CHILD'S FOOT MORPHOLOGY

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The study describes the foot morphology as a basal element of supporting-movement system. Foot morphology was observed in 263 boys and 248 girls of pre-school and primary school age. Longitudinal foot vault was evaluated by Plantographic method by index method and processed by "Foot" software; the big toe and little toe axis in the sense of valgozity and varozity, the size of foot angle. Statistically significant differences were evaluated by means of Wilcoxon, Mann-Whitney tests, Scheffe test and chí-quadrate test (Statistica, vers. 6).

The state of longitudinal foot vault appeared as relatively satisfactory. The normal foot of I. and II. degree was determined with highest frequency. The occurrence of flat foot and high foot did not signify any principal problem in these age categories. The deformation of big toe and little toe occurred in high frequency in both genders and in all age categories. In boys the valgoze angle reached the range 2.6–7.9°, in girls 4.3–8.1°. The average values of big toe varozity were higher. Little toe angle (valgozity) in the group of boys reached the range of values 15.4° to 20.4°, in girls 14.4° to 18.6°.

At the end we can evaluate the longitudinal foot vault in child's age categories as corresponding with the ontogenesis phase. The analysis of morphological parameters in the area of anterior part of foot proved the deformations in medial and lateral foot rays in high frequency. The foot angle in posterior part of the foot responds the reference values of established age categories.

Keywords: Plantographic method, longitudinal foot vault, anterior part of foot (forefoot), foot angles.

INTRODUCTION

The care of supporting-movement system includes foot care as well – which is in the most cases neglected. The state and foot function in adult age correspond with care and foot development from the birth. Child's foot is in the early developmental stages cartilaginous, less resistant against load and is more prone to deformities, especially in the area of forefoot. To healthy foot development there are necessary congenital dispositions but essential influence lies in foot wear quality, the possibility of foot muscle and ligament apparatus daily exercises without regard to load level, compensatory exercise application after inadequate load or overload of feet, for instance after training or prolonged walking, standing etc.

Childs foot acquires definitive shape with developed longitudinal and transversal foot vault in the period between 4–6 years of age. Up to 12 year of age, the child has the routing of equator behind (American College of Foot and Ankle Surgeons, http://www.aofas.org/index.shtml; American Orthopaedic Foot and Ankle Society, http://orthoinfo.aofas.org/fact/thr_report.cfm?Thread_I). This routing is done in the time when foot development is not yet completed. During the beginning of school period, the range of deformities starts to manifest themselves. In this age the existence of foot deformation does not have to be subjected to its hurtfulness, the child does not subjectively perceive it yet. The pain manifestation comes usually in adult age.

Foot deformations include wide range of defects, which are not only connected to collapse longitudinal foot vault but are represented by forefoot deformations. We classify forefoot deformity – the toes deformities (hammertoe, event clutches-type toes, little toe axis declination, the incidence of toe valgozity or varozity, enlargement of the forefoot). These defects are in later phases accompanied by metatarzalgies (Dungl, 1989; Matějovský et al., 2002). The incidence frequency of forefoot deformities is related as well with the length of metatarsal and digital bones.

The foot is not solely the organ of walking but it is as well the sensitive detector, which provides in the frame of feedback the influence of negative and positive exogen and endogen effects. If the foot morphology is modified, the foot capability to react to signals is altered and thus its function is influenced in the sense of elasticity, plasticity and reactivity. There become to appear changes in quantity of force and pressure, which take effect in the foot sole. The unpleasant feelings related to foot deformities can trigger discomfort in psyche domain – irritability, concentration loss, fatigue etc. The alteration of foot morphology has impact on the joints and muscle function in the upper body areas. Subsequently the modifications of

footstep and stereotype of walking and the modification of ones motoric potency can occur (Přidalová et al., 2003).

Following study is attributed to foot morphology in pre-school and primary school age. It complements and ties together with previous published conclusions regarding child's foot morphology (Přidalová et al., 2003; Přidalová & Najdekrová, 2003; Přidalová & Riegerová, 2002; Přidalová & Rýznarová, 2000).

The study objective is to monitor the frequency of foot type, determination of the longitudinal foot vault state (whose condition did not appear problematic in older age categories) and evaluation of forefoot parameters. The study component is as the punctual characteristics of the morphological points on the foot sole and indexes, eventually further parameters such as angles. We fail to find these punctual characteristics in number of studies (with exception of for example Brázdilová et al., 1985) and results of two authors are subsequently incomparable. On basis of experience and to facilitate processing of foot prints there was built "Foot" software (Elfmark & Přidalová, 2003) which enables processing and back up of data by computer.

METHODOLOGY

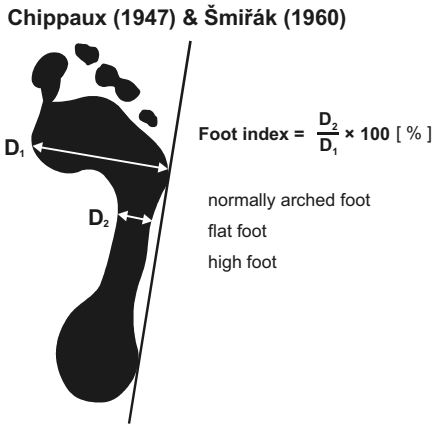
By way of plantographic method the footprints of 263 boys and 248 girls of pre-school and primary school age were evaluated. The children were considered asymptomatically healthy, they were divided according the gender and age which we regard as principal. Examination took part at the primary schools in Uničov, in Olomouc and in kindergarten in Litovel. The children's parents expressed approval with examination of their children.

The foot prints were taken throughout rubber membrane as a static plantogram on a France manufactured plantograph. After scanning, the foot prints were processed by "Foot" software which data identification is showed in Fig. 5. We worked with following anthropometrical parameters: foot index (Chippaux–Šmiřák, In Klementa, 1987), hallux angle, little toe angle – varozity and valgozity (Brázdilová et al., 1985; Dungl, 1989; Hegrová, 1999) a foot angle (Klementa, 1987). To divide the big toe angle we formed 3 categories: big toe without axis declination (0°), hallux misalignment to the lateral foot part – valgozity (> 0°), hallux misalignment to the medial foot part – varozity (with respect to differentiation possibility for statistical assessment, we choose negative values < 0°). The little toe angle division was similar: little toe without axis declination (0°), little toe misalignment to the lateral foot side – varozity, little toe misalignment to the medial foot side – valgozity. All monitored parameters are presented in Fig. 3 and 4. The foot types and its evaluation emerge from the Fig. 2. Statistically significant differences were evaluated by means of Wilcoxon, Mann-Whitney tests and chí-quadrate test (Statistica, vers. 6).

