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Relationship of flatfoot and high arch with main anthropometric variables

Düz ve yüksek tabanlığın temel antropometrik değişkenlerle ilişkisi

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Amaç: Tüm yaşlarda yürüme bozukluklarına ve postürel sapmalara neden olan düz (pes planus) ve yüksek tabanlık (pes cavus) önemli bir sağlık sorunudur. Bu çalışmada, yetişkinlerde düz ve yüksek tabanlığın temel antropometrik göstergelerle nasıl bir ilişki gösterdiği araştırıldı.

Çalışma planı: Araştırma, Ankara'da yaşayan ve yaşları 18-83 arasında değişen 516 katılımcı (253 erkek, 263 kadın) üzerinde gerçekleştirildi. Ortalama yaş erkeklerde 40.5±13.4, kadınlarda 43.3±14.9 idi. Bireyler yaşlarına göre 18-29, 30-39, 40-49, 50-59 ve ≥60 olmak üzere beş gruba ayrıldı. Bireylerin düz veya yüksek tabanlı olup olmadıkları ayak izlerinden yararlanılarak belirlendi. Araştırmaya katılan bireylerden toplam beş antropometrik ölçü alındı. Bunlar vücut ağırlığı, boy uzunluğu, ayak uzunluğu, ayak tarak genişliği ve ayak topuk genişliği idi. Ayrıca, bireylerin ayakkabı numaraları öğrenildi ve her bir birey için beden kütle indeksi (BKİ) hesaplandı.

Sonuçlar: İncelenen bireylerin 21'inde (%4.1) düztabanlık, altısında (%1.2) ise yüksek tabanlık görüldü. Cinsiyet ve yaş grupları arasında iki deformitenin varlığı açısından anlamlı fark görülmedi (p>0.05). Ölçülen antropometrik verilerden boy uzunluğu, vücut ağırlığı, BKİ, ayak uzunluğu, ayak tarak genişliği ve giyilen ayakkabı numarası ile düz ve yüksek tabanlık arasında anlamlı ilişki bulunmadı (p>0.05). Ayak topuk genişliği ise sadece düztabanlık ile anlamlı ilişki gösterdi (p=0.027).

Çıkarımlar: Bu bulgular ışığında, yüksek tabanlığın vücut yapısıyla ve ayak boyutlarıyla ilişkili olmadığı, düztabanlığın ise yalnızca topuk genişliğiyle ilişkili olduğu söylenebilir.

Anahtar sözcükler: Antropometri; düztabanlık/epidemiyoloji; ayak deformitesi.

Objectives: The deformities of flatfoot (pes planus) and high arch (pes cavus) are serious health problems causing gait and postural defects in all age groups. The aim of this study was to seek relationships of these two deformities with main anthropometric variables in adults.

Methods: This study was carried out in 516 community individuals (253 males, 263 females) aged between 18 to 83 years, living in Ankara, Turkey. The mean age was 40.5±13.4 in males, and 43.3±14.9 in females. The participants were analyzed in five age brackets, namely 18-29, 30-39, 40-49, 50-59, and ≥60 years. The presence of flatfoot or high arch was determined by the analysis of footprints. A total of five anthropometric variables were measured including body weight, body height, foot length, metatarsal width, and heel width. Body mass index (BMI) was calculated and shoe size of the individuals was recorded, as well.

Results: The incidences of flatfoot and high arch were 4.1% (n=21) and 1.2% (n=6), respectively. There were no significant differences between sex and age groups with respect to the frequency of both deformities (p>0.05). No associations were found between the presence of flatfoot or high arch and body weight, body height, BMI, foot length, metatarsal width, and shoe size (p>0.05). Only heel width showed a significant association with the presence of flatfoot (p=0.027).

Conclusion: These findings suggest that the presence of high arch is not related to body composition and foot dimensions, while flatfoot is associated only with heel width.

Key words: Anthropometry; flatfoot/epidemiology; foot deformities.

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The deformities of flatfoot (pes planus) and high arch (pes cavus) can cause difficulty in walking and problems with posture in all age groups and lead to even more serious health problems for seniors.[1,2] These deformities can also cause pains in the regions of the feet, calf, and waist. They can affect daily activies such as walking and remaining standing for a long time.[3]

Pes planus is described in the literature as an anomaly which is characterized by the decreasing or disappearing completely of the height of medial longitudinal arch (MLA) of the foot.[3-7] In other words, flatfoot is the declining of concavity of the sole completely or partially or the becoming smooth of the concavity. On the other hand, pes cavus is a pathologic condition which presents as the elevation of the height of the MLA of the foot.

