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THE FREQUENCY AND THE PLANTOGRAPHIC ASSESSMENT OF PES EXCAVATUS

The reported incidence of pes excavatus in the general population varies widely between one and fifteen per cent (see Discussion). Thus there is a lack of a basis for comparative studies on the occurrence of this anomaly in specific series in which of particular interest are patients with inborn malformations of the extremities. We have noted a frequent occurrence of pes excavatus e.g. in patients with lobster claw foot (Šmahel, Tolarová, in press). In the aim at an objective evaluation of our results, plantograms were obtained in a series of controls, characterizing both the longitudinal and the transverse plantar arches in adults; and these data were used also for studies into the influence of body weight on the configuration of the plantar arch (Šmahel, 1977). The original population sample was enlarged in order to obtain, as far as possible, most exact data on the actual frequency of pes excavatus. The ascertainment of these data in adults meets with difficulties associated with the collection of large series with an adequate age distribution.

On the basis of the investigated material we have subsequently attempted to devise a simple and convenient plantographic procedure for the assessment of a high longitudinal plantar arch. There are certainly differences between a break in continuity of the plantogram within a short segment only, and a foot where a proband walks only on the heel and on the region of metatarsal heads. The classification which was proposed so far and which is based on the absolute length of the gap in the footprint (Klementa, 1964) is not definite, since it does not take into account the differences between the length of the foot in males and females, or between individual probands (and of this reason it cannot be applied in children).

MATERIAL AND METHODS

Our studies included plantograms obtained in 147 males and 128 females ranging in age from 18 to 45 years. The study is based on the series of control plantograms which were described in more detail in our earlier communication (Šmahel, 1977), with an additional inclusion of individuals aged 18—19 years, as well as of patients with inborn malformations which cannot influence the configuration of the plantar arch, as it was shown by an independent assessment of subgroups with individual types of anomalies (consisting of patients with facial clefts and with slight forms of hypospadia). The results obtained in higher numbers of probands were more consistent than those ascertained in the original series of controls, and a higher frequency of pes excavatus allowed a subdivision into categories according to its degree.

Plantograms were obtained with use of printing ink during the transmission of whole body weight to the examined foot. From the investigated series were selected 21 males (i. e. 14.3 per cent) and 19 females (14.8 per cent) with unilateral or bilateral pes excavatus (pes cavus). The imprints obtained in these individuals were subjected to detailed analysis, as follows. For the reasons mentioned in the following the Schwartz-Clarke's angle of the transverse arch was determined in all cases of pes excavatus, together with the calculation of the suggested index of the ratio of the width of the break in continuity in the plantogram to its maximum length from the heel to the toes (*Fig. 1*). The figure shows that the extent of the gap is measured parallel to the external tangent. In unilateral forms we have determined (on the normal side) in addition to the transverse arch the Chippaux—Šmiřák's index