The children from kindergarten were divided into yearly age categories (3-, 4-, 5-, 6 years old) with regard to opportunity of longitudinal foot vault assessment by foot index since the formation of definitive longitudinal vault foot is not yet completed in pre-school age. Other age categories could be, on the basis of group homogenity (Scheffe test), integrated into the category 6–7 years old (it concerns children attending primary school) and 8–9 years old.

To monitor foot morphology there are problems with methodological differences and subsequently with incomparable results of various authors. Published results often summarize data without gender differentiation, regardless categorization in the junior phase of ontogenesis, which is fundamental for foot development. There is not always given punctual determination of individual morphological points. In Fig. 3 and 4 we attempted to make precise description of individual morphological foot parameters, which are further used in "Foot" software.

Fig. 1
Foot index – longitudinal normal and flat foot determination (modified according Klementa, 1987)



Normally arched foot:
1. degree from 0.1% to 25.0% (N1)
2. degree from 25.1% to 40.0% (N2)
3. degree from 40.1% to 45.0% (N3)

Flat foot:
1. degree from 45.1% to 50.0% – slightly flat (F1)
2. degree from 50.1% to 60% – medium flat (F2)
3. degree from 60.1% to 100.0% – severely flat (F3)

High foot:
1. degree from 0.1 cm to 1.5 cm slightly high (H1)
2. degree from 1.6 cm to 3.0 cm medium high (H2)
3. degree from 3.1 cm and above severely high (H3)

Fig. 2
Foot types (modified according Dungl, 1989)

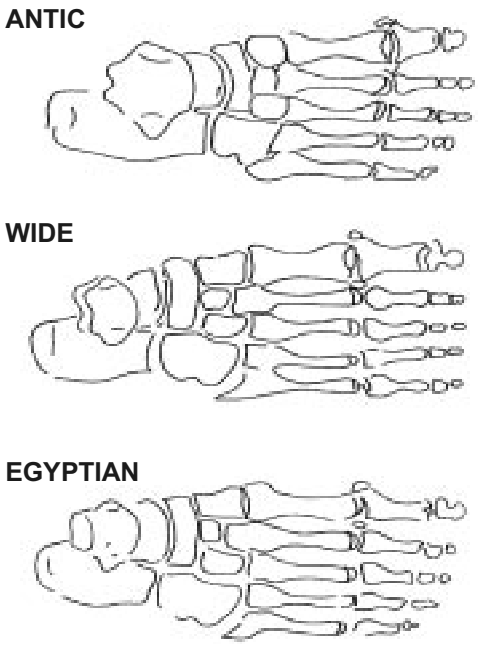
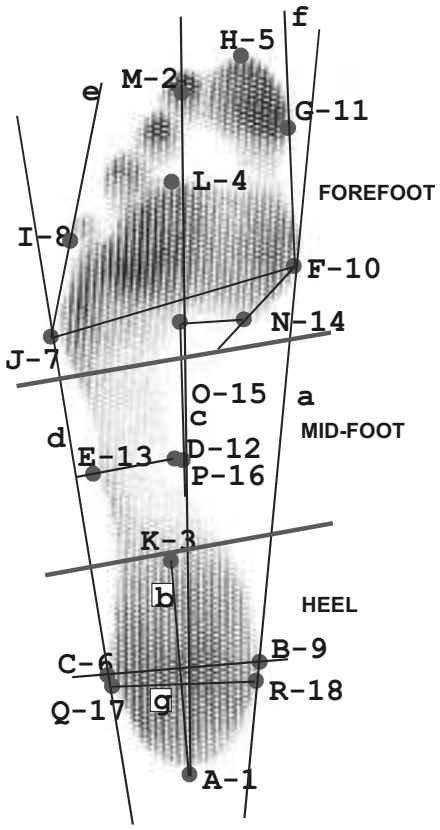


Fig. 3
Precise characteristics of morphological points on the foot sole

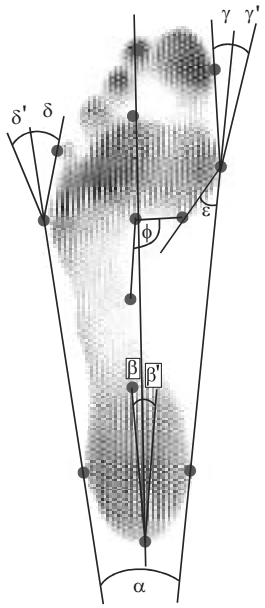


(the figures in the picture 3 respond
to the figures in the picture 5)

