Analysis of 6–10-Year-Old Children Feet Anthropometric Sizes and Pes Planus, Pes Cavus Predisposition in Central Anatolia

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Abstract

Background: Information on the foot structures of Central Anatolian children is limited. Foot structures of children aged 6–10 years were shown to be different according to sex and increasing age.

Objective: This study aimed to compare the foot anthropometric values by age and sex and collect the foot anthropometric data to reveal the relationship between pes planus and pes cavus in the arches of children according to age.

Methods: Footprints of 335 children (180 boys and 155 girls) aged 6–10 years were taken by the foot-print method and evaluated using 18 different parameters. To examine the relationship between the parameters, normality values were examined. Independent samples t-test was used to analyze sex differences in terms of foot size and shape.

Results: Correlations between other parameters were determined using the correlations analysis method. TFL (Truncated foot length), metatarsal circumference, and foot length were strongly correlated with age in the children. Foot rotation increased with body mass index in the girls compared to that in the boys.

Conclusions: Planning shoe production accordingly will contribute to the development of healthy feet in children. This article focused on foot structures of in Central Anatolia and to identify early foot deformities in children. This study found that the length of the TFL was smaller in boys than in girls.

Introduction

When designing shoes for any age group, anthropometric data of that group is of great importance. The use of correct foot sizes improves one's foot health and comfort. Shoes that do not fit the foot structure used at a young age can lead to permanent foot deformities. However, foot deformities that can be noticed at a young age can be eliminated before reaching the developmental period. Foot measurements can be taken by different methods. These are measuring with a caliper or tape measure, three-dimensional scanning, photographing, or foot-printing [1].

When studies on a similar subject are examined, foot morphologies may vary between sexes and different populations. As a result, the data obtained in this study vary according to age and sex [2–4]. Using these data, designing shoes, which is unique to foot morphology, can be beneficial for children's foot health.

Previous studies have determined the morphological dimensions of feet according to age groups in different nations. In Turkey, there are studies from anthropological studies such as sex prediction made from adult foot structure when examined. In this study, we aimed to determine the foot dimensions of the 6 – 10-year-old children in Central Anatolia and to identify early foot deformities in children.

Materials And Methods

This study included a sample group of 335 children (155 girls, 180 boys) aged between 6 and 10 years. The sample group consisted of children living in Central Anatolia, without any walking disorder and foot pathology. Approval was obtained from the ethical board committee of Ankara University, and informed consents were obtained from the families of the children included in the sampling before initiation of the study.

Data were collected from 24 different measurements including the shoe size of the dominant foot, metatarsal circumference, TFL, and Staheli arch index. In addition, demographic data such as height, body weight, and body mass index of children were measured (Table 1). The shoe types and sizes used by the children in the sample were subsequently determined.

Table 1
Demographic Data of Children

	Boys		Girls	
	Mean Value	**Standard Deviation**	**Mean Value**	**Standard Deviation**
Age (years)	7,4861	1,4999	7,5903	1,3490
Height (meter)	1,2658	0,1056	1,2611	0,0945
Body weight (kg)	28,3517	7,84902	27,9368	7,4789
Body Mass Index	17,3517	2,5926	17,3041	2,7715
Shoe Size	35,4431	3,5080	31,9484	3,3979

To determine the anthropometric dimensions of the foot, footprints were taken from the foot of the individuals using the foot-print method (Fig. 1.). The knee was flexed while the footprint was taken. The TFL, FL, X, Y, S, Arch Index (B / A + b + C), Chippaux Smirak Index (B / A * 100%), Staheli Arc, and foot rotation values of the children were examined (Table 2). In addition, metatarsal circumference and oblique measurements were taken directly from the feet of children (Table 3).

Table 2
Data from Footprint Assessment

	Boys		Girls	
	Mean Value	Standard Deviation	Mean Value	Standard Deviation
Ark Endeks	11,3700	1,13158	11,2503	0,8554
Chippaux Smirak Index	0,6207	0,17798	0,5647	0,1755
Staheli Arc Index	%96,21	%27,86	%86,80	%26,10
X Value (cm)	1,5617	1,06563	1,9658	1,0455
Y Value (cm)	5,7867	0,72693	5,5374	0,8837
S Angle (º)	23,1778	14,0184	29,6019	13,6776
TFL (cm)	15,5972	1,3882	15,4161	1,3415
FL (cm)	19,4522	1,7917	19,2510	1,6714
Foot Rotation (º)	21,9611	2,64968	21,3806	2,2885

Table 3
Data obtained from feet

	Boys		Girls	
	Mean Value	Standard Deviation	Mean Value	Standard Deviation
Metatarsal Measurement (cm)	18,4606	1,69878	18,0458	1,45648
Oblique (cm)	25,1044	2,6042	24,6594	2,2820

Statistical Analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS), version 23.0. When comparing the parameters, the normality values were first examined. Then, the independent samples t-test was used to analyze sex differences in terms of foot size and shape. To understand the relationship between other parameters, correlations analysis was performed.

