ANALYSIS OF MORPHOLOGY OF FOOT IN MORAVIAN MALE AND FEMALE STUDENTS IN THE AGE INFANS 2 AND JUVENIS

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Morphological foot type, foot index for longitudinal foot vault, misalignment of the big and little toes, heel angle and lower limb muscles condition were monitored in 106 male students and 162 female students from the Gymnasium school in Šternberk and the Integrated secondary school in Ostrava ranging in age from 12 to 18 years. A considerably higher frequency of Egyptian foot incidence was noted in both girls and boys (71.69% and 70.99% respectively). The quadratic foot was found in boys in a very small percentage (2.83%) with particular individual asymmetry; it was not discovered in girls. Flatfoot diagnosis by means of the Chippaux–Šmiřák method provided very favourable results (4.94–10.38% flatfoot occurrence). On the other hand, results using the Szriter–Godunov method were considerably worse (38.27–43.21% flatfoot occurrence). Zero condition misalignment of the big toe was encountered in less than a quarter of the files. The frequency of valgose and varose manifestations being almost equal in boys; the right big toe varose position was the dominant feature. As for the girls, the valgose position was dominant. The average values ranged from 4 to 7 degrees. The average little toe angle value characteristic for a valgose little toe was high. (17.73–21.90 degrees). The average heel angle was diagnosed in the range of 15 to 18 degrees. When evaluating relations of the lower limb muscle shortening and conditional foot vault functional disorders (only in men) we found statistically significant relation between heel misalignment and m. triceps surae sin. shortening, and between the heel angle and knee flexors sin. shortening.

Keywords: Morphological foot type, foot index, misalignment of the big toe and little toe, heel angle, muscle dysbalances.

INTRODUCTION

Several independent scholarly works comprehensively validate the evolutionary development of the human foot into a supportive structure in habitual bipeds. The regression of loose skeletal elements and the enlargement of stable elements of the foot facilitated the change of this part of the limb into a supportive structure. The concurrent development of the longitudinal and transverse foot vaults and the strong ligamentary apparatus enables distribution of load on the individual parts of the foot. The further loss of mobility of the big toe to account for perfect shift of body weight represents as a typical feature of the human foot.

The longitudinal vault is formed by the tarsal and the tarsometarsal joints; it is primarily held in place by a system comprising of ligaments and aponeuroses. The big toe is situated on the axis of the foot and it moves almost entirely vertically, the lateral movement being very limited. The talus and calcaneus serve to lift the heel from the ground at the moment of shift of the body centre of gravity to the other side. The transverse vault is defined by the shape and arrangement of the ossa cuneiformia and the proximal metatarsi, the task here being to provide protection to some of the soft tissue structures in the sole. The second and third cuneometarsal joints are stable parts of the forefoot. They remain in the original position even when the transverse vault warps while the peripheral metatarsi shift into elevation.

The preservation of the longitudinal and transverse vaults is dependent on the bone structure, the ligaments of the foot, and the lower limb and shank muscles. The muscles play an important role in the preservation of the leg vault during dynamic load. All longitudinal muscles participate in the preservation of the longitudinal vault; the toe flexors and m. tibialis posterior are also significant in the preservation of the foot vault. As for the muscles, quiescent tension of the big toe muscles, especially m. abductor hallucis and m. flexor hallucis brevis, is essential for vault preservation. The tibial foot-ridge is lifted by m. tibialis anterior. This muscle together with the m. peroneus longus forms a tendon stapes that maintains the vault and draws it in such a way that the vault remains longitudinal. M. peroneus longus keeps the transversal vault through transverse traction.

If the system of longitudinal and transverse vaults is preserved, the pace is springy in nature and the foot adapts itself to the demanding conditions. Hence, the central nervous system and the flexible part of the spine are protected against shocks.

The term flatfoot refers to an abnormal lowering or disappearance of the longitudinal vault. There are two types of flatfoot: congenital flatfoot when a part of the flatfoot in children's feet is maintained into adulthood, and acquired flatfoot.

