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Original Study Article

Results of foot assessment in healthy preschool children: visual assessment, FPI-6, dorsiflexion: A population study

Alena Yu. Dimitrieva

H. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery, Saint Petersburg, Russia

ABSTRACT

BACKGROUND: The reason for conducting this study was the lack of Russian literature on the relationship between visual foot assessment using the foot posture index (FPI)-6 and foot dorsiflexion in preschool children.

AIM: The aim was to evaluate the relationship between visual foot assessment, FPI-6, and dorsiflexion in healthy preschool children.

MATERIALS AND METHODS: The study included 81 children aged 5–7 years (162 feet). All children were examined through visual foot assessment, FPI-6, assessment of passive dorsiflexion, Beighton hypermobility score, and anthropometric measurements (height/weight). Dorsiflexion was assessed with posterior-segment stabilization and the knee joint in flexion and extension. The Kolmogorov–Smirnov test was used to assess the normality of data distribution, followed by the use of parametric and nonparametric statistical tests. The analysis of variance (ANOVA) was used to compare the means of three groups. Pearson's test was used to assess correlations.

RESULTS: Flatfoot was diagnosed in 41.0% of children. There were 2 times more boys than girls in the group with flatfoot and 1.5 times more girls in the group without flatfoot. The FPI-6 scores of the same feet were at least 8 in children with flatfoot and 0–4 in children without flatfoot. Moderate-to-medium correlations were found between the clinical diagnosis of flatfoot and FPI-6 scores. In 95% of the children aged 5–7 years, dorsiflexion with the knee joint in extension was 11.4°–34.2°. Mean dorsiflexion difference between flexed and extended knees was 24.1° ± 9.5°. ANOVA showed no significant difference in dorsiflexion between children with and without flatfoot.

CONCLUSIONS: The mean dorsiflexion angle in preschool children was 22.8° ± 5.7°. No significant difference in dorsiflexion was demonstrated between children with and without flatfoot. Gastrocnemius muscle retraction was evaluated quantitatively.

Keywords: children; flatfoot; visual assessment; FPI-6; dorsiflexion; gastrocnemius muscle retraction.

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Оригинальное исследование

Результаты оценки стоп здоровых детей дошкольного возраста: визуальная оценка, шкала FPI-6, величина тыльной флексии (популяционное исследование)

А.Ю. Димитриева

Национальный медицинский исследовательский центр детской травматологии и ортопедии имени Г.И. Турнера, Санкт-Петербург, Россия

АННОТАЦИЯ

Обоснование. Отсутствие в российской литературе данных о взаимосвязи визуальной оценки стоп с параметрами по шкале FPI-6 и величиной тыльной флексии у детей дошкольного возраста послужило инициирующим фактором для проведения данного исследования.

Цель — оценить взаимосвязь между визуальной оценкой стоп, параметрами по шкале FPI-6 и тыльной флексией стоп у здоровых детей дошкольного возраста.

Материалы и методы. Изучены результаты исследования 81 ребенка 5–7 лет (162 стопы). Всем детям произведена визуальная оценка стоп, оценка стоп по шкале FPI-6, оценка пассивной тыльной флексии, проанализированы величина гипермобильности по шкале Бейтона, антропометрические показатели (рост/вес). Тыльную флексию оценивали при стабилизации заднего отдела с согнутым и разогнутым коленным суставом. Для определения нормальности распределения данных использовали критерий Колмогорова – Смирнова, далее — критерии параметрической и непараметрической статистики. Средние значения трех групп сравнивали с помощью дисперсионного анализа ANOVA. Для оценки корреляционных связей применяли критерий Пирсона.