Specification of individual morphological points of foot sole

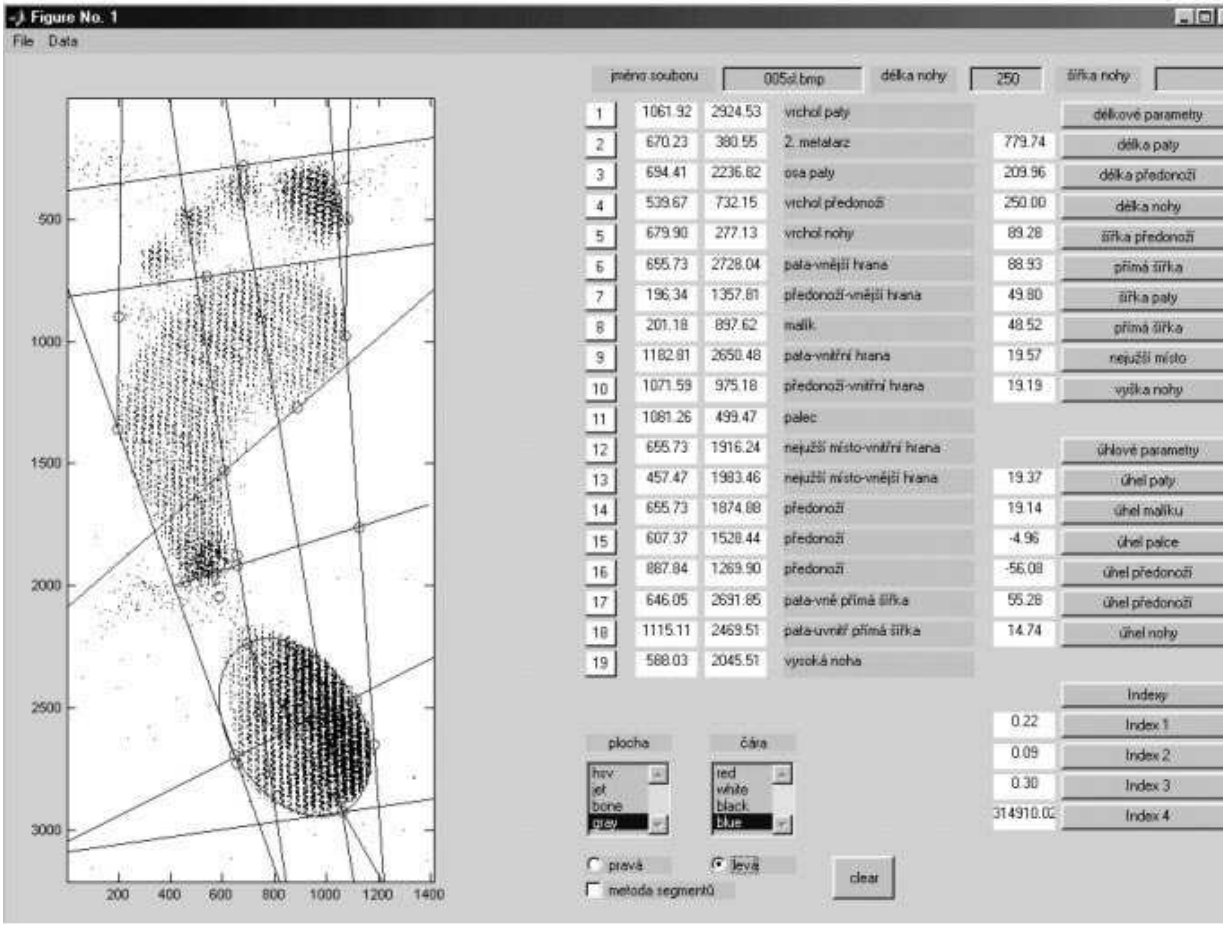
A	the most proximally positioned point of foot heel
B	the most medially positioned point of posterior part of foot
C	the most laterally positioned point of posterior part of foot
D	medially positioned point of medial part of foot on the vertical line in the narrowest part of foot
E	laterally positioned point of medial part of foot on the vertical line in the narrowest part of the foot
E⇒D	the narrowest part of the foot (vertical line to lateral tangent of foot)
F	the most medial point of anterior-part of foot on the head I. of metatarsus
G	the most medially positioned point on the big toe
H	foot top
I	the most laterally positioned point on the little toe
J	the most laterally positioned point on anterior-part of foot
J⇒F	the most wide part of foot, direct width of foot, vertical line to lateral tangent of foot
K	the top of posterior part of foot (the most distally positioned point of posterior part of foot)
L	the top of anterior-part of foot (the most distally positioned point of anterior-part of foot)
M	the centre of the second toe
N	the most proximally positioned point of anterior-part of foot
O	the top of arch of anterior-part
P	the point in the mid-part of medial part of the foot
Q	foot heel direct width – lateral
R	foot heel direct width – medial
a	medial tangent of the foot
b	foot heel axis
c	foot axis (its led through the centre of second toe)
d	lateral tangent of the foot
e	little toe tangent (straight line led through the most lateral point of the little toe form point J)
f	big toe tangent(straight line led through the most medial point of the big toe form point F)
g	the most width of foot heel

Fig. 4
The determination of individual angles on the foot sole



α	foot angle
β	foot heel angle in the direction to lateral side of foot sole (valgoze position of foot heel)
β´	foot heel angle in the direction to medial side (varoze position of foot heel)
γ	big toe angle in the direction to lateral side of foot sole (valgoze position of big toe)
γ´	big toe angle in the direction to medial side of foot sole (varoze position of big toe)
δ	little toe angle in the direction to medial side of foot sole (valgoze position of little toe)
δ´	little toe angle in the direction to lateral side of foot sole (varoze position of little toe)
ε	the Clark angle
ϕ	the angle of medial foot part

Fig. 5
The page of "Foot" software with evaluated planta figures



RESULTS

Longitudinal foot vault evaluation

In evaluation of the state of longitudinal foot vault in the group of boys and girls there were the most frequently the categories of normally arched foot. In all age groups it was the most frequent representation in the II. category. There was no statistically significant difference found in the sense of laterality. The I. category was minimally represented in kindergarten boys, in primary school boys the representation in this category increases and it reaches up to ¾ of the group in the oldest children. In younger girls this category was represented in mildly higher percentage than in boys. Normal vault foot III. degree occurred in lower percentage in boys, the frequency increases in the oldest boys. Higher frequency representation in older boys could be connected with indication of longitudinal vault foot decline – the representation in this category reflects it. Mildly higher frequency representation occurred in the category of normal foot type of III. degree in 4 years old girls (TABLE 1 and 2).

The flat foot category is most frequently represented in 3–4 years old boys, 8–9 years old boys and 5 years old girls. In pre-school children it is possible to explain the prevailing existence of fat-pad in the sole, which protects incompletely formed vault foot and this finding is physiological at this age.

Flat foot was found in mildly less frequent representation in 3 years old, 4 years old and 8–9 years old girls than in boys. We recorded significant difference in flat foot evaluation according to gender in the favour of 3 years old girls, on the contrary in 5 years old girls we find flat foot in significantly higher frequency in girls' group. High foot occurred sporadically in pre-school and the oldest age category (TABLE 1, 2).