The imbalance in ratio between the load intensity and load capacity of the foot leads to the condition of static flatfoot. As for cultural factors, persistent work related stress, lack of exercise and rest, the wearing of unsuitable footwear, walking on hard grounds, and being overweight, among other factors, contribute to the development of static flatfoot. The cultural adaptations of the footwear are subject not only to the climate but also to the socio-economic conditions and the fashion, which tend to act as negative factors in the ontogenesis of the foot.

Flatfoot can be divided into four stages according to the degree of deformity:

1. Tired foot where the shape is still preserved. However, weariness and pains appear after physical labour. On examination a valgose heel posture is usually detected.
2. Flaccid foot where the longitudinal arch falls when load is applied. The vault reappears upon cessation of load.
3. Flatfoot, when the foot vault remains permanently flat; it is loose and it can be shaped passively into regular shape.
4. Flatfoot with fixed deformity; the heel is valgose, the dorsal foot verges into pronation with overloading of the medial beam, it is widened, the big toe is pushed into a valgose position and a plantar swelling forms because of elevation of the fringe metatarsi. Hammertoes develop as a result. Rigorous pace leads to pain in the hip joint and the lumbar spine (Hegrová, 2001).

Flatfoot correction by means of surgical socks or shoes is often mentioned in research publications. However, the need for foot exercise focused on simulating the evolutionary conditions of phylogenetic development of the foot vault is lacking. Diverse foot morphology is given by the length of the metatarsi and the length of the phalanxes. Judging by the external shape, Egyptian, Ancient and quadratic feet is distinguished. Regarding the length of the metatarsi it is possible to divide each into subtypes according to predominance of the metatarsal, phalangeal or metarsophalangeal features.

The morphological foot type can be a restrictive performance factor (Kučera, 1994). The Egyptian foot implicates a large contact area for the toes thereby distributing even load. From an athletic point of view, it is the best foot type but it is more predisposed to the development of hallux valgus and rigidus than the other types. The Ancient foot is characterised by a smaller contact area. Two toes are always dominant: the 1st and 2nd or 2nd and 3rd. The load peak is in the area of phalanx-metatarsi transition. The quadratic foot is the least efficient regarding mechanical load, subsequently having a considerable sensitive response.

MATERIAL AND METHODS

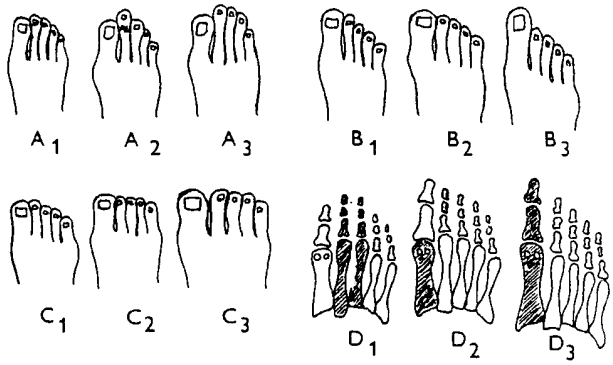
The research on foot morphology was carried out with a file of 106 male students and 162 female students belonging to the Gymnasium school in Šternberk and to the Integrated secondary school Na jízdárně in Ostrava. The age range of probands was 12–18 years and it included the age range of Infans 2 and Juvenis. Plantography was used to obtain the footprints. We monitored the morphological foot type, the foot index for evaluation of the longitudinal vault, the misalignment of the big toe and little toe, the heel angle and the condition of the lower limb muscles.

