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FLATFOOT OR NOT: SUBJECTIVE PERCEPTION OF THE HEIGHT OF THE FEET ARCH AMONG ORTHOPEDISTS

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Background. The visual assessment of flatfoot is the most commonly used method by pediatric orthopedists. It is necessary to confirm good consistency among specialists to justify its use as a standard.
Aim. The aim of this study was to determine the consistency of visual assessment of flatfoot among orthopedists.
Materials and methods. The first stage of this study included 187 primary school-aged children. The main methods used were clinical examination and computer plantography. Then, 130 images of the right foot were randomly selected in standard projections — medial and posterior, which were provided to 32 orthopedists (ten of whom were experts). Specialists needed to note whether the foot presented for analysis was flat. We used the *w*-Kendall concordance coefficient and τ-Kendall correlation coefficient to determine the inter-rater reliability. After five months, the intra-rater reliability was determined, and the Cohen coefficient was calculated.
Results. Our study demonstrated that the inter-rater reliability varied significantly depending on whether the orthopedist specialized in foot pathology. When calculating the concordance coefficient, an increase in the consistency among experts was noted after five months (0.58 and 0.76, respectively), compared with orthopedists who do not specialize in foot pathology. Although some heterogeneity was noted according to experts on the same foot, the overall correlation coefficient corresponded to a good and excellent level of consistency (0.65–0.84). Cohen's coefficient among specialists corresponded to a good level of confidence (0.72), whereas among orthopedists who do not specialize in foot pathology, there was a low level of confidence (0.31). According to experts, the frequency of flatfoot was 24.6%, whereas according to orthopedists who do not specialize in foot pathology, it was 40.9% when they evaluated images of the same feet.
Conclusion. Experts' answers regarding which foot should be considered flat demonstrated a good and excellent level of consistency. Therefore, they can be used to determine reference values of anthropometric parameters of the medial foot arch.

Keywords: children; flatfoot; visual diagnostics; intra-rater reliability; inter-rater reliability; statistics.

ПЛОСКОСТОПИЕ ИЛИ НЕТ: СУБЪЕКТИВНОЕ ВОСПРИЯТИЕ ВЫСОТЫ СВОДА СТОП СРЕДИ ВРАЧЕЙ-ОРТОПЕДОВ

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Обоснование. Визуальный метод диагностики плоскостопия является наиболее распространенным в практике детских ортопедов. Для обоснования его использования в качестве стандартного необходимо подтвердить достаточную согласованность специалистов.
Цель — определить согласованность в восприятии высоты свода при визуальной диагностике плоскостопия у детей.

Материалы и методы. На первом этапе были обследованы 187 детей (374 стопы) младшего школьного возраста. Все дети были осмотрены и всем была выполнена компьютерная плантография. Для проведения второго этапа исследования случайным образом были отобраны 130 изображений правой стопы в стандартных проекциях — медиальной боковой и задней, которые были предоставлены в электронном виде 32 врачам-ортопедам (десять из которых составили эксперты — врачи, специализирующиеся на патологии стоп). Специалистам необходимо было отметить, является ли стопа, представленная для анализа, плоской. Для определения межэкспертной согласованности использовали коэффициенты конкордантности *w*-Кендалла и корреляции τ-Кендалла, а спустя 5 мес. рассчитывали коэффициент к-Коэна.

Результаты. Исходя из результатов нашего исследования, показатели межэкспертной и внутриэкспертной надежности значительно отличаются в зависимости от того, специализируется ортопед на патологии стоп или нет. При расчете коэффициента конкордантности степень согласованности среди экспертов увеличилась спустя 5 мес. (0,58 и 0,76 соответственно) в отличие от ортопедов, не специализирующихся на патологии стоп. Несмотря на то что во мнениях экспертов по одной и той же стопе была отмечена некоторая разнородность, общий коэффициент корреляции соответствовал хорошему и отличному уровню согласованности (0,65–0,84). Коэффициент к-Коэна для оценки параметров устойчивости визуальных критериев диагностики плоскостопия среди специалистов соответствовал хорошему уровню надежности (0,72), в то время как среди ортопедов, не специализирующихся на патологии стоп, — низкому (0,31). При оценке изображений одних и тех же стоп согласно экспертам частота плоскостопия составила 24,6 %, в то время как согласно ортопедам, не специализирующимся на патологии стоп, — 40,9 %.