TABLE 1
Longitudinal foot vault evaluation in boys' group

Boys (n = 263)	3 years (n = 29, 1 = 3.4%)				4 years (n = 28, 1 = 3.6%)				5 years (n = 32, 1 = 3.1%)				6 years (n = 27, 1 = 3.7%)				6–7 years (n = 65, 1 = 1.5%)				8–9 years (n = 82, 1 = 1.2%)			
	L		R		L		R		L		R		L		R		L		R		L		R	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
N1	1	3.4	1	3.4	2	7.1	4	14.3	2	6.3	4	12.5	1	3.7	1	3.7	9	13.8	10	15.4	21	25.6	19	23.2
N2	10	34.5	9	32.1	15	53.6	14	50.0	16	50.0	19	59.4	19	70.3	16	59.3	30	46.1	26	40.0	31	37.8	35	42.7
N3	4	13.8	7	24.1	2	7.1	2	7.1	6	18.7	5	15.6	2	7.2	3	11.1	7	10.7	13	20.0	11	13.4	14	17.1
∑ N	15	51.8	17	58.6	19	67.9	20	71.4	24	75.0	28	87.5	22	81.5	20	74.1	46	70.7	49	75.4	63	76.9	68	82.9
F1	5	17.2	3	10.3	3	10.7	4	14.3	3	9.4	1	3.1	3	11.0	0	0.0	4	6.1	3	4.6	5	6.1	2	2.4
F2	5	17.2	6	20.7	3	10.7	2	7.1	3	9.4	1	3.1	1	3.7	5	18.5	0	0.0	0	0.0	6	7.3	4	4.9
F3	4	13.8	3	10.3	3	10.7	2	7.1	0	0.0	0	0.0	0	0.0	1	3.7	1	1.5	0	0.0	3	3.7	5	6.1
∑ F	14	48.3	12	41.3	9	32.1	8	28.6	6	18.7	2	6.3	4	14.8	6	22.2	5	7.6	3	4.6	14	17.1	11	13.4
H	0	0	0	0	0	0	0	0	2	6.3	2	6.3	1	3.7	1	3.7	14	21.5	13	20.0	5	6.1	3	3.7

TABLE 2
Longitudinal foot vault evaluation in girls' group

Girls (n = 248)	3 years (n = 26, 1 = 3.8%)				4 years (n = 31, 1 = 3.2%)				5 years (n = 36, 1 = 2.7%)				6 years (n = 30, 1 = 3.3%)				6–7 years (n = 42, 1 = 2.4%)				8–9 years (n = 83, 1 = 1.2%)			
	L		R		L		R		L		R		L		R		L		R		L		R	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
N1	3	11.5	3	11.51	5	16.1	3	9.6	2	5.4	5	13.8	9	30.0	6	20.0	7	16.7	8	19.0	19	22.9	23	27.7
N2	11	42.3	12	46.1	15	48.3	12	38.7	18	50.0	17	47.2	13	43.3	16	53.3	16	38.0	18	42.8	36	43.4	40	48.2
N3	4	15.3	4	15.3	7	22.5	9	29.0	3	8.3	3	8.3	4	13.3	3	10.0	6	14.2	4	9.5	8	9.6	10	12.0
∑ N	18	69.2	19	73.1	27	87.1	24	77.4	23	63.8	25	69.4	26	86.7	25	83.3	29	69.0	30	71.4	63	75.9	73	88.0
F1	3	11.5	1	3.8	1	3.2	4	12.9	5	13.8	4	11.1	4	13.3	4	13.3	3	7.1	2	4.8	6	7.2	1	1.2
F2	2	7.6	2	7.6	2	6.4	1	3.2	3	8.3	0	0.0	0	0.0	0	0.0	1	2.4	2	4.8	2	2.4	2	2.4
F3	1	3.8	1	3.8	0	0.0	1	3.2	3	8.3	5	13.8	0	0.0	0	0.0	1	2.4	0	0.0	1	1.2	0	0.0
∑ F	6	23	5	19.2	3	9.6	6	19.2	11	30.5	9	25.0	4	13.3	4	13.0	5	11.9	4	9.5	9	10.8	3	3.6
∑ H	2	7.6	3	11.5	1	3.3	1	3.2	2	5.4	2	5.4	0	0.0	1	3.3	8	19.0	8	19.0	11	13.3	7	8.4

The average value of foot index ranged in 3 years old boys, both-sides above 40%. Index exceeded limit of 40% only in 3 years old girls on the left foot. In further age categories of boys we can observe the average value of foot index declination, with the statistically relevant difference in the sense of laterality in 4 years old boys. In the other age categories of boys the average value of foot index ranged from 30.8–37.6%. The average values in girls appeared mildly lower (27.9–35.9%).

The lowest average index value was found on the right foot in 3 years old boys (5.2% – the indication of high foot can be considered even though Klementa does not respect this index value as high foot indicator). The maximum value exceeded in younger age categories 70% the index limit. In older boys it ranged above 65% (TABLE 3, 4). Maximal values of index values in girls differed from boys categories, they were represented below 70% limits. In kindergarten girls we observe mild decrease of foot index in the process of development with the significant difference of index values in 3 years and 6 years old girls.

The anterior-part of foot (forefoot) parameters evaluation

In all groups the category of hallux without axis declination was represented maximally by 8 probands. Significant side difference is possible to observe only in the groups of 4 years old and 6 years old boys. We found this laterality trend in group of men of older age groups (Přidalová et al., 2000, 2002), in particular by probands in those with high physical activity.

Hallux valgozity occurred in boys' group with significantly higher frequency representation than hallux varozity, with the exception of 8–9 years old, where those two categories approximating in frequency. Hallux varozity in the oldest boys surpassed limit of 40% of group. We found balanced frequency occurrence of hallux varozity and valgozity as well in 3–5 years old girls.

In girls above 6 years old age limit the valgozity appeared in higher frequency than varozity. Valgozity surpassed 60% of group and in 6–7 years old girls affected more than 90%. There was no significant difference found in hallux valgozity occurrence between the groups of girls and boys. Statistically significant difference in hallux varozity occurrence was found in all groups of 3–6 years old children, with lower frequency of varozity in favour of boys.