RESULTS AND DISCUSSION

TABLE 1
Frequency representation of morphological foot types

Files		Morphological foot type					
		Egyptian		Ancient		Quadratic	
		n	%	n	%	n	%
Boys sin.	n = 106	76	71.69	29	27.36	1	0.9
Boys dex.	n = 106	72	67.92	31	29.24	3	2.83
Girls sin.	n = 162	115	70.99	47	29.01	–	–
Girls dex.	n = 162	115	70.99	47	29.01	–	–

Fig. 1
Frequency representation of morphological foot types (A_1–A_3 Ancient, B_1–B_3 Egyptian, C_1–C_3 Quadratic, D_1–D_3 subtypes according to predominance of the metatarsal, phalangeal or metarsophalangeal features)



A considerably higher frequency of Egyptian foot was found in both the boys and girls. The quadratic foot

found in the boys was in a very low percentage showing some individual asymmetry. It was not ascertained in the girls.

Riegerová (1997) was monitoring the relationship of anatomical foot structure and somatype of 282 students from first year PE students of the Faculty of Physical Culture, the Pedagogical Faculty and the Faculty of Law of Palacký University. She states that important feedback was provided as to the prevalence of the Egyptian foot in the female PE students who, according to their somatype, belonged to a category of the proportional – medium type. The male PE students had the highest frequency of Egyptian foot in the category of somatype with dominant *ectomorphal* components. Even here the feedback comes into play because *mesomorph ectomorphs* and *mesomorphal ectomorphs* are very good prerequisites for locomotive endurance from the point of efficiency prediction. Riegerová also found a significant prevalence of the Ancient foot in the Law School and Pedagogical Faculty students (71.43%), which is much higher than the population average quoted by Kučera (1994).

Přidalová (2002) monitored the occurrence of particular morphology foot types with various population groups and with sportsmen. She discovered normal or higher proportion of Egyptian foot; prevalence of the Ancient foot was not apparent.

The above mentioned method is based on the evaluation of the proportion of the narrowest and widest part of the plantogram. Footprints with values of up to 45% are formally classified as vaulted foot, footprints over 45% are classified as flatfoot. With both men and women, the normal foot is prevalent; the number of high or flatfeet is relatively low.

Fig. 2
Chippaux-Šmiřák's method; Klementa, 1987

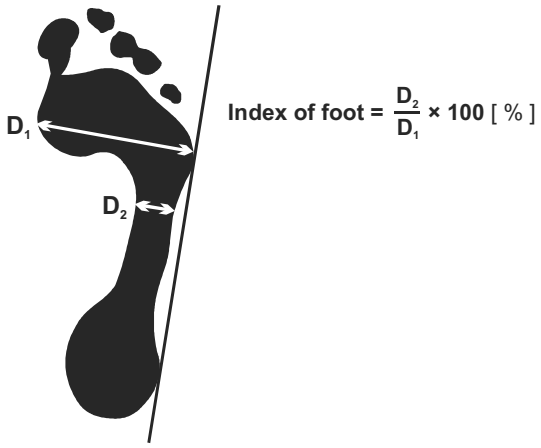


TABLE 3
Frequency and percentage of the individual foot vault categories (Szriter–Godunov's method)

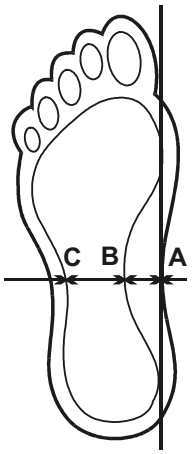
Files	Foot vault condition categories					
	High		Normal		Flat	
	n	%	n	%	n	%
Boys sin.	9	8.49	54	50.9	43	40.6
Boys dex.	4	3.77	61	57.6	41	38.7
Girls sin.	11	6.78	89	54.9	62	38.3
Girls dex.	8	4.94	84	51.9	70	43.2

TABLE 2
Frequency and percentage of particular foot vault condition categories (Chippaux–Šmiřák's method; Klementa, 1987)

Files	Foot vault condition categories																	
	High						Normal						Flat					
	1. gr.		2. gr.		3. gr.		1. gr.		2. gr.		3. gr.		1. gr.		2. gr.		3. gr.	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Boys sin.	2	1.89	–	–	4	3.77	28	26.41	54	50.94	7	6.6	6	5.66	2	1.89	3	2.83
Boys dex.	–	–	1	9.94	1	0.94	25	23.58	59	55.56	9	8	6	5.66	3	2.83	2	1.89
Girls sin.	–	–	3	1.86	8	4.94	60	37.03	77	47.59	6	3.7	7	4.32	–	–	1	0.62
Girls dex.	2	1.23	3	1.86	3	1.86	50	30.86	82	50.61	14	8.64	7	4.32	1	0.52	–	–

