Evaluation of longitudinal and transverse foot arches in 7-8-year-old children

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Abstract

Introduction: Posturaldefects are an essential social problem. The rapid development of technology resulted in limited physical activity among the youngest children, which leads to postural defects and abnormalities in foot development in children.

Material and methods: The study encompassed 42 children aged 7-8 years and was carried out in spring 2016. A podoscope was used to assess the feet parameters.

Results: The study findings confirm a significant correlation between the Clarke`s angle and gender. However, no effect of age on foot arches and BMI was demonstrated. The higher the BMI, the lower the Wejsflog's index values. Moreover, no effect of BMI on the longitudinal arches of feet was observed.

Conclusions: Gender affects longitudinal foot arches. Age does not affect foot arches and BMI. BMI affects the Wejsflog's index yet has not impact on longitudinal foot arches.

Key words: Clarke`s angle, Wejsflog's index, children

Introduction

The foot is a complex biokinematic structure; during ontogenesis it undergoes several changes adjusting it to high and dynamic loads. The foot has to be sufficiently strong to withstand the body weight and simultaneously to absorb shocks during locomotion (1,2,3).

The external foot architecture is composed of the system of transverse and longitudinal arches that stretch due to loads and return to their initial conditions during pressure relief. (1,2). The foot structure contains of 26 small bones of high articular areas. Thanks to proper functioning of the musculoligamentous system of feet, the skeleton can be properly aligned and supported (4).

The normally-structured foot under weight-bearing conditionsrests against the ground at 3 points - the calcaneal tuberosity and the heads of first and fifth metatarsal bones. Undernormal conditions duringbody weight-bearing, the medial longitudinal arch lowers by about 15-20 mm at the height of the navicular bone due to its own weightwhile the foot lengthens (2).

The foot arches have absorptiveand protective functions for the other human systems. The medial longitudinal arch (dynamic) runs from the calcanealtuberosity through the navicular and wedge bones to the head of the I metatarsal bone(1,5).The lateral longitudinal arch (static) joins the calcaneal tuberosity with the head of fifth metatarsal bone, passing through the cuboid bone, which is an apex about 5 mm from the ground (1,5). The transverse arch is located between the heads of first and fifth metatarsal bones and occurs only in

humans as it is an adaptation to the bipedal gait. The transverse arch flattens so that all metatarsal bones rest on the ground during walking, running or jumping. During weight-bearing, it returns to the position mainly supported on the first and fifth metatarsal bones (1,5,6).

The human feet fulfil two functions: dynamic - enabling locomotion and static allowing to maintain the upright position (3,7).Moreover, the feet are an important sense organ (3). The pre-school and early-school ages are the period of intensive development during which the child`s developing posture is exposed to postural deformities (8). Children feet although visually similar to these of adults, differ from them markedly. The majority of children are born with normal feet; in the period of the child`s development during free movements, the strength of the muscular system, ligamentous system of the lower limbs and of feet increases (3). The intensive development can lead to lower limb defects and abnormalities in foot shaping. Healthy feet have huge impact on the health of the entire body of small children. Foot defects hinder locomotion, cause pain and easy fatigue of the lower extremities (3).The deviations in foot arches are often reflected in the pathogenesis of various pedal diseases (9).

Improper heights of longitudinal arches have adverse effects on the posture and skeletomuscular system. They cause overloading of the spine and lead to irreversible bony changes (10).

The objective of the present study was to assess the effects of gender, age and BMI on longitudinal and transverse arches in children aged 7-8 years.

Material and methods

The study group consisted of 42 children aged 7-8 years (Table 1). The study design was approved by the Bioethics Committee, Jan Kochanowski University in Kielce. The school management and parents or legal caregivers gave their informed consent for participation of children in the study.

The children were assigned into age groups according to the following rules: the 7-year-old group- children born in 2009 and the 8-year-old group - children born in 2008. The age of 7-year-old children ranged from 7.00 to7.99 years, while those aged 8 years ranged from 8.00 to 8.99 years (Table 1).

Table 1: Age according to gender

Age	Girls		Boys		Total	
	N	%	N	%	N	%
7 years	21	80.7	11	68.75	32	76.2
8 years	5	19.3	5	31.25	10	23.8
Total	26	100.00	16	100.00	42	100.00

According to BMI, the following groups were formed: the underweight group - children with BMI lower than the 5th centile, the slim group - children with BMI between 5th-25th centile, the normal weight group - children with BMI 25th-85th centile, the overweight group - children with BMI of 85th -95th centile and the obese group - with BMI above 95th centile (table 2).