Заключение. Ответы экспертов в отношении того, какую стопу считать плоской, продемонстрировали хороший и отличный уровни согласованности, что может быть использовано для определения референтных значений антропометрических показателей медиального продольного свода.

Ключевые слова: дети; плоскостопие; визуальная диагностика; внутриэкспертная надежность; межэкспертная согласованность; статистика.

According to the definition of the Great Medical Encyclopedia, flatfoot is "the foot deformity characterized by a decrease in its arches" [1]. Despite this conceivably simple definition, disagreements exist in describing this condition of the foot, although most specialists agree that flatfoot is essentially accompanied by a decrease in the height of the medial longitudinal arch. Studies reported that visual inspection is most often used, among numerous methods, for assessing the height of the foot arch in pediatric patients [2–4]. This assessment method is unfavorable mainly because of its subjectivity, since doctors define the foot as flat based on personal experience [5]. Significant variability also exists even when evaluating inter-rater reliability, that is, the opinions of different specialists regarding the same foot. Thus, Dahle et al. (1991) showed a good agreement between visual assessment of the arch height (κ-Cohen coefficient 0.72), while Cowan et al. found low agreement (τ-Kendall 0.35) [6, 7]. Redmond et al. (2006) analyzed the main parameters of the visual assessment of the foot shape and position, as presented in the literature, and identified six of them with the highest inter-rater and intra-rater reliability. Thus, the foot posture Index-6 scale was developed to assess the foot shape and position [8–11]. However, this rating scale has low inter-rater reliability with respect to individual evaluation parameters [12, 13].

Thus, to use confidently the method of visually assessing the foot arch height for the clinical diagnosis of a flatfoot, the level of consistency among specialists should be determined, which makes the present study relevant. In the future, results herein will enable the development of common criteria for visual assessment of the foot arch height.

This study aimed to determine the consistency among orthopedists of the assessment of the arch height in the visual diagnosis of flatfoot in pediatric patients.

Materials and methods

This study was carried out in stages. In stage 1, a preventive examination was conducted in one of the schools of 187 pediatric patients of primary school age (7–11 years). The examination protocol was performed in accordance with the principles of the Helsinki Declaration of Human Rights, and written consent was obtained from the parents or guardians.

To obtain images in standard views, 374 feet were scanned using the DiasledScan instrument and hardware system with the Plantoscan module (DiaService, Russia). The inclusion criteria were as follows: age 7–11 years and absence of orthopedic or neurological pathology, except flatfoot.

In stage 2, the consistency of visual diagnosis of flatfoot was analyzed. For this purpose, 130 images of the right foot in standard views were randomly selected, namely, the medial lateral and posterior views (by which the visual assessment was made),

from each age group (aged 7, 8, 9, 10, and 11 years) in equal numbers (26 images each). Electronic images were presented to 32 orthopedic surgeons (10 of which were medical experts). We considered specialists as orthopedists who have been engaged mainly in foot pathology for more than 5 years. Specialists had to note the preferred response on whether the foot was flat or not. For further statistical analysis, numerical coding of the responses of specialists was performed as follows: 1, "Yes, it is"; 2, "No, it is not"; 3, "I doubt it." To determine the inter-rater consistency, the criteria for nonparametric statistics were used for κ-linked samples with the calculation of the w-Kendall concordance coefficients and the τ-Kendall correlation coefficient. To determine intra-rater consistency, after 5 months, the same specialists received the same images of the feet for analysis (in different order). The repeated assessment involved 20 doctors, including nine specialists. Statistical analysis was performed by calculating the κ-Cohen coefficient. Figure 1 presents an example of an assessment protocol.