Staheli arc index was evaluated by forming seven different groups. The percentages of the participants were determined. Staheli arc index values between 0% and 19% were 3°; pes cavus, between 20% and

39% were 2°; pes cavus, between 40% and 59% were 1°; and pes cavus (Fig. 2), between 60% and 79% values as normal arc structure (Fig. 3), between 80% and 79% values as 1°, between 100% and 119% values as 2°, and 120% and above values as 3°. It was classified as pes planus and evaluated (Fig. 4).

Results

The participants of the study consisted of 335 children (155 girls and 180 boys) aged between 6 and 10 (average: 8) years living in Central Anatolia. The body weights of the participants were between 14,60 – 55,50 kg and their heights were between 96 – 152 cm.

When the TFL values of the children were examined, the range was 11.50 – 19.80 cm, and the median was 15.5 cm. The normal distribution of the TFL values was found to be good. The range of the foot length was 14.12 – 24.89 cm, and the median was 19.28 cm. When the FL values were examined, the range was 14.00 – 25.50 cm, and the median was 19.2 cm; the values were found to be normally distributed. The range of the first metatarsal to ground distance was 0.83 – 3.80 cm, and the median value was 1.65 cm. When Chippaux Smirak index values were examined, the range was 0.00 – 1.01, and the median was 0.57.

Further, the correlation (0.177) between body mass index and foot rotation was found to be very weak.

When the correlation results of S value were analyzed, a weak correlation was observed between the S, Navicular ground distance, and 1st Metatarsal ground distance. Additionally, a weak correlation (-0.369) was found between the Chippaux Smirak index and Navicula to ground distance.

When the correlation analysis with other values of the Staheli Arc Index was examined, a weak correlation between the LLA angle and Navicula ground distance was observed. There were also weak correlations between the LLA angle, body mass index, foot rotation, and calcaneus angle.

A strong correlation (0.795) was observed between the TFL and Metatarsal circumference, as well as between the TFL and oblique measurement (coefficient, 0.848). Further, strong correlations were found between age and the TFL (coefficient, 0.727), FL (coefficient, 0.748), oblique measurement (coefficient, 0.721), arc index (coefficient, 0.717), shoe size (coefficient, 0.723), and foot length (coefficient, 0.650); however, the correlations between age and the 1st metatarsal to ground distance (coefficient, 0.294), Chippaux Smirak Index (coefficient, -0.133), Staheli Arc Index (coefficient, -0.129), and foot rotation (coefficient, -0.030) were weak.

A relationship was found between the metatarsal circumference and sex, which was stronger in the boys than in the girls (P = 0.18). No significant differences were observed between the sexes in terms of the 1st metatarsal to ground distance, TFL (P = 0.227), and foot length; however, there was a statistically significant difference in foot rotation between the sexes (P = 0.034), with girls having smaller foot rotation than boys.

According to the evaluation results with the classification made with the Staheli arch index, 0.30% of the sample was 3° pes cavus (1 individual [1 male]), 2.69% 2° pes cavus (9 individuals [1 male, 8 female]), 6.87% 1° pes cavus (23 individuals [9 boys, 14 girls]), 27.76% of the normal arch structure (93 individuals [48 boys, 45 girls]), 22.09% 1° pes planus (74 individuals [39 boys, 35 girls]), 17.70% 2° pes planus (66 individuals [37 boys, 29 girls]), and 20.60% 3° pes planus (69 individuals [45 boys, 24 girls]) were identified (Table 4).

