in 10–12 year-olds*. Eur J Clin Exp Med. 2019;17(1):33–37. doi: 10.15584/ejcem.2019.1.6

the foot and hindfoot alignment in children aged 10-12 years. It was investigated which of the above-mentioned deformities prevailed more often and whether excessive weight increased the risk of their development.

Materials and methods

The study was conducted in September and October 2015. Prior to the start of the study, consent of the local ethics committee was obtained (no 3/0177/2014). Four schools were randomly selected and all pupils attending grades four through six were initially invited to participate in the study. Participants were assigned to the study samples based on a written informed consent of their parent or a legal guardian and lack of medical certification of disability. Those children, who had previously been treated due to hip dysplasia or Perthes disease, and those who had suffered from injuries to their lower limbs within six months prior to the study, were excluded from the examination. Eventually, a total of 362 pupils aged 10-12 years (10.89 ± 0.78), including 183 girls (50.5%) and 179 boys (49.5%), participated in the study.

Participants' height and weight measurements were taken, their BMI calculated and their weight status categorized. Body height was measured within 1 cm by means of a calibrated anthropometer (ZPH Alumet No 010208, Warsaw, Poland), measuring the distance from the floor to the highest point on the head. During measurements, participants stood motionless with their legs together and feet flat on the floor and with their sight directed straight ahead. Body weight was measured within 0.1 kg on the Tanita scales (bf-350 Tanita Corporation of America, Inc., Arlington Heights, Illinois, USA). Measurements were taken from participants undressed to their underwear and without footwear. Based on the results obtained, BMI was calculated dividing body weight (kg) by the square of body height (m). Participants' body weight status was categorized using the BMI-for-age thresholds for overweight and obesity, developed for children by Cole et al.[7]

The baroresistive BTS P-walk platform (**BTS Bioengineering Corp., NY, USA**) was used to measure the longitudinal arch of the foot. The Arch Index (AI) was determined in two feet standing, for the right and left foot, calculated as the ratio of the area of the middle third of the footprint to the entire footprint area. The AI is an easy and objective method of assessing the quality of the longitudinal arch of the foot, and its characteristic value for the foot with a normal arch equals from 21% to 28%. Its values below 21% refer to a high foot arch, and those above 28% denote flat foot. The hindfoot alignment was measured by a goniometer (KaWe, Horn Wellness Group Ltd. Poznan, Poland) and defined as the angular deviation between the tibial anatomical axis and the calcaneus longitudinal axis. The angle above 5° indicated hindfoot valgus.[8] Participants assumed relaxed posture and stood with their legs a little apart. Individual measurements were taken in a pre-arranged order, by the same experienced physiotherapists, before the noon and in a well sun-filled room.

The mean, median, minimum and maximum values and standard deviation were used to analyze the data collated. The normal distribution of variables was assessed by means of the Shapiro-Wilk test. The difference between the samples was determined by means of the t-test for independent samples (at normal distribution), and by the U Mann-Whitney test (at lack of normal distribution) or by the Kruskal-Wallis and post hoc Tukey's tests (at comparing three samples at the same time). Correlations between variables were assessed by Pearson's linear correlation. The level of significance was accepted at $p = 0.05$.

Results

Girls were slightly taller and lighter than boys. BMI did not significantly differentiate boys and girls (Table 1). Excessive body weight was discovered in 99 participants, out of which 72 were overweight (18.9%) and 27 obese (7.5%). Overweight was more typical of girls, and obesity in boys (Table 2). The AI for the right and left foot was slightly greater in boys, which implied that they had lower foot arches than girls (Table 1). A fallen arch in the right foot was found in 19.1% of participants, i.e. in every fourth boy and in every sixth girl. A fallen arch in the left foot was discovered in 16.3% of participants, i.e. in every fourth boy and every ninth girl (Table 2). A high arch in the right foot was found in 31.5%, and in the left foot in 36.7% of all participants. In the case of both feet, high foot arches were more typical of girls.

The hindfoot valgus angle in the right foot was greater in girls, and in the left foot in boys; however, those differences were not of statistical significance (Table 1). The hindfoot malalignment was revealed in over 50% of participants. The valgus deformity in the right foot prevailed more often in girls, while in the left foot in boys (Table 2). The comparison of the hindfoot malalignment in participants with the high, normal and flat foot disclosed a statistically significant difference only in the size of the hindfoot valgus angle in the right foot in children with the normal foot and flat foot (Table 3). The valgus deformity in the right foot was discovered in 207 participants - 31.4% of them had the high-arched foot, 45.4% normal and 23.2% flat foot. The valgus deformity in the left foot was found also in 207 participants - 34.8% of them had the high-arched, 45.9% normal and 19.3% flat foot.