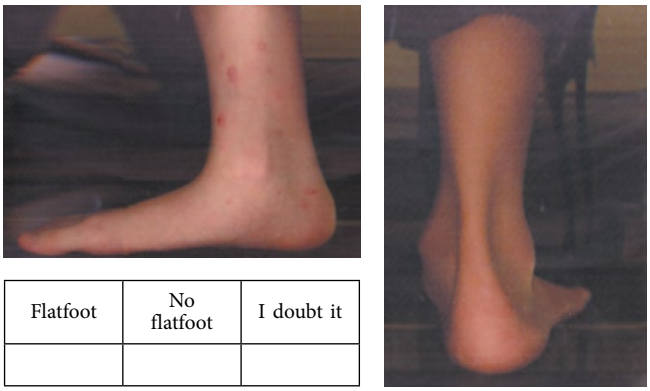

Fig. 1. Protocol for evaluating images of the feet

Results

First, we determined the inter-rater consistency, that is, how much the opinion of one specialist coincides with the opinion of another specialist with respect to the same foot. Thus, we calculated the initial *w*-Kendall concordance coefficient and the concordance coefficient after 5 months. In addition, we calculated the τ-Kendall coefficient to determine the degree of correlation between the responses of specialists. This parameter was also determined during the initial assessment of the images of the feet and after 5 months. Table 1 presents the results of this assessment.

As shown in the table, with regard to visual assessment of flatfoot in pediatric patients, the overall consistency among orthopedists was 0.33 ($p < 0.0001$), 0.27 among non-specialists in foot pathology, and 0.58 among specialists ($p < 0.001$). After 5 months, the value of the total consistency coefficient was 0.452, and the greatest increase in the degree of consistency was noted among specialists, at 0.76 (while the maximum coefficient of consistency was 1).

The τ-Kendall correlation coefficient ranged from 0.28 ($p = 0.015$) to 0.63 ($p < 0.0001$) for non-specialists in foot pathology and from 0.64 ($p = 0.0034$) to 0.89 ($p = 0.0022$) for specialists. The correlation coefficient demonstrates that the degree the responses of two specialists coincide with respect to the same series of estimates (in this case, with respect to the presence or absence of flatfoot). Thus, among specialists, the concordance coefficient (characterizing the consistency) was 0.58, while the correlation coefficient was 0.64–0.89. This implies that, despite the heterogeneity in the opinions of specialists on the same foot, they did not have diametrically opposite responses. For example, with respect to the same foot, there were variants 1 and 3 or 2 and 3, that is, "Yes, flatfoot"/"Doubt" or "No, no flatfoot"/"Doubt," but the variants "Yes, flatfoot"/"No, no flatfoot" with respect to the same foot were extremely rare, unlike the assessments of

Table 1

Dynamics of the *w*-Kendall concordance coefficient and τ-Kendall correlation coefficient among specialists and non-specialists in foot pathology

Coefficients	Total coefficient		Specialists		Non-specialists in foot pathology	
	0 month	5 months	0 month	5 months	0 month	5 months
w-Kendall	0.333 ($p < 0.0001$)	0.452 ($p < 0.0001$)	0.58 ($p = 0.0035$)	0.76 ($p < 0.0001$)	0.27 ($p = 0.0042$)	0.29 ($p = 0.003$)
τ-Kendall	0.39–0.68*	0.28–0.7*	0.64–0.89*	0.65–0.84*	0.28–0.63*	0.21–0.67*

Note. 0 month, concordance coefficient calculated at the initial assessment; 5 months, concordance coefficient determined after 5 months. * $p < 0.05$.

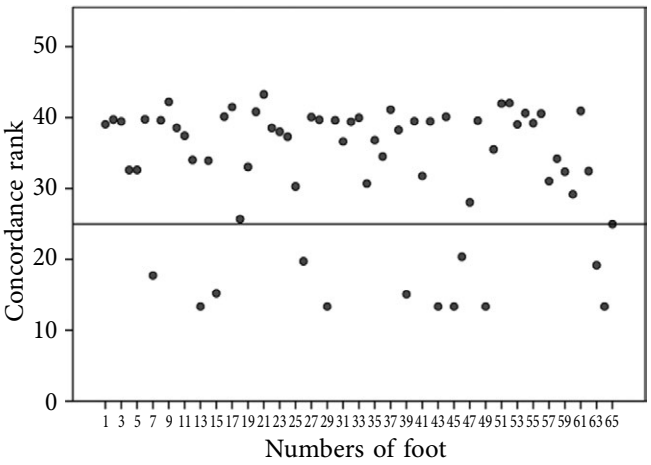

Fig. 2. Consistency among specialists regarding the feet images according to the rank distribution

non-specialists in foot pathology, which affected the degree of correlation. At the same time, the correlation coefficient did not significantly change at 5 months among specialists and decreased among non-specialists in foot pathology, that is, the opinion of specialists was more stable over time.