Table 4
Distribution of children according to low arc values

Values	Diagnosis	Number of Children	Boy	Girl
0%- 19%	High Arc (Pes Cavus) 3.º	1	1	0
20%-39%	High Arc (Pes Cavus) 2.º	9	1	8
40%-59%	High Arc (Pes Cavus) 1.º	23	9	14
60%-79%	Normal Arc	93	48	45
80%-99%	Low Arc (Pes Planus) 1.º	74	39	35
100%-119%	Low Arc (Pes Planus) 2.º	66	37	29
120% and Over	Low Arc (Pes Planus) 3.º	69	45	24
	Total	335	180	155

According to the data determined in the classification made via the Staheli arch index, pes cavus is more common in girls than in boys. However, pes planus is more common in boys than in girls. Based on the Staheli arc index, almost the same number of girls and boys had a normal arc structure.

Discussion

This study evaluated the foot measurements of children living in Central Anatolia using different methods. The rate of increase in foot sizes of girls and boys aged between 6 and 10 years varied. When

the measurements of boys and girls of the same age were examined, it was found that the length of the TFL was smaller in boys than in girls.

The relationship between foot length and other parameters of children

Foot length was strongly correlated with age (r = 0.736 for girls; r = 0.725 for boys). Foot length and height were strong correlated (r = 0.906 for girls; r = 0.887 for boys). Body weight and foot length of children were strongly correlated (r = 0.822 for girls; r = 0.836 for boys). There was a strong correlation between the metatarsal circumference measurements and foot length (r = 0.756 for girls; r = 0.817 for boys). The relationships between the oblique measure and foot height of children (r = 0.837 for girls; r = 0.858 for boys) and between the calculated arch index and foot length (r = 0.946 for girls; r = 0.946 for boys) were strong. It was determined that the foot height had a moderate relationship with the X angle (r = 0.695 for girls; r = 0.625 for boys). The distance of the medial malleolus to the ground was moderately related to the height of the foot (r = 0.526 for girls; r = 0.546 for boys).

Comparison of FL with other nations

In this study, FL values of Turkish children at different ages were examined. In this context, these were evaluated in different countries. Xu's study also used data from Chinese children [5]. Delgado's study included data of Spanish children [6]. Barisch's [7] study included data of German children and Waseda's [8] study included data from Japanese children. Data of Mexican children were included in Prado-Leon's study [9]. In these studies, the age ranged from 6 to 12 years. In addition to the comparison, Bari's study included boys aged 5 and 6 years [10]. The data are given in Fig. 5.

The height of the navicular can be defined as the distance from the base of the medial projection of the navicular tuberosity to the ground. When the relationship between navicular height and age was examined, a low correlation was observed (r = 0.344 for girls; r = 0.354 for boys). Figure 6 shows the comparison of Turkish children with navicular height and Waseda's (2014) study with Japanese children [8].

The arc index value of Turkish children was also calculated and compared with that of children from other countries. In this context, the arch index values of German children were taken from Müller's study [11]. The arch index values of children living in two different countries are given in Fig. 7.

The Chippaux Smirak index of Turkish children was examined by age [12]. Comparison of children with those from other nations has been made. Sacco's [13] study obtained the values of Brazilian and German children. A comparison of Echarri's [1] study with children in Congolese with Turkish children was made. The Chippaux Smirak indexes of children from four different countries are given in Fig. 8.

The Staheli Arc values of children were examined according to age [14]. However, the Staheli Arc values of Turkish children were compared with those of Brazilian, German, and Congolese children. Comparison

of Staheli Arc values is given in Fig. 9.

Conclusion

This study aimed to determine the foot sizes and foot structures of children living in Central Anatolia. The results of the study may be used as an important resource for shoe designers in terms of child foot health. Foot structures of children aged 6 – 10 years were shown to be different according to sex and increasing age. The data of the study varies according to the number of individuals participating in the sampling and the techniques used to measure the foot structure; therefore, increasing the sample size and the use of three-dimensional scanning system to analyze Turkey's different regions of the foot and arch structure is proposed.

Declarations

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Authors' contributions

S.A., S.G., E.G., A.O., Y.A.: developed study protocol, study material, collected the data, preliminary analysis of data and did the final write up. S.A., N.A.: supervisor, conceptualisation of study, assisted with data collection and reviewing data analysis and review of final write up; All authors have read and approved the manuscript.

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Availability of data and materials

All the data that support the findings of this study are contained within the manuscript. Any requests for additional data can be made available upon reasonable request from the corresponding author and with permission of Ethics Department of the University of Ankara.

Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. Consent to participate was obtained from the parents/ guardians of the minors included in this study (minors are considered anyone under the age of 16). The protocol was approved by the Medical Science Ethics Committee of Ankara University (No.16/242). Parents and children provided their written consent to participate.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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