Table 2: Categories according to BMI

Categories according to BMI	
Underweight	< 5th centile
Slimness	5-25th centile
Normal weight	25-85th centile
Overweight	85-95th centile
Obesity	≥95th centile

The height of children was determined with a Seca height scales to an accuracy of 0.1m and body weight - using a Tanita device to an accuracy of 0.1 kg (Table 3).

Table 3: Height of boys and girls

	Below 115 cm		115-130 cm		Above 130 cm		Total	
	N	%	N	%	N	%	N	%
Girls	2	66.67	18	58.1	6	75	26	61.9
Boys	1	33.33	13	41.9	2	25	16	38.1
Total	3	100.00	31	100.00	8	100.00	42	100.00

The results were used to calculate BMI according to the formula body weight/height^2. BMI centile was calculated using the OLAF/OLA calculator. The data obtained were compared with centile charts. Subsequently, feet were photographed in a computer podoscope. During the examination, children stood bare-footed with both feet on the podoscope crystal surface. The picture was recorded and analysed. Analysis was based on theparameters facilitating the diagnosis of major foot detects, i.e. width, length, Clarke`s angle and Wejsflog's index (the length-to-width ration). MS Office Excel and R.3.3.1 software were applied. The basic descriptive statistics measures were calculated for all parameters-arrhythmic mean, standard deviation, minimum and maximum for the entire group and subgroups according to gender. Correlations among variables were analysed using non-parametric tests - Pearson`s correlation, Chi-square test. $P<0.05$ was considered statistically significant.

Results

In the study population, 52.4% of children had normal MBI; underweight was found in about 9.5%, slimness in 16.7%, overweight in 11.9% and obesity (which is hazardous for proper development of foot arches and postures amongst the minors) in 9.5% of children (Table 4).

Table 4: BMI of girls and boys

BMI	Girls	Boys
	N	N
Underweight	3	1
Slimness	3	4
Normal weight	14	8
Overweight	3	2
Obesity	3	1
Total	**26**	**16**

Analysis of the values of Clarke`s angle of the right and left foot demonstrated that 73.8% of children had normal longitudinal arches of the right and left foot; according to gender , 71% and 29% of girls and boys, respectively (Table 5,6).

Table 5: The Clarke`s angle of the right foot

Right foot Clarke`s angle	Below 42°		42°-54°		Above 54°		Total	
	N	%	N	%	N	%	N	%
Girls	4	36.36	22	71	0	0	26	61.9
Boys	7	63.64	9	29	0	0	16	38.1
Total	11	100.00	31	100.00	0	100.00	42	100.00

Table 6: The Clarke´s angle of the left foot

Left foot Clarke`s angle	Below 42°		42°-54°		Above 54°		Total	
	N	%	N	%	N	%	N	%
Girls	3	30	22	71	1	100	26	61.9
Boys	7	70	9	29	0	0	16	38.1
Total	10	100.00	31	100.00	1	100.00	42	100.00

The findings revealed that 73.8% of 7-8-year olds had normal longitudinal arches in both feet. The Clarke`s angle was within the normal limits of 42-54°. In 25% of children the Clarke` s angle was below 42° and in 1.2% above 54°, which indicated abnormal longitudinal arches (Table 7).

Table 7: The Clarke´s angle of both feet amongst girls and boys

Number of feet of Girls and boys	N	%
Below 42º	21	25
42º-54º	62	73.8
Above 54º	1	1.2
Total	84	100.00

The study results demonstrated abnormalities in the transverse arches of right feet in 62.5% of girls and 37.5% of boys; the values of Wejsflog's index were lower than 2.5 (Table 8). Moreover, analysis of transverse arches of left feet revealed that the Wejsflog's index lower than 2.5 was found in 37.5% of girls and 62.5% of boys; the Wejsflog's index above 2.71 was observed in 75% of girls and 25% of boys, which evidenced normal foot arches (Table 9).