The lowering of the longitudinal arch of the foot correlated with increased BMI (Table 3). Significant differences in the BMI value were seen between participants with the high-arched and normal foot, and between the high-arched and flat foot. The analysis of dependencies

Table 1. Comparison of variables in girls and boys

Variable	Group	Mean	Median	Minimum	Maximum	Stand. Dev.	p
Height [cm]	Girls	147.88	147.80	128.40	171.00	9.55	0.34[a]
	Boys	147.11	145.90	124.40	178.30	8.95	
Weight [kg]	Girls	41.68	41.80	21.00	73.20	10.67	0.34[b]
	Boys	41.70	38.40	23.60	100.60	12.98	
BMI [kg/m^2]	Girls	18.80	18.59	12.70	29.32	3.27	0.51[b]
	Boys	18.97	17.74	11.85	38.57	4.26	
AI right foot [%]	Girls	22.06	23.46	1.96	36.42	7.03	0.08[b]
	Boys	22.90	24.80	0.90	41.64	8.36	
AI left foot [%]	Girls	20.95	22.37	1.90	37.28	7.22	0.09[b]
	Boys	22.17	23.38	0.78	38.66	8.12	
Right hind valgus angle [°]	Girls	6.32	6.00	0.00	13.00	2.65	0.75[b]
	Boys	6.25	6.00	2.00	15.00	2.49	
Left hind valgus angle [°]	Girls	5.96	6.00	0.00	13.00	2.53	0.75[b]
	Boys	6.71	7.00	1.00	18.00	2.81	

*statistically significant differences, [a] t test, [b] U Mann-Whitney test

Table 2. Weight status, foot arches and hindfoot alignment in girls and boys

Variable	Group	Girls		Boys		All	
		n	(column %)	N	(column %)	n	(column %)
Weight status	Normal	138	(75.4%)	125	(69,9%)	263	(72.6%)
	Overweight	38	(20.8%)	34	(19.0%)	72	(18.9%)
	Obesity	7	(3.8%)	20	(11.1%)	27	(7.5%)
Right foot arch	High arched	61	(33.3%)	53	(29.6%)	114	(31.5%)
	Normal	94	(51.4%)	85	(47.5%)	179	(49.4%)
	Flat	28	(15.3%)	41	(22.9%)	69	(19.1%)
Left foot arch	High arched	73	(39.9%)	60	(33.5%)	133	(36.7%)
	Normal	90	(49.2%)	80	(44.7%)	170	(47.0%)
	Flat	20	(10.9%)	39	(21.8%)	59	(16.3%)
Right hindfoot alignment	Normal	76	(41.5%)	78	(43.6%)	154	(42.5%)
	Valgus	107	(58.5%)	101	(56.4%)	208	(57.5%)
Left hindfoot alignment	Normal	87	(47.5%)	67	(37.4%)	154	(42.5%)
	Valgus	96	(52.5%)	112	(62.6%)	208	(57.5%)

Table 3. Comparison of variables in children with high-arched, normal and flatfoot (Kruskal-Wallis and post hoc Tukey's tests)

	Variable	Foot arching groups	Mean	Median	Minimum	Maximum	Stand. Dev.	p
Right foot	Hindfoot alignment [°]	High-arched	6.39	7.00	0.00	13.00	2.65	H & N p=0.38
		Normal	6.91	7.00	2.00	15.00	2.50	H & F p=0.55
		Flatfoot	6.91	7.00	2.00	15.00	2.50	N & F p=0.028*
	BMI [kg/m^2]	High-arched	17.42	16.64	11.85	24.62	2.98	H & N p=0.00002*
		Normal	19.34	18.88	13.10	31.75	3.70	H & F p=0.00003*
		Flatfoot	20.05	19.24	13.13	38.57	4.45	N & F p=0.99
Left foot	Hindfoot alignment [°]	High-arched	6.26	6.00	0.00	14.00	2.73	H & N p=0.99
		Normal	6.27	6.00	1.00	18.00	2.74	H & F p=0.67
		Flatfoot	6.68	7.00	2.00	12.00	2.50	N & F p=0.64
	BMI [kg/m^2]	High-arched	17.38	16.79	11.85	25.55	2.88	H & N p=0.00004*
		Normal	19.39	18.79	13.10	31.75	3.70	H & F p=0.0000001*
		Flatfoot	20.71	20.27	12.98	38.57	4.57	N & F p=0.17

* statistically significant differences, H= high-arched foot, N=normal arched foot, F=flatfoot

Table 4. Correlations between variables

Correlated variables	Right foot		Left foot	
	r	p	R	p
BMI & Arch Index	0.31	0.0001*	0.32	0.0001*
BMI & Hindfoot valgus angle	-0.07	0.19	-0.09	0.06
Arch Index & Hindfoot valgus alignment	0.23	0.06	-0.01	0.85

*statistically significant correlation

between variables also revealed significant positive correlation between the BMI and AI values for the right and left foot (Table 4). No significant correlations between the AI and the hindfoot valgus angle or between BMI and the hindfoot valgus angle were discovered.