Результаты. Плоскостопие диагностировано у 41,0 % детей, в группе детей с плоскостопием мальчиков было в 2 раза больше, чем девочек, а в группе детей без плоскостопия — в 1,5 раза больше девочек. При оценке одних и тех же стоп по шкале FPI-6 показатели детей с плоскостопием составили 8 баллов и более, детей без плоскостопия — от 0 до 4 баллов. Выявлены корреляционные связи умеренной и средней силы между клиническим диагнозом «плоскостопие» и параметрами по шкале FPI-6. Для 95 % детей 5–7 лет тыльная флексия с разогнутым коленным суставом составила 11,4–34,2°. Средняя разница в величине тыльной флексии с согнутым и разогнутым коленным суставом равнялась 24,1 ± 9,5°. При помощи дисперсионного анализа было выявлено, что дети с плоскостопием и без него достоверно не отличаются по величине тыльной флексии.

Заключение. Средняя величина тыльной флексии у детей дошкольного возраста составила 22,8 ± 5,7°. Продемонстрировано отсутствие достоверной разницы в отношении величины тыльной флексии у детей с плоскостопием и без него. Количественно проанализирован такой параметр, как ретракция икроножной мышцы.

Ключевые слова: дети; плоскостопие; визуальная оценка; шкала FPI-6; тыльная флексия; ретракция икроножной мышцы.

Как цитировать

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BACKGROUND

During pediatric orthopedic consultations, flatfoot is among the most common complaints. However, in Russia, no high-quality population studies have examined the prevalence of flatfoot and the degree of dorsiflexion in children of different ages. Available epidemiological data on flatfoot, predominantly from international sources, demonstrate prevalence rates widely ranging from 0.6% to 77.9% [1, 2]. This variability can be attributed, among other things, to the significant differences in prevalence across age groups. For example, studies have shown that the prevalence of flatfoot ranges from 64.8% to 77.9% among children aged 3–7 years, whereas in children aged >7 years, the prevalence decreases to 0.6%–20% [1, 2]. According to some Russian authors, the prevalence of flatfoot among preschool and early school-age children varies between 24.2% and 67.3% [3, 4].

Researchers often rely on visual assessment when selecting participants for groups with or without flatfoot. However, this diagnostic method is significantly limited by its subjectivity [5, 6]. During outpatient consultations for foot pathology, orthopedic surgeons primarily diagnose flatfoot based on visual assessment, relying on subjective experience and qualitative evaluation, typically expressed in dichotomous terms such as, "Yes, this is clearly flatfoot" or "No, this is clearly not flatfoot." However, which specific criteria allow physicians to make these definitive judgments remains unclear. In addition, clinical practice often presents situations where such judgments are ambiguous. In these cases, a physician may encounter a situation when one evaluation method is uncertain (e.g., visual) and additional diagnostic methods (such as plantography, podometry, or radiography) may be required to more confidently determine the presence or absence of flatfoot. This raises questions regarding the practicality and resource demands of using these methods routinely, particularly during screening and preventive examinations.

In 2023, researchers conducted the first and only Delphi consensus in Russia on the diagnosis and treatment of flatfoot in children [7]. Most experts agreed that visual assessment is often used for diagnosing flatfoot in children. They also concurred that plantography and podometry are not considered routine diagnostic methods and that radiography should only be employed in symptomatic cases or when planning surgical treatment. The data also indicated that the foot posture index-6 (FPI-6) scale, which demonstrated excellent inter-expert agreement, is reliable for foot shape assessment in scientific research [8]. In addition, the Delphi consensus emphasized the importance of assessing foot mobility—particularly dorsiflexion—as a key indicator of mobility [7]. Despite the limited studies on triceps surae muscle retraction in healthy children, global data on the prevalence of mobile and rigid forms of flatfoot among children of different ages are limited [9]. Moreover, most Russian studies on the prevalence of flatfoot were conducted over 15 years ago.

Thus, the need for applying additional clinical diagnostic methods for flatfoot, particularly during preventive and screening examinations, can be addressed by supplementing visual assessment with parameters such as the FPI-6 scale and dorsiflexion measurements, specifically in ambiguous cases. The absence of such literature data provided the impetus for conducting this study.

This **study aimed** to evaluate the correlation between visual assessment of the feet, FPI-6 scale parameters, and dorsiflexion in healthy preschool-aged children.