The average values of valgoze hallux in boys ranged from 2.6° do 7.9° and were on average lower than in varozity. The lowest values of valgozity were determined in the group of 3 years old. In further age groups the values of valgoze big toe occurred approximately on the

TABLE 3
Basic statistical characteristics of monitored morphological parameters of foot in boys' group

Parameters		3 years (1 = 3.4%)		4 years (1 = 3.6%)		5 years (1 = 3.6%)		6 years (1 = 3.6%)		6–7 years (1 = 1.5%)		8–9 years (1 = 1.2%)	
		L	R	L	R	L	R	L	R	L	R	L	R
Hallux angle >0°	n	15.0	13.0	24.0	17.0	18.0	14.0	14.0	16.0	61.0	63.0	44.0	43.0
	%	51.8	44.8	85.7	60.7	56.3	43.8	51.9	59.2	93.8	96.9	53.6	52.4
	$\bar{X}$	3.1	2.6	4.5	5.8	5.0	5.7	4.7	5.5	7.9	6.5	4.8	4.7
	SD	2.1	1.8	2.0	1.6	0.9	1.6	0.8	1.1	3.5	3.8	4.2	4.5
	Min.	2.0	2.0	1.0	2.0	3.0	3.0	2.0	2.0	1.7	1.0	2.0	384 73
	Max.	10.0	11.0	12.0	18.0	10.0	11.0	12.0	10.0	18.5	14.2	14.0	18.0
Hallux angle <0°	n	6	8.0	4.0	3.0	6.0	10.0	5.0	10.0	2.0	2.0	34.0	34.0
	%	20.7	27.6	14.2	10.7	18.8	31.3	18.5	37.0	3.1	3.1	41.5	41.5
	$\bar{X}$	–8.6	–8.3	–6.5	–6.7	–6.4	–7.9	–6.8	–6.8	–5.7	–6.1	–6.9	–4.8
	SD	3.2	2.9	2.2	1.9	0.7	2.9	1.6	1.2	0.8	1.2	1.4	1.1
	Min.	–2.0	–5.0	–4.0	–3.0	–3.0	–5.0	–2.0	–2.0	–2.0	–3.0	–3.0	–2.0
	Max.	–15.0	–11.0	–13.0	–9.0	–12.0	–15.0	–13.0	–13.0	–12.0	–14.0	–13.0	–12.0
0°	n	8.0	8.0	0.0	8.0	8.0	8.0	8.0	1.0	2.0	0.0	4.0	5.0
	%	27.5	27.6	0.0	28.0	25.0	25.0	29.6	3.7	3.1	0.0	4.9	6.1
Little toe angle	$\bar{X}$	16.0	19.1	20.1	15.4	19.5	17.8	20.4	18.3	16.4	15.9	17.4	17.1
	SD	6.1	5.9	6.5	5.9	6.4	6.8	7.6	5.4	7.2	7.1	7.6	7.2
	Min.	9.0	9.0	7.0	7.0	9.0	7.0	11.0	7.0	2.0	3.0	7.0	6.5
	Max.	29.0	23.0	39.0	38.0	39.0	29.0	36.0	35.0	34.1	33.9	29.3	31.8
Foot index	$\bar{X}$	47.1	41.9	40.4	35.7	35.4	32.8	37.6	36.9	31.6	34.8	34.9	30.8
	SD	6.1	5.9	6.5	5.9	6.4	6.8	4.2	5.4	9.8	9.4	6.1	8.6
	Min.	24.1	5.2	12.0	12.0	7.6	6.9	25.0	25.0	7.5	9.1	10.9	14.2
	Max.	68.3	70.1	75.9	66.7	50.9	51.5	59.0	60.0	56.7	65.3	51.8	47.7
$\sum$	n	29.0	29.0	28.0	28.0	32.0	32.0	27.0	27.0	65.0	65.0	82.0	82.0

TABLE 4
Basic statistical characteristics of monitored morphological parameters of foot in girls' group

Parameters		3 years (1 = 3.9%)		4 years (1 = 3.2%)		5 years (1 = 2.8%)		6 years (1 = 3.3%)		6–7 years (1 = 2.4%)		8–9 years (1 = 1.2%)	
		L	R	L	R	L	R	L	R	L	R	L	R
Hallux angle >0°	n	9.0	11.0	17.0	13.0	15	15.0	18.0	17.0	40.0	40.0	54.0	52.0
	%	34.6	42.3	54.8	41.9	41.7	41.7	60.0	56.6	95.2	95.2	65.1	62.6
	$\bar{X}$	5.9	7.0	5.2	4.3	6.7	4.6	7.8	5.5	8.1	7.0	6.4	5.9
	SD	2.4	1.8	1.9	1.6	1.5	1.9	2.1	1.6	4.1	3.3	1.5	1.3
	Min.	2.0	3.0	3.0	4.0	3.0	2.0	2.0	2.0	2.0	1.3	1.5	1.5
	Max.	9.0	10.0	15.0	8.0	16.0	14.0	9.0	13.0	17.0	13.2	15.8	15.2
Hallux angle <0°	n	11.0	9.0	10.0	14.0	14.0	14.0	9.0	11.0	2.0	2.0	23.0	27.0
	%	42.3	34.6	32.3	45.2	38.8	38.8	30.0	36.7	4.8	4.8	27.7	32.5
	$\bar{X}$	−7.6	−6.1	−6.8	−8.5	−6.3	−7.1	−6.3	−6.6	−4.3	−5.3	−5.0	−6.2
	SD	2.8	1.3	1.8	2.0	2.1	2.0	1.8	2.3	1.5	2.1	1.1	0.6
	Min.	−3.0	−5.0	−2.0	−2.0	−2.0	−2.0	−2.0	−2.0	−2.0	−2.0	−3.0	−2.0
	Max.	−11.0	−10.0	−8.0	−15.0	−8.0	−15.0	−9.0	−21.0	−16.0	−12.0	−13.0	−8.0
0°	n	6.0	6.0	4.0	4.0	7.0	7.0	3.0	2.0	0.0	0.0	6.0	4.4
	%	23.1	23.1	12.9	12.9	20.6	20.6	10.0	6.6	0.0	0.0	7.2	4.8
Little toe angle	$\bar{X}$	16.9	15.9	17.4	18.6	18.3	14.8	18.4	21.7	18.6	16.6	15.7	14.4
	SD	4.3	3.9	3.7	3.4	4.1	5.4	5.5	5.8	4.8	7.3	8.9	4.8
	Min.	5.0	4.0	4.0	4.0	4.0	4.0	6.0	10.0	6.4	2.5	4.3	5.6
	Max.	34.0	39.0	28.0	36.0	34.0	36.0	28.0	37.0	28.5	29.7	29.8	31.2
Foot index	$\bar{X}$	42.8	39.5	35.9	35.4	35.9	32.5	30.7	31.3	27.9	30.9	31.4	32.8
	SD	5.1	2.9	5.7	3.8	6.2	5.3	4.2	4.1	11.2	9.1	7.9	9.5
	Min.	12.7	20.9	20.0	5.4	22.6	10.9	21.2	10.0	6.5	11.2	18.9	25.2
	Max.	65.1	66.1	58.6	48.3	66.7	57.4	44.4	42.9	50.0	46.9	49.8	47.8
∑	n	26.0	26.0	31.0	31.0	36.0	36.0	30.0	30.0	42.0	42.0	83.0	83.0