Discussion

The process of shaping foot arches completes at about age ten when the foot assumes its mature structure.[9] Foot deformities observed at that time may become a chronic, life-long condition. Our study revealed foot malalignment in more than 50% of the 10-12-year–old participants. A fallen longitudinal arch in the right foot was typical of every sixth, and in the left foot, of every fifth participant. One third of our participants had high foot arches. The hindfoot valgus deformity was seen in 57.5% of all participants. A similar prevalence of flat foot was observed in the 9-year-olds by El et al.[10], who revealed moderately or considerably fallen arches in 17.2% of their participants. Flat feet and plano-valgus feet were also disclosed in 16.7% of the 10-12-year-olds in the study of Szczepanowska-Wołowiec et al.[11]

Flat feet have been a subject matter of numerous academic and research discussions. On the one hand, some researchers claim that pediatric fallen foot arches are asymptomatic and they do not require any treatment.[12] On the other hand, other researchers maintain that flat feet lead to unfavorable changes in the dynamic functions of the whole lower limb and increase the incidence of knee, hip and back complaints.[13,14] According to the most common definition of flat feet, this deformity consists of fallen foot arches, forefoot abduction and the hindfoot valgus deformity.[5,15-17] Hindfoot valgus concomitant with flat foot was confirmed by Coughlin and Kaz.[18] It should also be mentioned that the abduction of the calcaneus results in changes to the gait pattern connected with the rotation in the hip joint and the pelvic tilt in the sagittal plane.[16]

Flat feet are more typical of boys than of girls. It was confirmed in the studies of Changa et al. and Ezema et al., and also by our findings.[19,20] The correlation of the hindfoot valgus deformity with gender is not so distinct. In our study, the valgus deformity in the right foot was slightly more often discovered in girls, while in the left foot more frequently in boys. In the right foot, hindfoot valgus was found in 57% of participants with the high-arched foot, in 53% with normal and in 71% with flat foot. In the left foot, those values were 55%, 57% and 68% respectively. No significant differences in the value of the hindfoot valgus angle in children with the high-arched, normal and flat foot were found despite a greater prevalence of the hindfoot valgus deformity in children with flat feet. No significant correlations between the hindfoot valgus angle and the height of the medial longitudinal arch were also found by Kanatli et al.[21] In their study, they examined 206 voluntary participants aged 4-20 years, in which the mean hindfoot valgus angle for the whole sample was $5.2^{o} \pm 3.3$. That score was lower than in our study.

One should take into account a considerable incidence of high foot arches in the participants in our study. They prevailed, as mentioned before, in 57.5% of all participants. In the 4-13-year-olds examined by Woźniacka et al., that proportion was even higher and it reached above 61%.[22] In their study, the hollow foot was also discovered in obese children, although the lowered medial longitudinal arch of the foot was more typical of their participants. In our study, in the sample of obese children, high foot arches were disclosed in the right foot in 3.7%, and in the left foot in 11.1% of participants. A significant correlation between excessive body weight and flat feet was observed as well. That correlation was also confirmed by Halabchi et al.[12] Moreover, Ezema et al. reported that obese school children had flat feet three and a half times more often than their mates with healthy body weight.[20] Pauk et al. claimed that the 8-14-year-olds with a low BMI less often had the plano-valgus foot.[23] According to the reports on young adolescents of both genders, both fallen foot arches and hindfoot valgus more often prevailed in obese individuals.[24] In our study, a correlation between BMI and the height of the medial longitudinal arch of the foot was found but no significant correlation either between BMI and the hindfoot valgus angle, or between the height of the medial longitudinal arch of the foot and the hindfoot valgus angle were revealed.

Conclusions

1. The hindfoot valgus deformity prevailed in school children more frequently than flat feet. It was manifested by both girls and boys with the flat, normal and hollow foot.
2. The valgus foot deformity did not correlate with the medial longitudinal arch of the foot. Therapeutic corrections of the valgus deformity of the foot should be varied, depending on the quality of the longitudinal arch of the foot.
3. Although the valgus foot deformity did not correlate with excessive body weight, there was a significant correlation between the BMI and the longitudinal arch of the foot.