MATERIALS AND METHODS

This study was conducted in accordance with the principles of the Declaration of Helsinki on Human Rights. Written consent was obtained from parents or guardians for their children's participation during a preventive medical examination conducted at the preschool department of a gymnasium in Saint Petersburg.

Children with neurological or orthopedic diagnoses other than flatfoot were excluded.

Fig. 1. Assessment of foot dorsiflexion (Silfverskiold test)

The study included 81 children aged 5–7 years (44 boys and 37 girls), corresponding to a total of 162 feet. All children underwent visual foot assessment, with the children standing barefoot in a relaxed posture and their feet parallel to each other and spaced shoulder-width apart. Visual assessment was qualitative and children were categorized into one of three groups. Group 1 included children with an unequivocal diagnosis of flatfoot based on visual assessment, group 2 was composed of children without flatfoot, and group 3 included children with an uncertain diagnosis of flatfoot. Moreover, the following assessments were performed: FPI-6 (evaluation of foot structure and alignment), manual foot mobility assessment (including passive foot dorsiflexion), hypermobility assessment by the Beighton scale, and anthropometric measurements (height and weight).

Right and left foot dorsiflexion was assessed using the Silfverskiold test, which involved rear-foot stabilization. Dorsiflexion was measured in both the bent and extended knee positions (Fig. 1).

Data were analyzed using the SPSS software. The Kolmogorov–Smirnov test (applied to a sample size >50 participants) was performed to assess data normality. Depending on the data distribution, both parametric and nonparametric statistical tests were used. The analysis of variance (ANOVA) was performed to compare the mean values across the three groups and Pearson's correlation test was performed to evaluate the relationships between the variables.

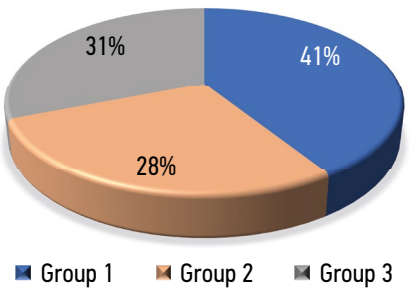

Fig. 2. Distribution of preschool-aged children by group based on visual assessment

RESULTS

The Kolmogorov–Smirnov test was performed to evaluate the normality of the data distribution because the sample included >50 participants.

Parameters such as height, weight, and joint hypermobility (measured using the Beighton scale) did not follow a normal distribution. The median values were as follows: height, 118 cm in boys and 112 cm in girls; body weight, 20.75 kg in boys and 19.0 kg in girls; joint mobility (Beighton scale), 2 points in boys and 3 points in girls.

The distribution of children based on the visual assessment of their feet is shown as a pie chart, illustrating the percentage composition of the three groups (Fig. 2).

According to the visual foot assessment, 33 children (22 boys and 11 girls; 41.0%) were diagnosed with flatfoot, whereas 25 children (13 boys and 12 girls; 31.0%) had an uncertain diagnosis. Notably, the number of boys with flatfoot was twice that of girls. Conversely, in the group without flatfoot, the number of girls was 1.5 times higher than that of boys. In those with an uncertain diagnosis, the sex ratio was relatively balanced.

Foot assessment using the FPI-6 scale yielded the following scores: group with flatfoot (group 1), ⩾8 points; group without flatfoot (group 2), 0–4 points; group with uncertain diagnosis (group 3), 5–7 points. These findings demonstrate a clear correlation between the total score on the FPI-6 scale and the presence or absence of flatfoot, as determined by visual assessment.

To determine the potential for optimizing the flatfoot diagnosis and improving the FPI-6 scale, a correlation analysis was performed. The relationship between the presence of flatfoot (based on visual assessment) and FPI-6 parameters was examined. The Pearson correlation coefficient was calculated and the results are presented in Table 1.