There are several opinions which explain the reason of development of pes planus and pes cavus. Some authors suggest that these deformities may be related with the habit of wearing shoes and the starting age of wearing shoes.[3,8-9] In addition to these factors, some other authors argue that obesity or body weight should also be taken consideradion in the process of the occurence of these deformities. For instance, in their study Scahithanandam and Joseph,[8] examined the relationships between flatfoot and body mass index (BMI) which is an indicator of obesity and they came to conclusion that there was no association between these two variables.

The relationship between pes planus or pes cavus and anthropometric variables other than body weight and BMI have not yet been investigated. For example is there any association between body height and the foot deformities? Were pes planus and/or pes cavus affected from the dimensions of foot? There are no satisfactory answers to these questions. For this reson, the present study was aimed to investigate the relationsips between pes planus/pes cavus and some anthropometric variables which are reflections of general body morphology such as weight and height, and foot dimensions such as foot length and breadth.

Material and method

The research was carried out on 516 subjects aged between 18 and 83 years (253 males and 263 females). The ages ranged between 17.6 and 82.5 (mean 40.51 years, SD = 13.39 years) in male subjects, and 17.7 and 82.9 (mean 43.33 years, SD = 14.86 years) in female subjects. The subjects were categorized into five subgroups based on their age ranges: 18-29, 30-39, 40-49, 50-59, 60 and over. Table 1 displays the number of individuals in each group.

Care was taken that the socioeconomic characteristics of the subjects reflected those of the general population of Ankara, Turkey. In other words, during the sampling procedure, it has not been concentrated on a specific socioeconomic or occupational group, contrarily there were interviews with members of all socioeconomic groups and occupations livin in Ankara at the time of the study. The subjects were chosen among the persons who accepted to participate in the study voluntarily. Information about the aim of the study and research procedure (anthropometric measurements and foot prints) were given to the volunteers. After the volunteers had signed the consent form, foot prints and anthropometric measurements were taken.

The deformities of pes planus and pes cavus were determined from the subject's footprints. Footprints were taken on B4 size tracing paper. The individuals were asked to totally wet their soles in buckets of water and then step on tracing paper, so as to facilitate measurements. This method was observed to facilitate the successful obtainment of footprints. In most of the samples, the footprints were taken successfully, only 7 individuals (1.4%) were asked for a second trial.

There are several techniques to determine pes planus and pes cavus. However, the techniques based on radiological examination, clinical observation, and footprints are the most used ones. Authors stated that the footprint's technique is one of the more effective methods for determining of pes planus and pes cavus[6,8,10] because it was more practicle and cheaper than others.[10] This non-invasive technique provides

Table 1. Sample size by sex and age groups

Age groups	Males	Females	*Total*
18-29	65	58	123
30-39	67	63	130
40-49	60	62	122
50-59	41	50	91
≥60	20	30	50
Total	253	263	516

advantages to both investigators and subjects particularly in the field studies.

In the literature, there is a tendency that the footprints are classified into three groups as 'flatfoot,' 'high arched' and 'normal foot.'[8] Although there is no universal agreement on at what point an MLA become a flatfoot,[4] it can said that the approach devised by Rose and co-workers[5] is preferred. In the present study we used the procedure and methodology of Rose et al.[5]

The five anthropometric measurements taken from the individuals were as follows: body weight, height (stature), foot length, foot breadth, and heel breadth. Body weight was measured when the subjects were wearing minimal clothes and no shoes on a digital weighing machine which is sensitive to 100 grams.[11] Body height (stature) was taken when subjects were standing in an erect position without shoes and the head of the subject was measured in Frankfurt plane with a portable Martin type anthropometer in millimeters.[11] Foot measurements (as described in the following sentences) were taken via a sliding caliper from the bare left foot of the individuals while they were standing, the measurement was in millimeters.

Foot Length is taken as the distance between the pternion (extreme point of the heel) and the akropodion (extreme point of longest toe). [12]

Foot Breadth is the distance between the surface of the first and fifth metatarsal bone heads.[12,13]

Foot Heel Breadth is taken as the distance between the extreme points on the lateral protrusions of the heel.[13]

Furthermore, body mass index (BMI) values of the subjects were calculated and the number of the shoes were recorded.