Files	Overall percentile and frequency representation in categories of the foot vault condition					
	High		Normal		Flat	
	n	%	n	%	n	%
Boys sin.	6	5.66	89	84	11	10.4
Boys dex.	2	1.89	93	87.7	11	10.4
Girls sin.	11	6.79	143	83.7	8	4.94
Girls dex.	8	4.93	146	90.1	8	4.94

Fig. 3
Sztriter–Godunov's method



$$\text{Index Ky} = \frac{B - C}{A - C}$$

Pes excavatus	0.00–0.25
Norma	0.26–0.45
Pes panus I°	0.46–0.49
II°	0.50–0.75
III°	0.76–1.00
Age: 8 years	0.44–0.54
9 years	0.41–0.53
10 years	0.40–0.53
11 years	0.39–0.54

Szriter–Godunov's method (Kasperczyk, 1998) belongs among the so-called index methods. Its evaluation is less vague than the Chippaux–Šmiřák's method and the percentage of flatfoot detection is much higher here.

As already mentioned in the beginning of this article, the foot can function properly if anatomical regularity is obeyed. Pursuant to the exogenous and endogenous factors, the resistance of a foot changes throughout life and subject to the footwear opted for typical deformities of the dorsal foot, such as misalignment of the big toe, transverse vault warping related to widening of the dorsal foot, hammertoes, etc., arise.

According to Hegrová (2001) the toe angle values are, from a minimum medical requirements perspective, graded according to the foot size, the limit being 6 grades, or, according to Wejsflog (1956), even 9 grades. We cannot fully agree with this statement and our opinion centres around the belief that misalignment of the big toe (even though the process might have just begun) shows a current muscular imbalance that will deepen in the absence of special exercise. Misalignment of the big toe also shows disorders of the dorsal foot, i.e. transverse vault warping. It is, therefore, necessary to develop both the foot and the shank flexors, including the big toe muscles on the basis of primary prevention. There are several devices for developing the foot vault as standard.

We have encountered zero misalignment of the big toe in less than 1/4 of our files. The frequency of valgose and varose manifestations was almost equal in boys. As a matter of fact, right big toe varose position was the dominant one. As for the girls, valgose position was the dominant one; the difference in frequency between positive and negative *misalignment* was statistically significant. The average values of the big toe angle ranged from 4 to 7 degrees, maximum misalignment reaching 18 degrees. It is essential to pay attention to misalignment of the big toe from pre-school age.

TABLE 4
Frequency and percentage of misalignment of the big toe

Files	Big toe angle					
	Zero condition		Positive misalignment (valgose big toe)		Negative misalignment (varose big toe)	
	n	%	n	%	n	%
Boys sin.	18	16.98	44	41.51	44	41.51
Boys dex.	21	19.81	35	33.02	50	47.17
Girls sin.	41	25.31	98	60.49	23	14.19
Girls dex.	35	21.6	81	50	46	28.39

The limit for right little toe position is set from 5 to 1 degree (Hegrová, 2001). In our study, the average value of the little toe angle was high in both boys and girls.

The average heel angle was diagnosed as a range from 15 to 18 degrees with high maximum values signifying valgose heel. It is necessary to point out that valgose heel anticipates or accompanies longitudinal flatfoot.