Table 1 highlights the multiple correlations between the clinical diagnosis of "flatfoot," established through visual assessment, and FPI-6 scale parameters. Notably,

Table 1. Correlation between the visual flatfoot diagnosis and FPI-6 scale parameters

Parameter	Flatfoot	TH	TNJ	CLM	CA	LAH	FF
Flatfoot	1	–0.532**	–0.231*	–0.277*	–0.414**	–0.634**	–0.125
TH	–0.532**	1	0.483**	0.586**	0.543**	0.442**	0.276*
TNJ	–0.231*	0.483**	1	0.290*	0.445**	0.350**	0.171
CLM	–0.277*	0.586**	0.290*	1	0.573**	0.217	–0.051
CA	–0.414**	0.543**	0.445**	0.573**	1	0.407**	0.248*
LAH	–0.634**	0.442**	0.350**	0.217	0.407**	1	0.218
FF	–0.125	0.276*	0.171	–0.051	0.248*	0.218	1

Note: ** Correlation is significant at the 0.01 level (two-tailed). * Correlation is significant at the 0.05 level (two-tailed). TH, talar head; TNJ, talonavicular joint; CLM, contours of the lateral malleolus; CA, calcaneal axis; LAH, longitudinal arch height; FF, forefoot. The term "flatfoot" is coded as follows: 1, children with flatfoot; 2, children without flatfoot; and 3, children with uncertain diagnosis.

Table 2. Parameters of dorsiflexion in preschool-aged children

Parameter	DFR	DFR KNEE	DFL	DFL KNEE
M	22.8	48.6	25.2	48.5
σ	5.7	6.8	7.3	8.2

Note. DFR (dorsiflexion right), dorsiflexion of the right foot; DFL (dorsiflexion left), dorsiflexion of the left foot; DFR KNEE, dorsiflexion of the right foot with a bent knee; DFL KNEE, dorsiflexion of the left foot with a bent knee; M, mean value; σ, standard deviation.

Table 3. Ranges of dorsiflexion angles in preschool-aged children across the three groups

Dorsiflexion angle (°)	Group 1	Group 2	Group 3
<10	0	0	0
10–15	1	1	4
16–20	6	7	6
21–25	9	4	4
26–30	9	2	5
>30	8	9	6

Note. Group 1, children with flatfoot; group 2, children without flatfoot; group 3, children with uncertain diagnosis of flatfoot.

moderate-to-strong negative correlations were observed between the diagnosis of "flatfoot" and FPI-6 parameters such as palpation of the talar head, calcaneal axis alignment, and longitudinal arch height. This finding indicates that as the flatfoot severity increases, these FPI-6 parameters recorded higher scores. However, the results for the parameter "position of the forefoot" were not significant, indicating the need for its review or refinement for future use.

In this study, the dorsiflexion angles of preschool children followed a normal distribution ($p > 0.05$). Consequently, the mean values and standard deviations were calculated. The dorsiflexion range for healthy preschool-aged children is summarized in Table 2.

As shown in Table 2, 95% of children aged 5–7 years demonstrated dorsiflexion angle with the knee extended within the range of 11.4°–34.2°.

The degree of gastrocnemius muscle retraction was evaluated by calculating the quantitative difference in dorsiflexion with the knee flexed and extended. The average difference was 24.1° ± 9.5° for the right foot and 23.1° ± 11.8° for the left foot.

No significant differences were observed in the dorsiflexion angles between the right and left feet.

During the clinical examination, none of the children exhibited dorsiflexion angles <10° with the knee extended.

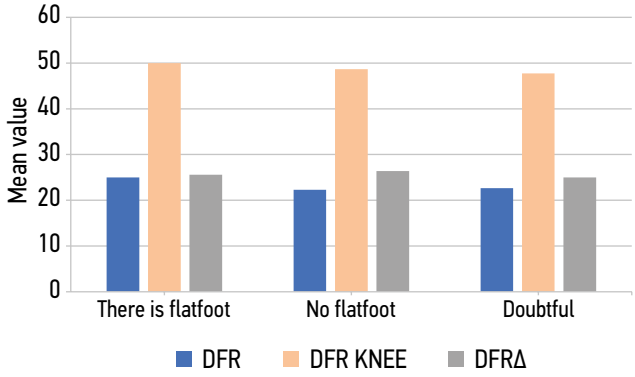

Fig. 3. Mean dorsiflexion angles of the feet across the three groups of children. Refer to Table 4 notes for parameter details

However, in the same cohort, 25 children displayed dorsiflexion angles <20° (Table 3).

