THE HEIGHT OF THE LONGITUDINAL FOOT ARCH ASSESSED BY CHIPPAUX-ŠMIŘÁK INDEX IN THE COMPENSATED AND UNCOMPENSATED FOOT TYPES ACCORDING TO ROOT

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It is known that functional types and subtypes of foot according to Root differ, among others, by the height of foot arch when load is applied. The study objective was to use the Chippaux-Šmiřák index (CSI) to evaluate the height of the longitudinal foot arch in functional (sub)types according to Root. The test group consisted of 141 women (17–85 year, x = 58.8, SD = 12) and 87 men (22–86 year, x = 58.7, SD = 11.91), mainly middle aged and older. One examiner assessed the foot types and subtypes in all test subjects – rearfoot varus compensated (RFvarC), partially compensated (RFvarP) and uncompensated (RFvarN), forefoot varus compensated (FFvarC), partially compensated (FFvarP) and uncompensated (FFvarN), forefoot valgus flexible (FFvalgF), semiflexible (FFvalgS) and rigid (FFvalgR) and neutral foot (N). The other examiner evaluated all footprints and he assessed CSI. The sequence was determined on the basis of average CSI; significance of the differences we found was tested by ANOVA and the post-hoc Fisher LSD test. The results showed that functional subtypes could be – with high significance – divided into 2 extreme groups. On one side of the spectrum are the compensated, resp. flexible subtypes with high CSI (thus lower longitudinal foot arch). On the other side of spectrum are uncompensated, respectively rigid subtypes with low CSI. In the central part of the spectrum there are intermediate subtypes. Neutral types can be placed in the central group, rather into its left side. Gender influence is negligible. The results also confirmed the assumption concerning the differences among functional (sub)types in the height of the longitudinal foot arch when load is applied. Nevertheless it cannot by itself replace a personal and physical examination by an examiner who is greatly acquainted with functional anatomy and kinesiology.

Keywords: Rearfoot varus, forefoot varus, forefoot valgus, Chippaux-Šmiřák index.

INTRODUCTION

Classical clinical typology distinguishes 3 basic foot types: flat foot, normal foot and high foot. Althougth the first description of flat foot is attributed to Galen (Xarchas & Tsolakidis, 2004), the term flat foot was introduced into contemporary practice by Durlacher in 1845 who also designed a suitable shoe padding. In 1888, Whitman completed the patomechanics in pes valgus and he considered muscle activity as a principle factor for foot stabilisation and muscle weakening as a cause for the overloading of other muscles and ligaments and the cause of pain as well. In the twenties, the classic typology was completed with a tripod model of foot arch that is related to the classic orthopaedic concept of collapsed arches as a cause of metatarsalgy. In spite of the fact that the tripod model has been recently repeatedly disputed (Henning & Milani, 1993; Roy, 1988; Cavanagh, Rodgers, & Ibioshi, 1987) it can be still granted a certain validity (Vařeka, 2003). Nevertheless it is obvious that from the aspect of function, a diagnosis of flat foot is about as vague as a diagnosis of bad posture. When evaluating the findings, it is appropriate to take into account the difference between longitudinal and transversal flat foot because the heightened longitudinal arching is often accompanied by lowered transversal arching. Terminologically and practically it is also good to distinguish between the clinical findings of flat foot and pes planus diagnosis. A high arch (pes cavus) is the opposite of a flat foot. As far as the diagnostics and orthotics therof, it is important that the accentuation of longitudinal arching is often accompanied by lowering of transversal arching under metatarsal heads. Various clinical examinations are used for their being placed into the mentioned categories, including simple footprints and anthropometric measurements. In an attempt to achieve greater objectivity and to obtain valid results, imaging technology (X-ray) and sophisticated systems measuring the distribution of pressure under the planta are used (e.g. footscan or EMED pedar). The interpretation of these results in accordance with classic typology is insufficient because classic typology does not deal in great detail with dynamic changes of the loaded foot during the gait cycle.