Table 8: The Wejsflog's index for right feet

Right foot Wejsflog`s index	Below 2.5		2.51-2.7		Above 2.71		Total	
	N	%	N	%	N	%	N	%
Girls	5	62.5	16	61.5	5	62.5	26	61.9
Boys	3	37.5	10	38.5	3	37.5	16	38.1
Total	8	100.00	26	100.00	8	100.00	42	100.00

Table 9: The Wejsflog's index for left feet

Left foot Wejsflog`s index	Below 2.5		2.51-2.7		Above 2.71		Total	
	N	%	N	%	N	%	N	%
Girls	3	37.5	17	65.4	6	75	26	61.9
Boys	5	62.5	9	34.6	2	25	16	38.1
Total	8	100.00	26	100.00	8	100.00	42	100.00

Analysis of transverse foot arches disclosed that 19.05% of the study population had normal arches of both feet, as the Wejsflog's index in them was near the borderline value, i.e. above 2.71. In 61.9% of feet of girls and boys the Wejsflog's index also demonstrated normal arches- the values were within the range of 2.51-2.7.In 19.05% of the study population, the Wejsflog's index was lower than 2.5, which could evidence abnormalities in transverse arches (Table 10).

Table 10: Wejsflog's index of both feet amongst girls and boys

Number of feet of girls and boys	N	%
Below 2.5	16	19.05
2.51-2.7	52	61.9
Above 2.71	16	19.05
Total	84	100.00

Furthermore, the study findings and their analysis revealed that gender affected longitudinal foot arches while BMI influenced the transverse arches of the left foot.

The correlations between MBI and Wejsflog's index were verified using the Pearson`s correlation coefficient. A statistically significant correlation was demonstrated between BMI and the transverse arch of the left foot. The higher the BMI, the lower the Wejsflog's index (Fig.1). No such a correlation was found for the right foot.

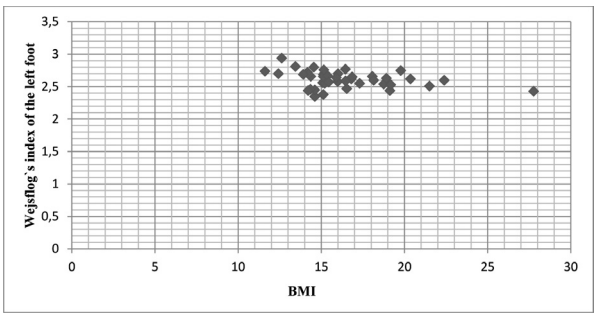

Fig. 1. Analysis of correlations between BMI and Wejsflog`s index

Moreover, the effects of gender on the Clarke`s angle were analysed. The χ^2 test was applied to verify any possible correlations. The results

explicitly demonstrated a statistically significant correlation between the above variables.

The study findings did not show a significant correlation between gender versus the Wejsflog's index of the right and left foot and BMI. Likewise, no correlation was found between age versus foot arches and BMI. The developmental age of the study population was comparable; therefore, further studies are required involving the population of a wider age range and bigger to be able to analyse the above correlations more precisely.

Analysis of the effects of BMI on the Clarke`s angle of both feet did not reveal statistically significant correlations.

Discussion

Our study analysed the effects of gender on the longitudinal arches of feet. The findings demonstrated a statistically significant correlation between gender and the Clarke`s angle of both feet. The values of longitudinal arches of the right and left foot determined using the Clarke`s angle were higher in girls compared to boys. The Clarke`s angle of the right and left foot was normal in 85% of girls and only in 56% of boys. Our results are comparable with those reported by Rykała et al.(2) and Jankowicz-Szymańska and Pociecha (8). According to Jankowicz-Szymańska and Pociecha (8), the values of Clarke1s angle were higher in girls than in boys. The authors carried out the study in 226 kindergarten children. Thus, our findings and observations of other authors confirm that foot arches are gender dependent (8). Moreover, our findings demonstrated normal longitudinal arches in 74% of the right and left feet. Binek and Olszewski (11) have reported similar results comparing both feet (61% of right feet and 63% of left feet were normal). In our study these values were equal. According to Binek and Olszewski (11), the common deformities occurring in 3-6-year-old children were lowered longitudinal arches of feet. The arches increased to normal limits thanks to appropriate corrective exercises applying proper pressure on the first metatarsals. Likewise, Jankowicz-Szymańska and Pociecha (8) have not reported significant differences in the Clarke`s angle of the right and left foot. According to Rykała et al. (2), the longitudinal arches indicated muscular or ligamentous inefficiency, as some 7-8 -year-old children had lowered longitudinal arches. The data calculated for the entire group disclosed that the longitudinal arch lowered under pressure. The values of Clarke`s angle evidenced normal longitudinal arches in girls and lowered longitudinal arches in boys.