To investigate the significant differences or their absence in dorsiflexion among the three groups of children, an ANOVA was performed. Levene's test for homogeneity of variance yielded a value >0.05, confirming the appropriateness of the ANOVA.

The mean dorsiflexion angles for the three groups are visually represented as a bar chart (Fig. 3).

The bar chart illustrates nearly identical mean dorsiflexion angles among the three groups, particularly for DFRΔ (magnitude of gastrocnemius muscle retraction).

Table 4. Comparative analysis of mean dorsiflexion angles across the three groups of children

	DFR	DFR KNEE	DFL	DFL KNEE	DFRΔ	DFLΔ
p	0.642	0.277	0.296	0.531	0.495	0.095

Note. DFR (dorsiflexion right), dorsiflexion of the right foot; DFL (dorsiflexion left), dorsiflexion of the left foot; DFR KNEE, dorsiflexion of the right foot with a flexed knee; DFL KNEE, dorsiflexion of the left foot with a flexed knee; DFRΔ, arithmetic difference in dorsiflexion between the flexed and extended knees for the right foot; DFLΔ, arithmetic difference in dorsiflexion between the flexed and extended knees for the left foot; *p*, significance level.

To statistically compare the mean dorsiflexion angles among the three groups, a one-way ANOVA was conducted (Table 4).

As shown in Table 4, $p > 0.05$ represents the lack of significant differences in the dorsiflexion angles between the groups categorized as "with flatfoot," "uncertain," and "without flatfoot."

DISCUSSION

A key unresolved issue in pediatric orthopedics is establishing the clear diagnostic criteria for flatfoot: what should be considered flatfoot and which parameters should be prioritized in its assessment [10].

Visual foot assessment is the most readily available and frequently utilized technique in clinical practice [11]. Because the degree of flattening of the longitudinal arch is not always a decisive factor in determining the need for treatment, the use of visual assessment in routine practice is acceptable.

However, scientific studies and monitoring treatment outcomes require the use of a more objective diagnostic method. The Delphi consensus on flatfoot diagnosis and treatment in children recommends limiting the use of radiographic diagnosis because of the associated radiation exposure. Instead, radiographs should be reserved for cases with clear indications, such as pain or restricted foot mobility. Notably, 94% of the experts involved in the consensus proposed utilizing the FPI-6 scale as a quantitative tool for assessing the external foot parameters [7].

In this study, a total FPI-6 score of ⩾8 corresponded to the clinical diagnosis of "flatfoot," which aligns with findings in both the Russian and international literature. The correlation analysis revealed moderate-to-strong associations between visual assessment and specific FPI-6 parameters, particularly those related to the palpation of the talar head, calcaneal axis, and longitudinal arch height.

These findings indicate that the FPI-6 scale significantly enhances clinical diagnostic capabilities in children, particularly in cases where standard visual diagnosis is inconclusive. Furthermore, the FPI-6 parameters identified based on the obtained data, which indicated the highest correlation with the presence or absence of flatfoot, could provide a foundation for refining clinical diagnostic protocols for this condition.

Our findings also indicate that flatfoot is twice as prevalent in boys as in girls. Some researchers suggest that the medial longitudinal arch forms and stabilizes earlier in girls than in boys, which may explain this difference [12].

In this study, the dorsiflexion angles based on the presence or absence of flatfoot were not significantly different; thus, evaluating foot mobility, including dorsiflexion angles, remains a critical aspect of flatfoot diagnosis, particularly its symptomatic forms.