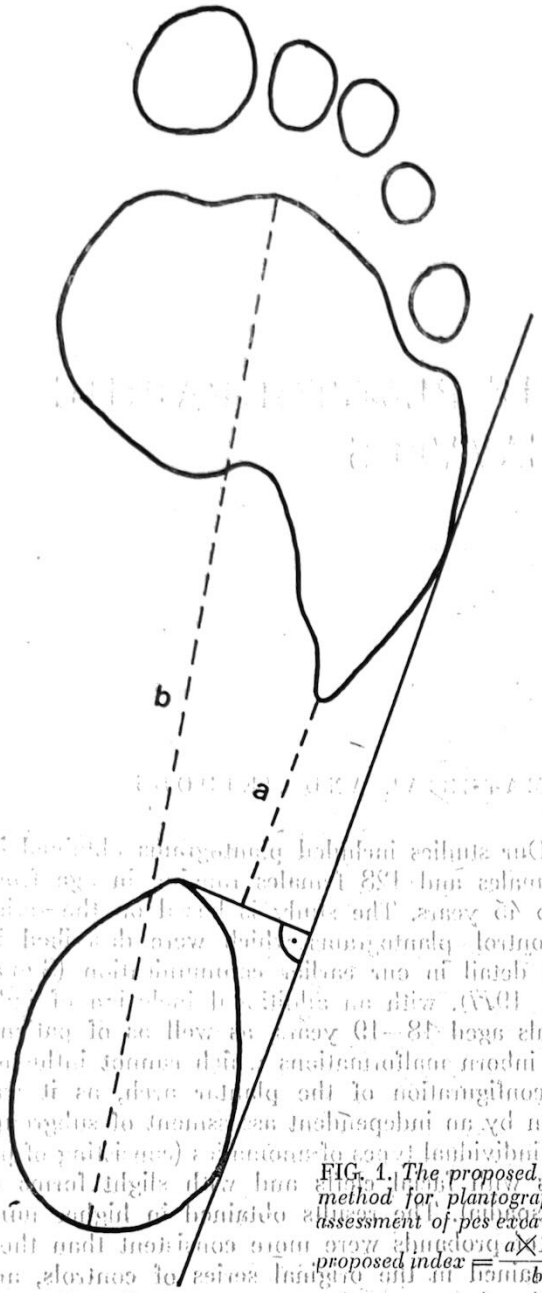

FIG. 1. *The proposed method for plantographic assessment of pes excavatus*

$$\text{proposed index} = \frac{a \times 100}{b}$$

for the assessment of the longitudinal arch (the methods were described e.g. in our earlier study). The data on the frequency rate were assessed and compared separately in males and females both on the right and left sides. The analysis of our material and the distribution of the values of the suggested index *(Fig. 1)* served as the basis for the classification of the deviation into three categories according to its morphologic extent. The results are presented in the following.

RESULTS AND DISCUSSION

The relative numbers of individual forms of pes excavatus occurring in our series are presented in *Tab. 1.* Worth mentioning are the almost identical data in both sexes. Bilateral or unilateral high longitudinal plantar arches were noted in 14—15 per cent of the individuals examined. One half had bilateral high arches and the second half unilateral types. The unilateral types showed an almost four times higher frequency on the left, than on the right. The simple addition of individual cases yielded a 9 per cent frequency rate on the right and a 13 per cent frequency rate on the left.

The Schwartz—Clarke's angle yielded high values *(Tab. 2)*, particularly in males (in females the calculated mean value for the left foot was significantly lower). The minimum values dropped in no case below the limit of 42° representing the boundary-value for a normal transverse arch. The correlation between the degree of pes excavatus, de-

TAB. 1. *Frequency of pes excavatus in our series and the comparison with the control series of Bavor (unpublished data).*

n	Men 147	Women 128	Bavor 55
Occurrence*)	21 (14.3 %)	19 (14.8 %)	6 (10.9 %)
Bilateral	11 (7.5 %)	10 (7.8 %)	1 (1.8 %)
Unilateral	10 (6.8 %)	9 (7.0 %)	5 (9.1 %)
dx	2	2	1
sin	8 (1 : 4)	7 (1 : 3.5)	4 (1 : 4)
Total dx	13 (8.8 %)	12 (9.4 %)	2 (3.6 %)
sin	19 (12.9 %)	17 (13.3 %)	5 (9.1 %)
dx + sin	32 (10.9 %)	29 (11.3 %)	7 (6.4 %)

*) *numbers of individuals with bilateral or unilateral pes excavatus*

TAB. 2. *Values of the Schwartz-Clarke's angle in pes excavatus*

	n	$\bar{X} \pm 3 \cdot s_{\bar{x}}$	s	min—max
Men right	13	54.58±3·1.74	6.28	42—66
left	19	54.74±3·1.18	5.14	44—64
Women right	12	51.67±3·1.38	4.76	45—59
left	17	*49.71±3·1.32	5.44	42—59