same level, with exception of 6–7 years old boys from primary school where we meet relatively high value of axis aberration. That one is 6.5° right-sided and 7.9° left-sided.

We find the average values of varozity in the interval 4.8°–8.6°. We can see the highest values (> 8°) in 3 years old boys which probably relates to kineziologic patterns of walking at this age. The maximum values of valgoze and varoze big toe reached relatively high values in all the age groups (TABLE 3).

The valgoze big toe values ranged in girls from 4.3° to 8.1°. Values of varozity were found in interval 4.3° to 8.5°. Differences between the varozity and valgozity values in the girls' group were smaller than in the boys' group. The maximum values of valgozity and varozity surpassed 15° (TABLE 4).

The little toe axis (valgozity) in boys' groups reached interval values 15.4° to 20.4°, in girls' group 14.4° to 18.6°. The little toe angle maximal values (more than 30°) evidence great misalignment and great deformation of anterior-part of foot in lateral ray area. The little toe misalignment appears on average lower in girls, minimal values ares lower as well.

Although little toe ray appears as "less significant" in the process of taking off, it surely has its foundation and its deformation has impact on the walking pattern. There was no occurrence of a foot without little toe misalignment. The little toe varozity was not present. In more than 80% of all groups there was determined little toe axis aberration above 9°, which can be considered according Hegrová (2001) as a border of high axis-declination. In hallux this border line is axis aberration of 6°.

The average values of foot angle ranged in boys' group from 15.5° to 16.8°, in girls' group from 15.9° to 16.8°. Minimal values were around 10°, maximal values, on the contrary, extend above 20° border. The frequency representation in individual categories is displayed in TABLE 6. Its obvious that the highest number of probands is in categories 15–18°. There were no significant differences in frequency representations between individual groups in the aspect of gender.

Foot type evaluation

In all groups the Egyptian foot, which seems to be the most optimal from the aspect of vertical force distribution in planta area, prevailed. Its related to achievement of maximal performance in sport and it can be supposed to have lower incidence of feet hurtfulness and collapse vault foot. In boys' group from kindergartens, the occurrence of Egyptian foot type – two sided – was reaching 87.9%. In girls' group from kindergartens the

occurrence frequency of Egyptian foot shifted in favour of Antique foot, right sided reached 78.8% of groups, on the left side 77.2%. This difference probably relates with higher occurrence of forefoot deformations in girls' groups.

TABLE 5
The average values of foot angles (Brázdilová et al., 1985)

Age	Hallux angle		Little too angle		Foot angle	
♀	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
3 years	3.2	5.8	7.9	5.1	14.2	2.2
4 years	3.5	5.4	9.8	4.8	14.3	1.9
5 years	3.4	5.4	8.9	4.9	14.3	1.9
6 years	4.6	5.3	9.2	4.9	14.4	3.4
7 years	4.8	4.8	9.8	4.6	13.9	1.9
8 years	5.4	5.1	9.5	4.7	14	1.9
9 years	6.1	5.3	9.6	4.3	14.1	1.8
♂	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
3 years	4.6	5.4	9.4	5.4	14.1	2
4 years	5.2	5.4	10	5.3	14.4	2.3
5 years	3.8	5.3	10.1	4.8	14.4	2.4
6 years	4.7	5.2	9.4	4.6	14.3	2.4
7 years	4	5.2	9.8	4.6	14.5	1.9
8 years	4.5	5.1	9.6	4.4	14.4	2
9 years	3.9	5.1	10.9	4.8	14.1	1.9

After starting to attend school the girls' group keeps similar ratio of foot type distribution, the shifting is again in favour of Antique foot type. In boys' group we recorded almost balanced distribution of foot types in the categories of Antique and Egyptian foot type. There is significant difference between genders in Antique type foot occurrence in the frame of individual age categories.

In 8–9 years old children the representation ratio is shifted in favour of Antique foot, however even Antique foot frequency is not trivial and it runs over 20% of group. In this age category there was not discovered statistically relevant difference in foot type occurrence between genders.

TABLE 7
Histogram of foot typology

Type foot		Egyptian				Antic				Wide			
		L		R		L		R		L		R	
		n	%	n	%	n	%	n	%	n	%	n	%
3–6 y.	♂	102	87.9	102	87.9	14	11.5	14	11.5	0	0.0	0	0.0
	♀	95	77.2	97	78.8	28	22.7	26	21.1	0	0.0	0	0.0
6–7 y.	♂	38	58.5	40	61.5	27	41.5	25	38.5	0	0.0	0	0.0
	♀	32	76.2	27	64.2	10	23.8	15	35.7	0	0.0	0	0.0
8–9 y.	♂	52	63.4	47	57.3	25	30.5	27	32.9	5	6.1	8	9.8
	♀	58	69.9	51	61.4	19	22.9	20	24.1	6	7.2	12	14.5

DISCUSSION

The monitoring of foot morphology in children in the sense of primary prevention is neglected abroad as well as in home workplaces. There were national researches realised in the Czech Republic, under the guarantee of Footwear Research Institute in Zlín followed by Technological faculty T. Baťa in Zlín, which are gradually completed by researches on the regional level, event in specific population groups (e.g. according sports specialisations, ethnic etc). The studies of various authors in abroad usually concern already progressive clinical syndromes which are nevertheless diagnosed in adult age. The relation between the structure and foot function in adult population is being tried to solve in the range of studies with various levels of technical devices.