The Silfverskiold test is widely performed to assess gastrocnemius muscle shortening. If the dorsiflexion angle with an extended knee is <10° but >10° with a flexed knee, isolated gastrocnemius muscle shortening can be diagnosed [13]. Proper foot roll during the gait cycle requires a dorsiflexion angle of at least 10°; however, a study suggested higher thresholds, ranging from 12° to 22° [14]. Moreover, dorsiflexion data in children of different ages are sparse and inconsistent. Despite isolated reports on dorsiflexion in school-aged children with flatfoot, no comprehensive data are available on this disorder in preschool-aged children without comorbidities, including flatfoot.

This study provides baseline dorsiflexion angles for preschool-aged children without neurological or orthopedic pathology other than flatfoot. The mean dorsiflexion angles were 22.8° ± 5.7° (right foot) and 25.2° ± 7.3° (left foot) with the knee extended and 48.6° ± 6.8° (right foot) and 48.5° ± 8.2° (left foot) with the knee flexed. The mean differences in the dorsiflexion angles between the flexed and extended knees were 24.1° ± 9.5° for the right foot and 23.1° ± 11.8° for the left foot. No significant differences were observed between the right and left feet. Therefore, future research may consider evaluating dorsiflexion in only one foot.

Valgus foot deformity may represent a compensatory position in cases of gastrocnemius muscle retraction. However, the variance analysis of dorsiflexion across the three groups revealed no significant differences [9, 15]. Thus, flattening of the longitudinal arch alone is unlikely a predictor of potential gastrocnemius muscle shortening as children age.

CONCLUSION

Visual assessment is the most commonly used method for diagnosing flatfoot in children, particularly during preventive and screening examinations. However, in cases of diagnostic uncertainty, additional methods, such as the FPI-6 scale and dorsiflexion angle measurement, provide valuable support in improving the diagnostic accuracy.

This study analyzed the feet of 81 children aged 5–7 years. Based on visual inspection, flatfoot was diagnosed in 41% of children, with boys being affected twice as often as girls. The FPI-6 scale was used for the quantitative evaluation of external foot parameters, with a score of ⩾8 corresponding to a clinical diagnosis of "flatfoot." The identification of the FPI-6 parameters strongly correlated with the visual assessment results, highlighting potential directions for refining the diagnostic methodology and improving its accuracy in uncertain cases.

In this study, the average dorsiflexion angle in healthy preschool-aged children is 22.8° ± 5.7° (range, 11.4°–34.2°) in 95% of children aged 5–7 years when the knee is extended.

In this age group, no significant differences in the dorsiflexion angle were observed between children with and without flatfoot. For the first time, a quantitative evaluation of gastrocnemius muscle retraction was conducted, measured as the difference in the dorsiflexion angle between flexed and extended knees.

To improve the clinical guidelines and establish normative foot parameters, large-scale population studies involving healthy children are needed.

ADDITIONAL INFORMATION

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Competing interests. The authors declare that they have no competing interests.

Ethics approval. The study was approved by the Local Ethics Committee of the H. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery, Ministry of Health of Russia (Protocol No. 24-5 dated September 3, 2024).

Consent for publication. Written consent was obtained from legally acceptable representatives of patients for publication of medical data.

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AUTHOR INFORMATION

Alena Yu. Dimitrieva, MD, PhD, Cand. Sci. (Medicine);
address: 64-68 Parkovaya str., Pushkin,
Saint Petersburg, 196603, Russia;
ORCID: 0000-0002-3610-7788;
eLibrary SPIN: 7112-8638;
e-mail: aloyna17@mail.ru

ОБ АВТОРЕ

Алена Юрьевна Димитриева, канд. мед. наук;
адрес: Россия, 196603, Санкт-Петербург,
Пушкин, ул. Парковая, д. 64–68;
ORCID: 0000-0002-3610-7788;
eLibrary SPIN: 7112-8638;
e-mail: aloyna17@mail.ru