TABLE 5
Basic statistical features of the big toe, little toe and heel angle (±)

Files	$\bar{x}$	s	min.	max.
Boys toe angle sin.	4.20	3.29	2.0	12.0
Boys toe angle sin.	–5.63	–3.09	–1.5	–14.0
Boys toe angle dex.	4.53	3.60	2.0	13.0
Boys toe angle dex.	–5.87	–3.49	–1.5	–18.0
Girls toe angle sin.	5.09	4.65	1.5	18.0
Girls toe angle sin.	–6.96	–3.90	–1.0	–16.0
Girls toe angle dex.	5.76	3.06	1.5	14.0
Girls toe angle dex.	–4.27	–4.02	–2.0	–17.0
Boys little toe angle dex.	21.40	7.30	5.0	35.0
Boys little toe angle sin.	21.90	7.21	6.0	39.0
Girls little toe angle dex.	17.73	7.50	4.0	40.0
Girls little toe angle sin.	18.08	7.47	3.0	41.0
Boys heel angle sin.	16.16	2.39	10.0	21.0
Boys heel angle dex.	16.96	2.50	11.0	22.0
Girls heel angle sin.	15.58	2.47	10.0	21.0
Girls heel angle dex.	16.01	2.40	10.0	22.0

The condition of muscles and muscular groups in the lower limb was monitored only in men. Janda (1996) adapted to an alternative evaluation method. All monitored muscles and muscular groups were affected, shortening of the knee-joint flexors being the dominant feature (56.80%). The frequency of shortening was high with other monitored muscles – m. tensor fasciae latae (52.30%), m. rectus femoris (40.90%), thigh abductors (38.60%) and m. triceps surae (21.40%). The relation between the monitored foot parameters and condition of the lower limb muscles was evaluated by means of the chí square. Statistically significant triceps shortening frequency of the surae and knee-joint flexors in both feet

was discovered, which is logical in respect to the kinetic chains integration. We supposed that more relations between lower limb muscle shortening and foot vault functional condition disorders will be detected. However, we could only confirm statistically significant relation of heel misalignment and m.triceps surae shortening in the left limb in men. As for the right limb, the value was on the borderline. Similarly, significant relation between heel angle and knee flexor shortening was found.

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ROZBOR MORFOLOGIE NOHY U CHLAPCŮ A DÍVEK VE VĚKU INFANS 2 A JUVENIS

(Souhrn anglického textu)

U 106 studentů a 162 studentek z Gymnázia ve Šternberku a Střední integrované školy v Ostravě ve věku 12–18 let byl sledován morfologický typ nohy, index nohy pro hodnocení podélné klenby nožní, vyosení palce a malíku, úhel paty a stav svalstva dolních končetin. U chlapců i dívek byla nalezena výrazně vyšší frekvence výskytu nohy egyptské (71,69 % a 70,99 %). Noha kvadratická se vyskytovala u chlapců ve velmi nízkém procentu (2,83 %) s určitou individuální asymetrií, u dívek nalezena nebyla. Diagnostika plochonoží metodou Chippauxe–Šmiřáka poskytla velmi příznivé výsledky (4,94–10,38 % výskytu ploché nohy), metoda podle Szritera–Godunova naopak nález podstatně horší (38,2–43,21 % výskytu ploché nohy). S nulovým stavem vyosení palce jsme se setkali u necelé čtvrtiny souborů. U souboru chlapců byla četnost projevu valgozity a varozity palce téměř vyrovnána, věcně převažovalo varózní postavení palce vpravo. U souboru dívek dominovalo signifikantně valgózní postavení. Průměrné hodnoty se pohybovaly v rozmezí 4 až 7 stupňů. Průměrná hodnota úhlu malíku, charakterizující vbočený malík, byla vysoká (17,73 až 21,90 stupně). Průměrný úhel paty byl diagnostikován v rozmezí 15 až 18 stupňů.

Při hodnocení vztahů mezi zkrácením svalů dolní končetiny a poruchami funkčního stavu klenby nožní (pouze u mužů) jsme nalezli potvrzení statistické významnosti závislosti u vyosení paty a zkrácení m. triceps surae sin. a signifikantní závislost mezi úhlem paty a zkrácením flexorů kolen sin.

Klíčová slova: morfologický typ nohy, index nohy, vyosení palce a malíku, úhel paty, svalové dysbalance.

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