In 1954–1966, Merton Root introduced the functional typology that lays stress on the foot as a dynamic complex and not merely as a static structure. He drew from the studies of Manter (movements in the subtalar and transversotarsal joint, 1941), of Hicks (orientation of joint axes, 1953), of Wright (rearfoot movements, 1956), of Elftman (locking of the transversotarsal joint during supination in the subtalar joint, 1960) and of Scheiber, Weinerman and Bar Levy (significance of the mutual position of forefoot and rearfoot, 1948 and 1950). It resulted in a new classification of normal and abnormal foot types. In basic ("normal", ideal) position according to Root, the axis of the lower ⅓ of the shank and of the heel passes vertically and at the same time the plantar planes of the heel and rearfoot coincide. The aberrations from this position are related to foot function disorders. The protocols for diagnostics and so called functional orthosis with the usage of chocks and backings were created on the above mentioned basis. Root, his colleagues and followers further improved this typology. The original classification of main types (rearfoot varus, forefoot varus and valgus forefoot) was completed with other subtypes and variations. Today it is a rather comlex system that enables us to explain logically the findings on the foot also at the proximal levels. Various foot types can have similar but not identical clinical findings. That is why it is mostly important to distinguish between the findings in the case of the unloaded foot and the same foot when it is loaded during standing and walking – when the potential compensations can occur. That requires a certain level of knowledge of foot kinesiology and patho-kinesiology and practical experience as well.

It is known from medical practice that Root's functional (sub)types differ – among others – by the height of the longitudinal arch when loaded. The objective of this study was to verify these differences.

METHODOLOGY

The test group consisted of 228 test subjects, 141 women (17–85 year, x = 58.8, SD = 12) and 87 men (22–86 year, x = 58.7, SD = 11.91). They were the clients of Luhačovice Spa Company, mainly middle aged or older. Kinesiological examination was carried out, including the static footprint by means of the membrane podoscope. Furthermore, we assessed the functional foot types according to Root. One examiner was performing continually this functional evaluation in the course of the whole research period. The other examiner assessed the footprints by means of the Chippaux-Šmiřák index (CSI) at the end of the whole research period. In CSI, the ratio of the smallest width of the middle part of the footprint to the biggest width of the forefoot is determined. The values of the smallest width of the forefoot are found on the line that is perpendicular to the lateral tangent of the footprint; the width of the front part of the footprint is measured at the joint point of the lateral and medial tangent point of the forefoot. Higher CSI can mean a relatively wider midfoot in comparison to the forefoot, which is considered to be an indicator of a lower arch. The reason why CSI was chosen for foot arch evaluation is because it correlates very well with the X-ray evaluation of an arch and because it is a very simple measurement (Maes, Andrianne, & Burny, 2004; Mathieson, Upton, & Prior, 2004). The methodology used draws upon Klementa's descriptions (1987).

The functional examination was based on the former works of Magee (1992), McPoil and Brocato (1990), Sutherland (1996), Valmassy (1996) and Vařeka and Vařeková (2003, 2005). We firstly performed the visual evaluation of the lower limbs in a standing test subject by viewing him/her from behind. Then the subject lies pronated with ⅓ of his/her lower limbs extending over the bed. He/she bent the non examined limb and put his/her foot's heel on the level of the fossa poplitea of the examined limb. The neutral position of the subtalar joint was determined by the palpitation method. The dorsiflexion and the locking of the transversotarsal joint were achieved by applying pressure with the thumb of the other hand on the sole below the head of the 5th metatarsus. Then we visually evaluated the rearfoot position relative to the shank axis and the forefoot position relative to the rearfoot (McPoil & Brocato, 1990; Sutherland, 1996; Valmassy, 1996; Vařeka & Vařeková, 2003, 2005). For the purpose of this study, three functional foot types were determined – rearfoot varus (RFvar), forefoot varus (FFvar), forefoot valgus (FFvalg) and neutral foot. We compared the findings in each foot when unloaded and loaded by the subject's standing on it and we determined the compensated (resp. flexible) and uncompensated (resp. rigid) subtypes. Inexplicit findings were placed as belonging to the intermediate subtype (TABLE 1).