The soft tissues with regard to their impairment were observed by Gooding et al., Cavanagh, Hennig, Rodgers and Anderson (1985) and they established reference data of measured foot parameters by radiographic method.

Rodgers (1995), Kapandji (1987), Sammarco (1995), Hamill and Knutzen (1995), Valmassy (1996) and the others occupied themselves with the configuration of medial area of longitudinal foot vault.

TABLE 6
The occurrence frequency of probands in individual categories of foot angle

Foot angle		< 15.0°				15.0°–18.0°				> 18.0°			
n/%		R		L		R		L		R		L	
		n	%	n	%	n	%	n	%	n	%	n	%
3–6 y. (n = 116)	♂	18	15.5	22	18.9	84	72.4	79	68.1	14	12.1	15	12.9
3–6 y. (n = 123)	♀	21	17.1	23	18.6	87	70.7	91	73.9	15	12.2	9	7.3
6–7 y. (n = 65)	♂	14	21.5	14	21.5	42	64.6	39	60	9	13.8	12	18.5
6–7 y. (n = 42)	♀	9	21.4	10	23.8	29	69	26	62	4	9.5	6	14.2
8–9 y. (n = 82)	♂	17	20.7	20	24.4	51	62.2	45	54.9	14	17.1	17	20.7
8–9 y. (n = 83)	♀	15	18.1	12	14.5	59	71.1	50	60.2	9	10.8	21	25.3

Varelas, Wessel, Clement, Doyle and Willey (1993) confirmed on the basis of monitoring the pressure and distribution of vertical forces in the area of foot sole that inadequate maximal physical load as well as insufficient one are always risk factors for foot sole deformation. Its overloading and failure is projected into total and local performance both physical and psychical.

In the clinical and research workplaces in various countries they apply laboratory technique devices for the evaluation of foot condition and function. Various companies offer various devices based on similar principals of detecting the static and dynamic pressure proportion on the foot sole, eventually in punctually defined areas of foot. Devices EMED-SF2-system, EMED-F01 system, FootScan®System, Musgrave Footprint, Pedar S5 and others enable the analysis of pressure forces for foot evaluation, further the establishment of the influence of various illnesses for the loading of the foot and the whole locomotory system, finding out the pressure distribution enables more quality manufacturing of footwear in the form of orthopaedic pads or orthopaedic footwear (utensils inserted directly into the shoe – such as F-Scan in Shoe transducer), (Meyring, Diehl, Milani, Hennig, & Berlit, 1997; Razeghi & Batt, 2002; Rosenbaum, Hautmann, Gold, & Claes, 1994; Přidalová, Seifertová, Elfmark, & Janura, 2003; Virmavirta & Komi, 1993; Virmavirta, Pettunen, & Komi, 2001).

The comparison with the data of other authors is usually problematic in regard with utilization of different methodology for longitudinal foot vault evaluation and other foot parameters.

Brázdilová et al. (1985) was occupied in monitoring of longitudinal foot vault state in her Grant K-76-322-003 final report. The concept of boot-tree innovation on the basis of carried out foot measurements in Czech population. The foot indexes and frequency differentiation are not mentioned.

As far as the length and width, the parameters of our observed groups of children do not differ from the parameters established by Brázdilova et al. (1985).

Similarly there was examination carried out in Czech childs' population in the years 1997–1999, where there were monitored morphological and health parameters of feet in 10 236 children aged 3–19 years (Šťastná, 1997, 2002a, b). Flat foot was diagnosed in boys with higher frequency than in girls (similarly as in our groups). The flat foot occurred in 53.3% of 3 years old boys, only 36.4% in girls. In the process of development the flat foot decline was determined. The flat foot occurrence ranged from 11.1–13.7% in 6 years old up to 8 years old age categories. In girls' group of 6 years old the flat foot was found in 11.5%, in 7–8 years old girls it occurred only up to 5%.

The flat foot in our groups is typical for younger age categories which is conditioned by fat-pad existence in the foot sole. In older children resp. 8–9 years old boys the flat foot can be characterised as pathological deviation of longitudinal foot vault. In this way the orthopaedist or general practitioner should approach it – as a starting point of primary care. The average values of foot index logically decline with age.

In Polish pre-school population there were foot parameters monitored by Nowakowski (2002) and Zeyland-Malawka and Nowakowski (2002), however they evaluated longitudinal foot vault by Wejsflog index (1955). Thus our data were not comparable. Polish colleagues recorded as well the trend of index value decline with age. The representation of flat foot categories was higher in boys than in girls. In the interval 3–6 years was the frequency of flat foot representation declining in individual age categories: in boys from 54% to 16%, in girls from 38% to 3%. In general the decline of foot index with age can be observed both in our children and in Polish children.

Volpon (1994) directed his study to child's foot of new-borns up to 15 years old children with yearly age categorisation. His contact index II. (Qamra et al.) does not enable comparison with our outcomes in regard with to dissimilar index calculation. Again there is obvious its decline from the birth to 6 years. Subsequently the discontinuance of index decline happens and its values appear constant. The frequency of flat foot (resp. low vault foot) occurrence was very low. In 3 years old to 6 years old it ranged to 5%.

Anderson, Blair and Green (1956) published in the predated study the relation between body weight, foot length and the length of lower limbs in children in the age 1–18 years. The authors apart from other things state that the boy's foot is growing even after the age of 12 whereas the girl's foot growth is completed. Concerning the acceleration trends, which express themselves in the area of foot, this statement is probably already unacceptable.

Rose, Welton and Marshall (1985) occupied themselves with flat foot in children as well. They confirmed the occurrence of flat foot in frequency 10% in children over 6 years age limit.

The big and little toe axis aberrations belong to the toes and anterior part of foot deformities and is usual in high frequency already in child's age categories. Valgozity occurs especially in female gender, varozity in male gender.