*) *significant as compared to men (sin), $t = 2{,}80$ ($p < 0.01$)*

TAB. 3. *Mean values of the proposed index for pes excavatus*

	n	$\bar{X} \pm 3 \cdot s_{\bar{x}}$	s	max
Men right	13	16.33±3·2.67	9.64	35.5
left	19	17.50±3·2.22	9.70	36.5
Women right	12	15.36±3·2.37	8.19	29.5
left	17	14.75±3·1.73	7.14	29.4

termined with the suggested index, and the angle is negligible (r = 0.134 i.e. insignificant, n = 61). This shows that the method devised by Schwartz and Clarke for the assessment of the transverse arch is not significantly influenced by the degree of pes excavatus and therefore is convenient for use in common cases (it cannot be used however, in a more marked pes excavatus with a depressed transverse arch where it does not provide an adequate determination of the situation).

Mean values of the proposed index for the assessment of the degree of pes excavatus on the basis of morphologic aspects *(Tab. 3)*, which conceivably need not correspond to the functional impairment vary around 15—17 index units (i.u.) and are only slightly higher in males than in females. Together with the ascertained maximum values they indicate the occurrence of more severe forms of this anomaly in males, but the difference is not statistically significant.

The classification of pes excavatus into subgroups according to the degree of its severity was based on the fact that it is characteristic for the quantitative features with a normal distribution (e.g. body height, IQ, as well as the plantar arch) exceeding a certain boundary value, and representing an anomaly, i.e. a qualitative change (microsomia → nanosomia; various degrees of oligophrenia, various degrees of pes excavatus), that there is a predominance of slight forms, while severe forms are less frequent. The same holds true for the functional impairment. The use of the classification devised by Klementa results in a contrary situation *(Tab. 5)*. We propose, therefore, a subdivision into categories which, on the basis of the results obtained in our series, is in close agreement with the above described observations. The boundary values of the suggested index for individual degrees of this anomaly are 15 and 25 i.u. *(Tab. 4)*. Figure 2 illustrates the distribution of the index; each column includes 5 index units (the first three columns represent a slight degree of this anomaly, the subsequent two a medium degree and the remaining columns a severe degree). It can be seen that there are only a few cases with an index up to 5 i.u. (lst column), while from the value of 20 i.u. onwards there is evidence of a decreasing frequency. Our series includes almost identical numbers of the slight and medium degree of this malformation, while severe anomalies were present in about 16 per cent of patients *(Tab. 4)*.

The distribution of unilateral and bilateral forms is in agreement with the above mentioned. The prevailing majority of the unilateral forms — about 63 per cent, is in the first category of a slightly higher longitudinal plantar arch (up to 15 i.u.), the remaining cases, but for one (i.e. 32 per cent), are in the medium category. Some of the slightest forms represent only a transitory state which disappears during fatigue or after protracted standing. The bilateral forms belong mostly into the medium category of 15—25 i.u. (about 43 per cent), while only 36 per cent are in the first category. The remaining 21 per cent enter into the third category which