To simplify the classification we did not establish the types upinated forefoot and that kind of finding was regarded as forefoot varus. Similarly, the finding of the plantarflexed first ray was regarded as forefoot valgus. Detailed description of individual foot types was published repeatedly (Scherer & Moris 1996; Valmassy, 1996; Vařeka & Vařeková, 2003, 2006).

The obtained data were sorted in the Excel program. ANOVA and the post-hoc Fisher LSD test in Statistica 6.0 were used to test the hypothesis. The differences were considered statistically significant at $p < 0.05$.

RESULTS

The basic descriptive statistics are shown in TABLE 2 where the subtypes are ranked according to CSI. Although the average values for the left and right foot differ a little, the ranking range is the same for both.

The significance of these differences (TABLE 3) convincingly confirmed the originally made assumption about the existence of differences in the height of the longitudinal foot arch among the individual functional subtypes that can be divided on the basis of CSI values into 3 subgroups – compensated (resp. flexible), intermediate and uncompensated (resp. rigid). On the right side of the spectrum are compensated, resp. flexible subtypes – FFvarC, RFvarC and FFvalgF with high CSI (thus a lower longitudinal arch). Within this group, FFvarC has also significantly higher CSI (thus a lower arch) than FFvalgF and RFvarC. On the other side of the spectrum are uncompensated, resp. rigid subtypes – FFvalgR, RFvarN and FFvarN with low CSI – these subtypes have no significant differences in CSI. In the middle part of the spectrum are the intermediate types RFvarP, FFvarP and FFvalgS – none of these subtypes have significant differences in CSI. Normal functional types can be put on the basis of CSI into the middle group, rather to its left side.

TABLE 1
Functional types and subtypes

Type	Subtype	Abbreviation
Rearfoot varus RFvar	compensated	*RFvarC*
	partially compensated	*RFvarP*
	uncompensated	*RFvarN*
Forefoot varus FFvar	compensated	*FFvarC*
	partially compensated	*FFvarP*
	uncompensated	*FFvarN*
Forefoot valgus FFvalg	flexible	*FFvalgF*
	semiflexible	*FFvalgS*
	rigid	*FFvalgR*
Neutral		*N*

TABLE 2
Foot subtypes ranked according to the average value of the Chippaux-Šmiřák index

Type		Left		Right	
	n	M	SD	M	SD
FFvarC	23	0.442	0.133	0.447	0.114
RFvarC	44	0.381	0.065	0.383	0.084
FFvalgF	32	0.357	0.048	0.356	0.038
RFvarP	26	0.340	0.089	0.329	0.089
FFvalgS	15	0.319	0.066	0.327	0.054
FFvarP	4	0.317	0.098	0.326	0.081
N	38	0.311	0.076	0.311	0.078
FFvarN	10	0.236	0.110	0.26	0.117
RFvarN	16	0.18	0.097	0.2	0.098
FFvalgR	20	0.163	0.091	0.18	0.091
Sum	228				

Legend:
n – number; M – simple average; SD – standard deviation
for the other abbreviations see TABLE 1

TABLE 3
Significance of differences in Chippaux-Šmiřák index value among functional subtypes

									FFvarC 0.44; 0.45
								RFvarC 0.38; 0.38	*
							FFvalgF 0.36; 0.36	ns	**
						RFvarP 0.34; 0.33	ns	dx*	sin** dx***
					FFvalgS 0.32; 0.33	ns	ns	sin(*)	sin*** dx**
				FFvarP 0.32; 0.32	ns	ns	ns	ns	*
			N 0.31; 0.31	ns	ns	ns	ns	**	***
		FFvarN 0.24; 0.26	sin(*)	ns	ns	sin*	sin** dx*	sin*** dx**	***
	RFvarN 0.18; 0.2	ns	***	*	sin*** dx**	***	***	***	***
FFvalgR 0.16; 0.18	ns	ns	***	*	***	***	***	***	***