References

1. Labovitz JM. The algorithmic approach to pediatric flexible pes planovalgus. *Clin Podiatr Med Surg.* 2006;23(1):57-76.
2. Herrera-Soto JA. Pediatric foot and ankle disorders. *Curr Opin Pediatr*. 2004;15(6):417-422.
3. Puszczałowska-Lizis E, Ciosek J. Shape of the feet and its relationship with body composition in pre-school children. *Studia Medyczne.* 2017; 33(3):214-221.

4. Jankowicz-Szymanska A, Mikolajczyk E. Genu valgum and flat feet in children with healthy and excessive body weight. *Pediatr Physl Ther.* 2016;28(2):200-206.
5. Fabry G. Static, axial, and rotational deformities of the lower extremities in children. *Eur J Pediatr*. 2010;169:529-534.
6. Nemeth B. The diagnosis and management of common childhood orthopedic disorders. *Curr Probl Pediatr Adol Health Care*. 2011;41(1):2-28.
7. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ.* 2000;320(7244):1240.
8. Prętkiewicz-Abacjew E. The influence of genu valgum and tarsus valgus on body positioning in the gait of children. *Pol J Environ Stud*. 2008;17(23):395-401.
9. Pfeiffer M, Kotz R, Ledl T, Hauser G, Sluga M. Prevalence of flat foot in preschool-aged children. *Pediatrics*. 2006;118(2):634-639.
10. El O, Akcali O, Kosay C, et al. Flexible flatfoot and related factors in primary school children: a report of a screening study. *Rheumatol Int.* 2006;26(11):1050-1053.
11. Szczepanowska-Wołowiec B, Wołowiec P, Kotela P. Faulty posture among population of children aged 10-12 in Maslow district. *Medical Studies*. 2010;17:41-45.
12. Halabchi F, Mazaheri R, Mirshahi M, Abbasian L. Pediatric flexible flatfoot; clinical aspects and algorithmic approach. *Iran J Pediatr*. 2013;23(3):247-260.
13. Lee JH, Sung IY, Yoo JY. Clinical or radiologic measurements and 3-D gait analysis in children with pes planus. *Pediatr Int*. 2009;51(2):201-205.
14. Kothari A, Dixon PC, Stebbins J, Zavatsky AB, Theologis T. Are flexible flat feet associated with proximal joint problems in children? *Gait & Posture*. 2016;45:204-210.
15. Vulcano E, Deland JT, Ellis SJ. Approach and treatment of the adult acquired flatfoot deformity. *Curr Rev Musculoskeletal Med*. 2013;6(4):294-303.
16. Svoboda Z, Honzikova L, Jaroszczuk S, Vidal T, Martinaskova E. Kinematic gait analysis in children with valgus deformity of the hindfoot. *Acta Bioeng Biomech*. 2014;16(3):89-93.
17. Kothari A, Dixon PC, Stebbins J, Zavatsky AB, Theologis T. The relationship between quality of life and foot function in children with flexible flatfeet. *Gait & Posture*. 2015;41(3):786-790.
18. Coughlin MJ, Kaz A. Correlation of Harris mats, physical exam, pictures, and radiographic measurements in adult flatfoot deformity. *Foot Ankle Int*. 2009;30(7):604-612.
19. Chang JH, Wang SH, Kuo CL, Shen HC, Hong YW, Lin LC. Prevalence of flexible flatfoot in Taiwanese school--aged children in relation to obesity, gender, and age. *Eur J Pediatr*. 2010;169(4):447-452.
20. Ezema CI, Abaraogu UO, Okafor GO. Flat foot and associated factors among primary school children: A cross-sectional study. *Hong Kong Physiother J*. 2014;32(1):13-20.
21. Kanatli U, Gözil R, Besli K, Yetkin H, Bölükbasi S. The relationship between the hindfoot angle and the medial longitudinal arch of the foot. *Foot Ankle Int*. 2006;27(8):623-627.
22. Woźniacka R, Bac A, Matusik S, Szczygieł E, Ciszek E. Body weight and the medial longitudinal foot arch: high-arched foot, a hidden problem? *Eur J Pediatr*. 2013;172(5):683-691.
23. Pauk J, Derlatka M. Antropometria stopy płasko-koślawej. *Modelowanie Inżynierskie*. 2009;38:153-159.
24. Przysada G, Drużbicki M, Łyszczak N. The Influence of Body Mass on the Formation of Foot Defects at Fifth Year Physiotherapy Students of Rzeszow University. *Prz Med Uniw Rzesz Inst Leków*. 2013;3:319-326.