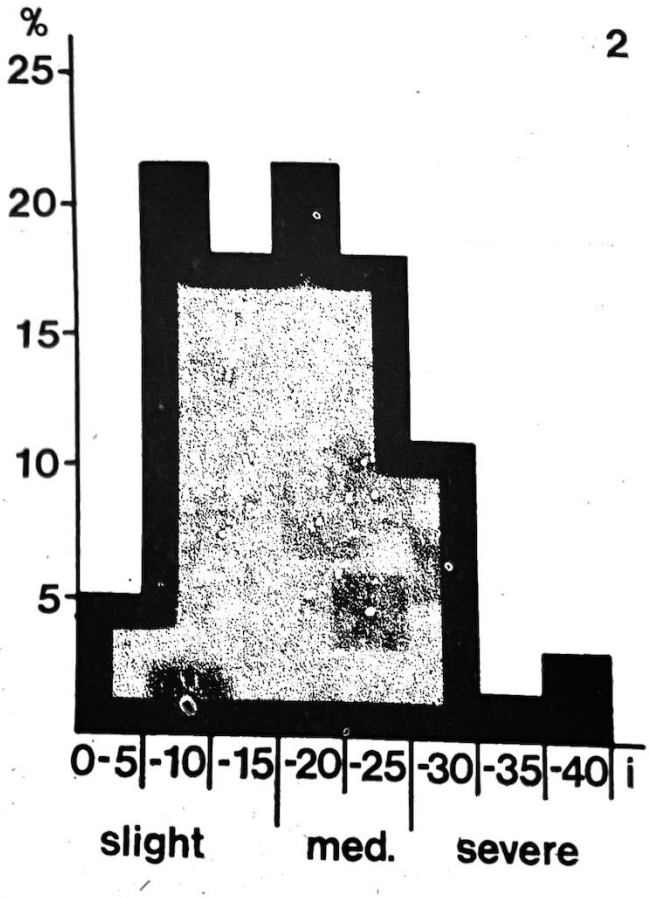

FIG. 2. *Distribution of the values of the proposed index for pes excavatus (a total of all plantograms i.e. n = 61). Individual columns include the range of 5 index units i.e. the 1st 0—5 i.u., the 2nd 5—10 i.u., the 3rd 10—15 i.u. etc.*

includes almost exclusively bilateral forms. When our patients with bilateral involvement are subdivided according to the more severly involved foot, only 20 per cent of individuals enter into the 1st category, and as many as 60 per cent into the 2nd category. Our first category includes approximately the first and the second category of Klementa's classification, since the mean length of the plantograms without toes in males is 214 mm and in females 193 mm (thus a gap measuring 3 cm will represent, on the average, 15 i.u. of the suggested index).

In unilateral form of pes excavatus (n = 19), the contralateral normal foot showed regularly normal longitudinal and transverse arches (mean values of the Chippaux—Šmiřák's index are 14.9 i.u. in males and 14.3 i.u. in females, of the Schwartz—Clarke's angle 48.6° in males and 48.2° in females).

The proposed index for the estimation of the degree of pes excavatus characterizes the morphological configuration of the plantar region and thus cannot provide information on the functional impairment associated with the anomaly in individual situations (similarly as in pes planus). However, an obvious correlation is actually present and if its objective assessment would be possible this procedure would provide an useful diagnostic aid.

TAB. 4. *Frequency of individual degrees of severity of pes excavatus according to the proposed classification*

	values of proposed index	Men				Women				Total	
		right		left		right		left			
		n	%	n	%	n	%	n	%	n	%
Slight	0—15	6	46.2	7	36.8	5	41.7	9	52.9	27	44.3
Moderate	15.1—25	5	38.5	8	42.1	5	41.7	6	35.3	24	39.3
Severe	25.1 →	2	15.4	4	21.0	2	16.7	2	11.8	10	16.4

TAB. 5. *Frequency of individual degrees of severity of pes excavatus according to Klementa's classification (1964)*

	Interrupted plantogram	Men				Women				Total	
		right		left		right		left			
		n	%	n	%	n	%	n	%	n	%
Slight	0—1.5 cm	3	23.1	3	15.8	2	16.7	4	23.5	12	19.7
Moderate	1.5—3 cm	2	15.4	4	21.1	3	25.0	5	29.4	14	22.9
Severe	3 cm →	8	61.5	12	63.2	7	58.3	8	47.1	35	57.4

In the first it would be necessary to determine the values of the index which are associated with an onset of clinical symptoms, as well as the rate of their occurrence in individual levels of index values. Therefore plantographic documentation is mandatory in each case of a high longitudinal plantar arch. The use of this index has the advantage that it allows objective follow-up studies of the development of pes excavatus in individual children and adolescents, with the exclusion of all changes which are due to the growth and to the resulting increase of the size of the foot (in the case of increasing index values early preventive measures should be instituted). Functional tests should be devised in a similar way, in particular tests of the influence of a weight-load resulting in individual types of the arch of the foot in differring responses (B a v o r, in press). Last and not least the proposed index will provide the possibility to carry out a statistical analysis, as well as a comparison of various series of pes excavatus, which so far was not possible. In the case when routine plantographic studies reveal the presence of pes excavatus the zero value should be included into the calculation of the mean and of the standard deviation; subsequently all individual cases of this anomaly should be assessed separately.