As an example, a scatter diagram illustrates the consistency of the foot arch height as defined by the specialists according to the rank distribution, and Fig. 2 presents that the images of feet under the numbers located below the conditional line are characterized by the highest consistency. Thus, the lower the rank value, the higher the consistency of specialists.

To calculate intra-rater reliability, we calculated the κ-Cohen coefficient for 20 doctors, which indicate the percentage ratio of possible answers and the degree of consistency of the specialists' answers with the initial data some time later. The total κ-Cohen coefficient among specialists showed a good level of intra-rater reliability (0.72; $p = 0.0021$), while among non-specialists in foot pathology, this coefficient corresponded to a low level of intra-rater reliability (0.31; $p = 0.0017$). Thus, the responses of the specialists in the visual diagnosis of flatfoot were stable over time.

To demonstrate clearly the differences in the subjective perception of the foot arch height among specialists and non-specialists in foot pathology, Fig. 3 presents a bar diagram of the percentage of possible responses; thus, as the data show, the frequency of flatfoot according to the responses of specialists on the analyzed images of the feet was 24.6% on average, while it was 40.9% (1.7 times higher) among non-specialists in foot pathology. In this case, in the repeated analysis after 5 months, the frequency of flatfoot was 24.3 and 33.8%, respectively. Thus, the responses of the specialists were stable over time. The same tendency was noted with respect to the feet with medium and high arches. That is, specialists reported that 61.9% (initial) and 63.4% (repeated) of the feet had medium and high arches, while non-specialists in foot pathology presented 41.7% (initial) and 54.7% (repeated) for this indicator. Moreover, the share of the "doubt" responses did not significantly differ between the two groups of orthopedists (Fig. 3).

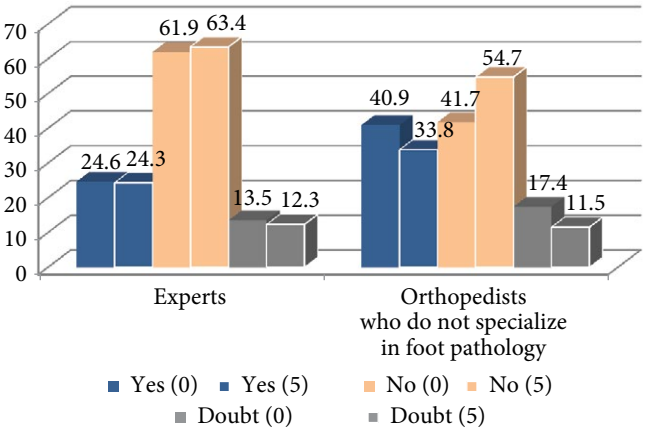

Fig. 3. Frequency of various responses of specialists regarding the analyzed images of the feet over time. Note: yes (0), "Yes, flatfoot" at the initial analysis of the images of the feet; yes (5), "Yes, flatfoot" at the repeated analysis of images of the feet after 5 months; no (0), "No, no flatfoot" at the initial analysis of the images of the feet; no (5), "No, no flatfoot" at the repeated analysis of images of the feet after 5 months; doubt (0), "I doubt" at the initial analysis of the images of the feet; doubt (5), "I doubt" at the repeated analysis of the images of the feet after 5 months

Discussion

The visual method of assessing the foot arch height is most often used in the clinical diagnosis of flatfoot. However, the subjectivity of this assessment provokes reasonable doubts as to the relevance of establishing a clinical diagnosis of flatfoot based on the visual assessment, since the degree of consistency among specialists regarding which foot is considered flat remains unknown.