During the analyses, values of the variables were divided into subgroups using percentile values as cut-off points. For example, the categorization of stature was determined by using the 25th and 75th percentile of the distribution of stature. A body height of 156.6 cm or less was assigned as "short," 156.7-172.1 cm as "medium," and 172.2 cm or more as "tall." Body weight and shoe size were also categorized using the same percentiles as cut-off levels. A body weight of 61 kg and less was defined as "underweight," 62-78 kg as "medium," and 79 kg or more as "overweight." A shoe size of 37 or less was identified as "small," 38-41 as "medium," and 42 or more as "large." Body mass index were grouped into two categories, with a BMI of 29.9 or less as "lean" and 30 or more as "obese."

The relationships or differences between pes planus/pes cavus and the variables of sex, age, stature, BMI, foot dimensions, and shoes size were analyzed using chi-square test. All mathematical calculations and tests were done using the subroutines of SPSS for Windows, version 16.0. P values of <0.05 were considered significant.

Results

It was observed that 21 individuals of 516 (4.1%) were flatfooted, and 6 individuals (2.1%) were abnormally high arched (Table 2). When we look at in terms of sex it can be said that these conditions are seen more often in males. The difference, however, is not significant statistically ($P>0.05$). For this reason, in the following sections the sexes will be considered together.

Table 3 displays the distribution of flatfooted and high arched according to age groups. As can be seen in Table 3, flat footedness occurs more in age groups of 18-39 in males, and 30-49 in females. Pes cavus, on the other hand, has a tendency to emerge in later years, especially in age group of 50-59 (Table 3). However, a chi-square test showed that the differences of pes planus and pes cavus in age groups are not significant statistically ($P>0.05$).

Table 2. The prevalances of pes planus and pes cavus

	Males		Females		*Total*	
	n	%	n	%	n	%
Normal	237	93.7	252	95.8	489	94.8
Pes planus	11	4.4	10	3.8	21	4.1
Pes cavus	5	2.0	1	0.4	6	1.2
Total	253		263		516	

Table 3. Distribution of pes planus and pes cavus by age groups

	Males (n=253)				Females (n=263)			
	Pes planus		Pes cavus		Pes planus		Pes cavus	
Age groups	n	%	n	%	n	%	n	%
18-29	4	6.2	1	1.5	1	1.7	–	
30-39	4	6.0	–		5	7.9	–	
40-49	2	3.3	1	1.7	2	3.3	1	1.6
50-59	–		2	4.9	1	2.0	–	
≥60	1	5.0	1	5.0	1	3.3	–	
Total	11	4.4	5	2.0	10	3.8	1	0.4

The findings about the relationship between body weight and the deformities investigated are given in Table 4. These findings suggest that there was no statistically significant association between categorized stature groups and pes planus and pes cavus (P>0.05). Similarly, our data showed that the values of BMI do not effect the prevalence of pes planus and pes cavus (Table 4).

In this study we also examined the relationship between pes planus/pes cavus and foot dimensions (Table 4). Chi-square analyses showed that there was no association between foot length and breadth and the deformities examined (P>0.05). On the other hand, there is a significant relationship between heel breadth and flatfootness (P = 0.027). Finally, the relationships between pes planus/pes cavus and shoe size was investigated and it was observed that there was no association between these variables (P>0.05).

Discussion

In childhood and adulthood pes planus and pes cavus are one of the most prevalent foot deformities. Therefore, there are many studies which focused on the relationship between these two deformities and

Tablo 4. The relationship between pes planus/pes cavus and stature, body weight, body mass index (BMI), and foot dimensions

	Pes planus		Pes cavus			Pes planus		Pes cavus	
	n	%	n	%		n	%	n	%
Stature groups					Foot breadth				
Short (≤156.6 cm)	9	7.0	1	0.8	≤9.0 cm	7	5.8	1	0.8
Medium (156.7-172.1 cm)	7	2.7	3	1.2	9.1-9.9 cm	8	3.1	5	2.0
Tall (≥172.2 cm)	5	3.9	2	1.5	≥10 cm	6	4.3	0	0.0
χ^2 *and p*	4.002; 0.135		0.328; 0.849		χ^2 *and p*	1.536; 0.464		3.185; 0.203	
Body weight groups					Heel breadth				
Underweight (≤61.0 kg)	10	7.3	2	1.5	≤6.5 cm	6	4.7	2	1.6
Medium (61.1-78.9 kg)	7	2.9	3	1.2	6.6-7.1 cm	4	1.7	4	1.7
Overweight (≥79.0 kg)	4	3.0	1	0.8	≥7.2 cm	11	7.1	0	0.0
χ^2 *and p*	4.877; 0.087		0.294; 0.863		χ^2 *and p*	7.190; **0.027**		2.598; 0.273	
BMI groups					Shoe size				
<30 kg/m^2	18	4.2	6	1.4	≤37	6	4.1	1	0.7
≥30 kg/m^2	3	3.3	0	0.0	38-41	6	2.9	3	1.5
χ^2 *and p*	0.151; 0.697		1.283; 0.257		≥42	9	5.5	2	1.2
Foot length					χ^2 *and p*	0.705; 0.703		0.455; 0.797	
≤23.3 cm	5	3.7	2	1.5					
23.4-25.7 cm	10	4.2	3	1.3					
≥25.8 cm	6	4.2	1	0.7					
χ^2 *and p*	0.063; 0.969		0.397; 0.820						