The comparison with responding fugues was not possible because authors usually don't differ big toe axis aberration to the medial and lateral side. If we compare with results of Brázdilová et al. (1985), it's evident that their values are lower, which is related to the given fact (TABLE 5). We believe that valgozity and varozity should be observed separately for varozity relates to inner rotation (adduction) of anterior-part of foot, it

evidences dissimilarly loaded muscle groups, another distribution of force in planta area, event. shortening of plantar aponeurosis. According Šťastná (2002) the big toe valgozity occurred with lower frequency than in our groups. In boys the frequency went up to 8.5% representation, in girls the valgoze hallux occurrence was up to 12.5% of group.

Contrary those authors Zeyland-Malawka and Nowakowski (2002) mentioned representation of valgoze big toe in more than half of the group and they evaluated the hallux axis aberration (again impossible to compare due to the methods using different means of evaluation) as very high.

Foot deformities in the area of anterior part of foot which we confirmed in our groups of children as well as in Polish population (Zeyland-Malawka & Nowakowski, 2002) are certainly in relation with wearing anatomically unsuitable footwear. This phenomenon has deepened recently in the Czech Republic in last years.

Comparing our results of little toe and the results of Brázdilová et al. (1985), its obvious that our average values of little toe angles are higher in all age groups. In some age groups it reaches double values. Comparing our average values of angle foot with the results of Brázdilová et al. (1985) we can see again higher values in our groups (TABLE 5).

CONCLUSIONS

The principal result was the determination of individual morphological points and parameters on the foot sole so that there would be no methodological inconsistencies in the case of comparing the results of various authors.

Longitudinal foot vault was evaluated in high frequency as normally physiologically developed in both genders. In the highest frequency was represented the category of normally arched foot of II. degree. The category of foot index of I. degree was represented with low frequency. Flat foot was determined in lower percentual representation with regard to normal foot type. In gender differentiation the flat foot was found in 3 years, 4 years and 8–9 years old girls in slightly lower occurrence than in boys of the same age. High feet occurred rarely in younger age categories in both genders.

In younger age categories, we meet higher values of foot index, crossing 40% limit. The average foot index value in boys' groups reached mildly higher limit than in girls. Maximal values of foot index were in boys' groups higher than in girls – over 70% of limits. We can notice mild decline of foot index in both genders in the process of development, with significant difference of index in 3 years old and 6 years old girls.

Relatively satisfactory finding in the foot vault area was completed with alarming results in forefoot deformations. Hallux axis aberration implicates anterior-part of foot deformations on the medial ray of foot. Hallux misalignment was monitored in the sense of valgozity and varozity, we consider this differentiation conditional. Hallux and little toe deformations can implicate traversal vault foot falling in. Hallux axis without aberration was found maximally up to 8 probands in groups. The average values of varozity reached in boys' groups higher values than in girls' group, on the contrary, valgozity values appeared higher in girls. Valgozity representation was higher in boys' groups. In 3–5 years old girls the frequency occurrence of varoze and valgoze hallux was represented almost equally. In girls over 6 years age limit valgozity occurred in much higher frequency than varozity. Maximal values of hallux misalignment were alarming and elusive.

Little toe axis aberration in boys and girls reached similar values. Maximal values crossed limit 30°. In spite that lateral ray has less significant importance for taking off of the foot, it indeed participates anatomical on manifestations and mechanisms of walking. Its deformation is thus projected into the walking pattern in a certain way.

The foot angle reached in individual girls' groups similar values as in boys. In all groups we find the highest frequency representation in category 15° to 18°. The size of foot angle could be in relation to foot valgozity or varozity, even though so far the relation appears not so clear.

The most frequently represented was the Egyptian foot, which appears optimal from the aspect of force and pressure distribution in planta area. Less favourable Antique foot type was represented with much lower frequency. The wide foot type almost did not occur.

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MORFOLOGIE DĚTSKÉ NOHY
(Souhrn agnlického textu)

Studie vypovídá o morfologii nohy jako bazálním článku podpůrně-pohybového systému, jehož stav a funkce ovlivňuje vyšší etáže a psychiku člověka. Morfologie nohy byla sledována u 263 chlapců a 248 dívek předškolního a mladšího školního věku. Děti byly považovány za asymptomaticky zdravé, byly rozděleny dle pohlaví a dle věku. Otisky nohou byly sejmuty plantografickou metodou jako statický plantogram a zpracovány softwarem „Noha".

Stav podélné nožní klenby odpovídal vývojové fázi, jevil se jako uspokojivý, v nejvyšší frekvenci byla determinována normální noha II. stupně. Výskyt ploché a vysoké nohy neznamenal zásadní problém u těchto věkových kategorií.

Ve vysoké četnosti se u obou pohlaví a ve všech věkových kategoriích vyskytovaly deformace palce a malíku, které řadíme k deformacím předonoží. Průměrné hodnoty úhlu palce ve smyslu varozity i valgozity a průměrné hodnoty úhlu malíku se jevily jako relativně vysoké. U chlapců dosahovaly hodnoty úhlu valgózního rozmezí, 2,6–7,9°, u dívek 4,3–8,1°. Průměrné hodnoty varózního vyosení byly vyšší. Úhel malíku se pohyboval u chlapců v rozmezí hodnot 15,4° až 20,4°, u dívek 14,4° až 18,6°. Maximální hodnoty vyosení byly překvapující.

V nejvyšší frekvenci se vyskytoval typ egyptské nohy, který se jeví z hlediska rozložení vertikální síly jako nejoptimálnější. Široká noha, jako méně optimální typ, se téměř nevyskytovala.

Hodnocení podélné nožní klenby odpovídalo jednotlivým fázím ontogeneze. Stav se jevil jako relativně uspokojivý. Analýza morfologických parametrů předonoží prokázala vysoký frekvenční výskyt deformací laterálního a mediálního paprsku.

Klíčová slova: plantografická metoda, podélná nožní klentba, přední část nohy, úhly nohy.

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1987–1988 lecturer in the Department of Zoology and Anthropology at the Faculty of Natural Sciences, PU in Olomouc,
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