Thus, Cowan et al. analyzed the consistency of six specialists (four orthopedic doctors and two podiatrists) in classifying the feet using photographs in standard views according to the five categories: category 1, absolutely flat feet; category 3, feet with medium height of the arch; category 5, feet with a distinctly high arch; categories 2 and 4, intermediate height. The authors demonstrated a low degree

of consistency among specialists (the τ-Kendall coefficient varied from 0.22 to 0.48) [7].

On the contrary, Dahle et al. analyzed the inter-rater consistency among specialists during the clinical examination. The study involved three physical therapists who, during the examination of 77 athletes, were asked to determine the position of their feet as pronation, neutral, or supination. Moreover, the authors showed good inter-rater reliability (κ-Cohen 0.72) [6].

The above studies are the main sources of information cited in subsequent publications on the reliability of visual diagnosis of flatfoot, despite the small number of specialists involved in the works presented and the diametrically opposite data.

According to the present study, the indices of inter-rater and intra-rater reliability can differ significantly depending on whether the orthopedist specializes in foot pathology (we considered this specialization to be an expert level of assessment). Thus, for example, when calculating the concordance coefficient, the increase in the degree of consistency among specialists after 5 months was noted (0.58 and 0.76, respectively), unlike non-specialists in foot pathology. Despite the heterogeneity in the opinions of experts on the same foot, the overall correlation coefficient corresponded to a good and excellent level of consistency (0.65–0.84). Cohen defined reliability level as follows: <0.2, insignificant reliability; 0.21–0.4, satisfactory; 0.41–0.6, moderate reliability; 0.61–0.8, good reliability; >0.81, excellent reliability [14]. The κ-Cohen coefficient for the assessment of the stability parameters of the visual criteria for diagnosing flatfoot among specialists corresponded to a good level of reliability (0.72), while it was satisfactory among non-specialists in foot pathology (0.31).

When specialists in foot pathology evaluated images of the same feet, the frequency of flatfoot was 24.6%. This indicator did not significantly change after 5 months. Meanwhile, according to non-specialists in foot pathology, the frequency of flatfoot was 40.9% and 33.8% in the initial and repeated assessments, respectively.

Conclusion

Most orthopedic surgeons use visual assessment in routine practice to establish the diagnosis of flatfoot. Obviously, the method of visual assessment of the foot arch height is characterized by a certain degree of subjectivity. In particular, different doctors may have varying opinions about the same foot. In this regard, we analyzed the inter-rater consistency regarding which feet are considered flat by doctors. In addition, the stability of the responses of the specialists participating in the survey over time, the so-called intra-rater reliability, was determined.

Our data show that the overall consistency among orthopedists in terms of the *w*-Kendall coefficient corresponds to the low level (0.333, $p < 0.0001$). However, we found that the magnitude of consistency depended on the specialization of the orthopedic surgeon. Thus, low consistency was noted among non-specialists in foot pathology (0.27), while there was good consistency among specialists in terms of visual perception of the foot arch height in pediatric patients (0.58). Moreover, the correlation coefficient among the answers of specialists was also high (0.64–0.89; $p = 0.0034$ and 0.0022, respectively). When assessing intra-rater reliability, the parameters of stability of responses in relation to visual diagnosis of the foot arch height showed a good level among specialists over time (the coefficient value of intra-rater reliability among specialists was 2.3 times higher than non-specialists in foot pathology).

As our data presented, this study is the most extensive study on the present problem in modern scientific literature, considering the number of doctors interviewed (32 doctors in stage 1 and 20 doctors in stage 2). Given that the inter-rater and intra-rater reliability values of the responses of the specialists regarding what foot should be considered flat showed good and excellent levels of consistency, this principle can be used to determine the reference values of the anthropometric indicators of the medial longitudinal arch. Thus, this finding provides useful information on how to apply more confidently the visual assessment method for clinical diagnosis of flatfoot.

Additional information

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Legal representatives of patients voluntarily agreed to participate in the study and publish the data.

Author contributions

V.M. Kenis exercised leadership, participated in the development of design and methodology of the study, and edited the manuscript.

A.Yu. Dimitrieva collected and processed the data, analyzed the literary sources, and wrote the manuscript.

A.V. Sapogovsky edited the manuscript.

All authors made a significant contribution to the research and preparation of the article and read and approved the final version before its publication.

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