COMPARISON WITH THE DATA FROM THE LITERATURE

The reported data on the frequency of pes excavatus can be compared with those ascertained by B a v o r (unpublished data) in female university students *(Tab. 1)*. The findings are in good agreement in unilateral types both with respect to their frequency (9.1 per cent), as well as to the ratio of the involvement of the right and left side (1:4). Due to the small numbers of bilateral forms (1.8 per cent), all other values stated by the author are rather lower, especially those for the right foot. In the above mentioned series this deviation was present in 11 per cent of the probands; which is not substantially lower than our findings.

There are only a few additional reports about the frequency of pes excavatus in the Czech population and the reported data are always only values obtained by simple addition of the involved right and left feet. The lowest values were found by N o v o t n ý (1965), i.e. 1—2 per cent in non-sporting university students, and 2—4 per cent in sporting university students. K l e m e n t a (1964) reported the following frequency of a high longitudinal plantar arch in adolescents within individual age groups: male students 0—12.5 per cent on the left and 0—3,2 per cent on the right; female students 3.1—8.8 per cent on the left and 2.9—6.8 per cent on the right; male apprentices in motor car mechanics 0—5 per cent sin and 0—2.5 per cent dx; male apprentices in gardening 0—5.5 per cent on both sides and female apprentices 0—6.8 per cent sin and 0—10 per cent dx (all of them were teenagers ranging in age from 14 to twenty years). Thus it is evident that there is a complete lack of any norm which could represent the adult population as a whole, including various age groups and occupations.

Of interest are recent reports on the relatively high frequency of pes excavatus in children. K l e-

menta (1974) reported in boys ranging in age from 7 to 15 years a mean value 7.2 per cent for the left foot and 5.3 per cent for the right foot (with a maximum of 12.2 per cent on the left at the age of eleven years). Smetana and Vejvoda (1973) reported for the right foot the following results of their longitudinal study: at the age of 6 years boys 2 per cent and girls 0.4 per cent; at the age of 9 years boys 5.3 per cent and girls 4.1 per cent; at the age of 12 years boys 7.2 per cent and girls 7.6 per cent. Thus a frequency exceeding 10 per cent might be actually expected in adults. In our study these values were in both sexes 9 per cent for the right foot, and 13 per cent for the left foot. From the studies reported so far it follows, that while the difference between the two sexes is negligible, definite evidence was provided of the higher frequency of pes excavatus on the left (in a simple addition of values approximately by one third).

The need for a subdivision of pes excavatus according to the degree of this anomaly is obvious. Plantograms are convenient for this purpose. In addition to the above mentioned classification devised by Klementa (1964), also Smetana and Vejvoda (1973) included in their pattern consisting of te categories, two categories for high longitudinal plantar arch. The frequency rate of the slighter forms, was, on the average, four times higher. Our procedure represents a third type of approarch which in our opinion is the most objective method, even though in practical view it is more time consuming than the former procedure. It should be complemented by the determination of its correlation with the functional impairment.

SUMMARY

An estimation of the frequency rate of pes excavatus according to sex and to the involved side in the adult Czech population is presented and compared with the findings of other Czech authors. An index of the ratio of the length of the gap within the plantogram to its maximum length, measured without the toes, was suggested for the assessment of the degree of the anomaly. The advantages and the possible utilization of this method of assessment are discussed. On the base of a further more detailed analysis of ascertained values of the index a subdivision of pes excavatus into three categories was proposed. Conspicuously this morphologic classification does not necessarily correspond with the functional impairment and therefore should be supplemented by the determination of the mutual correlation. The correlation between the degree of pes excavatus and the Schwartz-Clarke's angle of the transverse plantar arch is not significant.

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