various factors such as style of shoes, age to start wearing shoes, obesity, age, and sex.[14-17] The authors are in consensus that pes planus and pes cavus are "pathologic conditions" and these deformities should be diagnosed and treated at the earliest age possible.

Flatfoot and high arch, at the same time, is a serious public health problem which is related to working life because these deformities negatively effect the productivity of employees. Therefore pes planus and pes cavus were treated in ergonomics-oriented studies and it has been advised that the persons with these deformities should not be employed in jobs which require much standing.[18]

In our sample the prevalance of pes planus was 4.1% (in males 4.3% and in females 3.8%). The ratio of our sample and those of other populations are approximately same. For instance in their study Sachithanandam and Joseph determined the prevalance of pes planus was 2.9% in a sample which consist of 1864 subjects aged 16 years or over.[8] Similarly, Rose et al. observed that the ratio of flatfootedness as 3.5% in footprints of 100 individuals aged 16 years through 65 years living in England.[5] Ferciot estimated that the prevalance of pes planus was 5.0% for both children and adults.[19] Taking this data, we can suggest that the problem of flatfootedness in our sample is as common as other countries or populations.

In our sample the prevalance of pes cavus is 1.2% (in males 2.0% and in females 0.4%). As it can be seen clearly, this ratio is less than those of pes planus. The prevalance of pes cavus was investigated in an English and Indian community and it was founded as 7.0% and 10.5% respectively.[5,9] This data showed that pes cavus in our sample is not more common than other human populations. Some authors asserted that there was a negative relationship between pes planus and pes cavus.[5,9] In other words, when the prevalance of flatfootedness rises the ratio of pes cavus decreases. Our findings supported this hypothesis.

Our findings indicated that both pes planus and pes cavus are deformities that can occur in every age group in both sexes. However, when we look at our findings closely it can be stated that the deformity of flatfootedness generally occur in young adults (age group of 18-40) in male group, but it occurs relatively late ages in females (age group of 30-50). Staheli and co-workers examined the changes of flatfootedness' ratio in different age groups and they stated that the ratio is higher in childhood, among adolescents and young adults the prevalance decreases to the lowest level, and than it tends to increase.[20] In addition to this, our findings suggest that after the age of 50 both the prevalence of pes planus and pes cavus starts to decrease again.

In the present study no significant correlation between pes planus/pes cavus and many of the anthropometric measurements (body weight, stature, foot length, and foot breadth) investigated was found. The only significant positive correlation was observed between pes planus and heel breadth. Although in the literature there are many studies which indicate that pes planus are closely related with the shoe style and size[7,8] in our study it has not been found any cohesion between these variables.

When we look the studies concerning pes planus and related factors it can be seen that obesity is generally concerned as a factor.[2,3,14,21-26] In these studies, authors were used body weight or BMI as a criterion in order to show this interaction. Research on this subject displayed that there was a negative correlation between body weight and the longitudinal medial arch (LMA) of foot. Strictly speaking, as body weight increases the height of plantar arch decreases, and consequently the ratio of pes planus rises. For example, Mickle et al. measured the mean height of plantar arch in normal and obese children as 0.9 ± 0.3 cm and 1.1 ± 0.2 cm respectively.[27] In this study, however, the findings of both body weight and BMI did not support this hypothesis. A large majority of the above-mentioned studies carried out on children and juveniles. The hypothesis argues that positive correlation between pes planus and obesity is possibly valid for only children and adolescents, not adults and elderly people. In sum, to achieve accurate results more detailed studies are needed to be made.

An interesting situation is encountered when we examine the relationships between the deformities investigated and the dimensions of foot and shoe size. Among the variables encountered only the association between pes planus and heel breadth was significant statistically. Accordingly, among the

people whose heel breadth are relatively wider the chance to find of flatfooted persons is higher. The source of this high correlation may be the growing of heel breadth in flatfooted persons. If this is true we will also expect to find a significant correlation between pes planus and foot breadth. Our findings, however, did not indicate such a correlation.

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