Otherwise, Rykała et al. (2) have not observed a statistically significant difference in transverse arches in girls, as compared to boys. Our findings are consistent with those reported by Rykała et al. There was no correlation between age and the Wejsflog's index of both the right and left foot. Wacławek et al. (3) have demonstrated that the Wejsflog's index of feet in girls and boys was within normal limits, proving normal feet. In our study, 19.05% of children had normal arches of both feet. The Wejsflog's index was higher than 2.71. In 61.9% of feet in girls and boys, the values were lower although high enough to consider them normal - 2.51-2.7.

Our study carried out among the first-form schoolchildren revealed that the most common abnormality observed in them was improper longitudinal foot arches.

Wacławek et al. (3), who analysed the development of feet in pre-school children aged 3,4,5 years have demonstrated that the feet of girls and boys in the period of their progressive development shaped in a similar way. The level of foot arch development was found to be higher in 5-year-old children, as compared to the remaining age groups. The study carried out by Rykała et al (2) among 182 children aged 7-10 years with body weight-bearing

feet, has demonstrated that the transverse arches worsened with age while the indices of longitudinal arches improved. Likewise, Jankowicz - Szymańska (8) have reported that the Clarke1s angle in boys increased with age. The longitudinal arches in the right and left foot of 5-6-year-old girls and boys varied. Our study also analysed the effects of age on foot arch parameters; no significant differences were observed in foot shaping of girls and boys. The study sample was small, which is likely to account for the lack of this correlation. To deepen the analysis, further research should be carried out in a larger 7-8-old-population.

Nalepa et al.(12) studied the effects of the number of meals on BMI, demonstrating that BMI is affected by age and gender. Our findings are inconsistent with those reported by other authors who have demonstrated the impact of age on BMI, which could be associated with a small population at the similar developmental age.

Many factors affect proper postural development; one of them is body weight. Obesity and overweight are a serious global problem. The results of epidemiological studies are alarming and show increasing BMI in the general population. Obesity in children is often accompanied by somatic disorders, i.e. osseoarticular abnormalities, which can lead to postural defects, such as knee valgity or platypodia; moreover, they can cause back pain. The properly-structured feet can bear high mechanical loads and body weight, adjust to ground changes and movements (13).

The issues of effects of BMI on foot parameters are widely discussed. Rykała et al. (2) assessed longitudinal and transverse arches of loaded and body weight-bearing feet in the population of 182 children aged 7-10 years. They have demonstrated that the values of the parameters of arches of body weight-bearingfeet were within normal limits. The only exception regarded the parameters of Clarke`s angle of the right feet. Our study, which also analysed the effects of BMI on longitudinal arches did not show a statistically significant correlation between the parameters. Moreover, our findings demonstrated slight abnormalities in the Clarke`s angle of both feet (2).

Furthermore, our study determined the Wejsflog`s index; its values near 2 evidence abnormal transverse foot arches while these near 3 denote proper arches. In our study, the lowest value of Wejsflog's index was 2.35 and concerned the left foot. The majority of results evidenced proper transverse foot arches in the study population. Similar assessments were performed by Mosór and Kromka-Szydel (14). Their results are consistent with our findings, which revealed predominance of normal transverse arches. The authors mentioned above analysed the effects of BMI on the quality of foot arches; 25% of subjects reported problems with maintaining proper body weight and proper BMI. It has been revealed that 85% of children had normal feet or feet with lowered arches despite problems with maintaining proper body weight. Our study findings demonstrated the effects of BMI on the Wejsflog`s index of the left foot. The higher the BMI, the lower the Wejsflog`s index was, which resulted in lowered transverse foot arches. No such a correlation was observed for the right foot, which is likely to be associated with a small study sample analysed.

The study by Leszczak (1), regarding characteristics of selected anthropometric parameters of the lower extremities under weight- and body-weight bearing conditions in school children, have shown thatthe transverse arches of all feet were normal under weight- bearing condition, both in single-leg and two-leg stances.

Conclusions

1. The values of transverse arches of feet in the study population are higher in girls, as compared to boys.

2. Age affects longitudinal foot arches.
3. Age does not affect foot arches and BMI.
4. There is no correlation between BMI and longitudinal foot arches.
5. The higher the BMI, the lower the Wejsflog`s index is.

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