Legend:
functional subtypes ranked according to average value of CSI, average value is shown in order left; right ns – non-significant
(*) p < 0.06 (non-significant); * p < 0.05; ** p < 0.01; *** p < 0.001
for the other abbreviations see TABLE 1

TABLE 4
Influence of gender

	CSI_L		CSI_R	
	F	p	F	p
Gender	2.098	0.149	0.953	0.330
Gender* subtyp	1.370	0.229	1.579	0.156

Legend:
CSI_R(L) – Chippaux-Šmirak index left (right); F – ANOVA test criterion; p – significance level; Gender* subtyp – interaction between gender and subtype

TABLE 4 shows the gender influence on results showed in TABLE 3. It is obvious that the interaction between gender and foot subtype has no significant relation to CSI value, so the differences in CSI among foot subtypes is approximately similar in men as well as in women.

DISCUSSION

The results show agreement with the early published descriptions of loaded foot arch in the individual functional subtypes of foot during a gait cycle (McPoil & Brocato, 1990; Pratt & Sanner, 1996; Valmassy, 1996). The foot does not go through a whole gait cycle when taking the static footprint; nevertheless the static load is approximately comparable to midstance.

Compensated rearfoot varus with sufficient compensatory pronation in the subtalar joint (and adduction and plantarflexion of the talus) enables the contact of the medial edge of the foot with the ground. Rearfoot pronation is very quick and remains throughout the whole support phase. Thus the foot arch is decreased, which corresponds with the higher CSI values of our test subjects. On the contrary, in uncompensated rearfoot varus, the pronation in the subtalar joint does not occur so when one treads fully on one's foot, the permanent load stays in the lateral edge of the foot. As a substitutional compensatory mechanism, the 1st ray plantar flexes and it causes the accentuation of the medial curve of the foot arch (McPoil & Brocato, 1990; Valmassy, 1996), which again corresponds with our results.

It is typical for compensated forefoot varus that there is hyperpronation in the subtalar joint with heel valgus when one treads fully on one's foot. As a result, the transversotarsal joint is unlocked and the foot arch is flattened (Hunt, 1990; Pratt & Sanner, 1996). Concerning the fact that even greater compensatory pronation occurs in this case than in compensated rearfoot varus, the foot arch flattening should be more prominent as well. Our finding of the significant highest CSI from all subtypes is in accordance with this assumption. In uncompensated forefoot varus, unlocking and flattening does not occur, which is again in accordance with low CSI findings.

Flexible forefoot valgus is characterised by a sufficient opportunity for forefoot supination along the longitudinal axes of transversotarsal joint so that the forefoot can reach the ground when loaded. Thus it does not need compensatory supination in the subtalar joint (Hunt, 1990; Pratt & Sanner, 1996). But the supination in the transversotarsal joint unlocks the forefoot and in that it worsens the forefoot's resistance to applied load in the midstance phase of the support and taking off phases. The foot medial curve collapses while loaded, which clinically manifests itself by showing a prominent difference in the height of the medial curve of the foot arch while loaded and unloaded. Rearfoot pronation remains throughout the whole support phase and through the initiation of the foot heel taking off. It corresponds with higher CSI in our test subjects. In rigid forefoot valgus, the compensatory supination along the longitudinal axis of transversotarsal joint does not occur. To achieve the situation that the whole area of the forefoot has contact with the ground, the compensatory inversion/supination of calcaneus (Hunt, 1990; Pratt & Sanner, 1996) with talus dorsiflexion and adduction (in transversal level) is needed. The lateral edge of the foot is overloaded when (among others, because of the lower ability of a rigid structure to absorb the load at the time). In gait cycle analysis, the rearfoot supination in heel contact is evident (sometimes even before the heel reaches the ground) and the medial curve of the foot arch is accented both when loaded and unloaded. In our test group, the subjects with this subtype had the lowest average values of CSI, ergo the lowest longitudinal arch.

CONCLUSION

The obtained results support our assumptions about foot arch height differences among individual functional foot types and subtypes. Compensated (resp. flexible) subtypes have lower longitudinal arches than uncompensated (resp. rigid) subtypes, which finding correlates with previously published kinesiological articles (Hunt, 1990; Magee, 1992; Pratt & Sanner, 1996; Valmassy, 1996; Vařeka & Vařeková, 2003, 2005). Gender influence is negligible. Footprint analysis can to a certain extent help to estimate the level of compensation or flexibility in individual functional foot types. Footprint evaluation cannot by itself replace a personal and physical examination by an examiner who is well acquainted with foot functional anatomy and kinesiology. For example a descriptive diagnosis of flat foot based on footprints cannot differentiate between compensated subtypes of rearfoot/forefoot varus and the flexible forefoot valgus. The situation is similar in the field of uncompensated (resp. rigid) subtypes. Also, the middle values of CSI can indicate not only a normal foot but also partially compensated (resp.semiflexible) subtypes. The ways of compensatory orthoses are then different (Pratt & Sanner, 1996; Valmassy, 1996; Vařeka & Vařeková, 2005) and their unsuitable application could lead to problem accentuation.

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VÝŠKA PODÉLNÉ NOŽNÍ KLENBY STANOVENÁ METODOU CHIPPAUX-ŠMIŘÁK U KOMPENZOVANÝCH A NEKOMPENZOVANÝCH TYPŮ NOHY DLE ROOTA

(Souhrn anglického textu)

Je známo, že funkční typy a subtypy nohy dle Roota se liší mimo jiné i výškou nožní klenby při zatížení. Cílem této práce bylo porovnat výšku podélné nožní klenby u funkčních (sub)typů nohy dle Roota pomocí Chippaux-Šmiřákova indexu (CSI). Soubor tvořilo 141 žen (17–85 let, x = 58,8, SD = 12) a 87 mužů (22–86 let, x = 58,7, SD = 11,91) převážně středního a vyššího věku. Jeden vyšetřující stanovil u všech probandů funkční typ a subtyp nohy – varozní zánoží kompenzované (RFvarC), částečně kompenzovaná (RFvarP) a nekompenzované (RFvarN), varozní předonoží kompenzované (FFvarC), částečně kompenzované (FFvarP) a nekompenzované (FFvarN), valgozní předonoží flexibilní (FFvalgF), semiflexibilní (FFvalgS) a rigidní (FFvalgR) a neutrální typ (N). Druhý vyšetřující zhodnotil všechny plantogramy a stanovil CSI. Na základě průměrné hodnoty CSI bylo stanoveno pořadí a statistická významnost zjištěných rozdílů byla testována pomocí ANOVA a post-hoc Fisherova LSD testu. Výsledky ukázaly, že funkční subtypy lze s vysokou mírou statistické pravděpodobnosti rozdělit do 2 krajních skupin. Na jedné straně spektra leží subtypy s vysokou hodnotu CSI (tedy nižší podélnou klenbou), kompenzované, resp. flexibilní subtypy. Na opačné pravé straně spektra leží nekompenzované, resp. rigidní subtypy s nízkou hodnotou CSI. Ve střední části spektra leží přechodné subtypy. Neutrální funkční typ lze zařadit do střední skupiny, spíše k levé straně. Vliv pohlaví je zanedbatelný. Výsledky tak potvrdily předpoklad o rozdílech mezi funkčními (sub)typy ve výšce podélné nožní klenby při zatížení. Stanovení výšky podélné klenby nohy pomocí plantogramu může pomoci při odhadu stupně kompenzace či flexibility jednotlivých funkčních typů. Samo o sobě však nemůže nahradit vlastní aspekci a fyzikální vyšetření nohy vyšetřujícím, který je dobře seznámen s funkční anatomií a kineziologií.

Klíčová slova: varozní zánoží, varozní předonoží, valgozní předonoží, index Chippaux-Šmiřák.

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