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Prevalence and types of pes planus in a sample of Nigerian college students

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ABSTRACT

Background: The arch index serves as an early warning sign of structural and functional defects at the foot in a given population and also useful in determining the prevalence of pes planus and possibly predicting pathologic foot condition.

Aim: The study aimed at evaluating the plantar arch index using Staheli's plantar index method and determined the point prevalence, type, and gender distribution of pes planus. It also investigated the gender differences in the plantar arch index, and types of pes planus.

Method: This ex-post-facto study recruited 240 volunteers (120 males and 120 females) apparently healthy undergraduates, aged between 17-30 years old. Participants' biodata were noted and their footprints collected using the ink method. Footprints were traced and selected foot dimensions were taken on the footprints. Plantar arch index for each foot was calculated using Staheli's plantar index method where the plantar index (PI) equals the ratio of central region (A) to heel region (B) (PI=A/B). Data collected were summarized and analyzed using descriptive statistics of mean and standard deviation, percentage, Pearson's Chi-square, and independent T-test. Alpha level was set at 0.05.

Result: The result showed a point prevalence of pes planus as 3.8%. Male participants had a significantly higher plantar arch index, but female participants had a higher prevalence of pes planus. Unilateral and rigid types of pes planus were more common than bilateral and flexible types respectively. Rigid pes planus was more common among males than females while the flexible type was more common among females than males. Also, unilateral pes planus was more common among females than males while the bilateral type was more common among males than females.

Keywords: Pes Planus, Staheli's plantar index, Prevalence.

INTRODUCTION

The human foot is the region most affected by anatomical variation in the entire human body and one of the most important characteristics presenting the highest level of variability is the medial longitudinal arch, and an arch index provides a quantitative measure of the plantar arch which can be compared to other measurements[1]. The foot consists of twenty-six bones: seven tarsals, five metatarsals, and fourteen phalanges[2]. The normal foot has two significant arches, the transverse and the longitudinal arches. The longitudinal arch of the foot is further subdivided into a medial and a lateral longitudinal arch[3]. These arches act as shock absorbers, help in supporting the weight of the body in the erect posture, and are also important in propulsion during gait[4]. The assessment of plantar arch development, using the relationship between the widths of the central region and the heel region obtained on a footprint, was proposed by Engel and Staheli[5]. According to Igbigbi et al[6], arch indices could range from 0.0 - 1 and are indicative of cavus and planus foot respectively. The arch index may serve as an early warning sign of structural and functional defects of the foot in a given population and also useful in determining the prevalence of pes planus and possibly predicting pathologic foot condition[6].

Pes planus (flatfoot) is a biomechanical problem and consists of a constellation of physical features[7], that include excessive eversion of the subtalar complex during weight-bearing, with plantar flexion of the talus, plantar flexion, and abduction of the navicular, supination of the forefoot, and valgus posture of the heel[8]. Studies on several aspects of pes planus abound in literatures[1; 6; 7; 9]. However, Hernandez et al[1] reported that the plantar arch index is easy to obtain from footprints and reported a significant difference between the plantar arch index of sides (right and left foot) in the population sample. Igbigbi et al[6] found that males had significantly higher arch index than females. Eluwa, et al[10] found the overall incidence of pes planus as 22.20% with a prevalence of 8.80% among males and 13.40% among females. This study was aimed at evaluating plantar arch index and pes planus prevalence among healthy undergraduates; the difference in plantar arch index between sides (right and left foot); the gender differences in the foot plantar arch index (same side); the gender distribution of pes planus; the difference in occurrence between unilateral and bilateral pes planus; and the difference in occurrence between flexible and rigid pes planus.

METHOD

This ex-post facto research design involved 240 (120 males and 120 females) undergraduate students of the College of Health Sciences, Nnamdi Azikiwe University Nnewi campus. They were all apparently healthy individuals aged between 17 to 30 years, who met the inclusion criteria. They were selected using a purposive sampling technique. The procedures employed for the study were approved by the Ethics Review Committee of Nnamdi Azikiwe University Teaching Hospital, Nnewi, Anambra State, and permission was taken from the authority of the College for data collection, before the commencement of the study. The procedures were explained to the participants, and their informed consent was obtained. Participants' bio-data were noted and their footprints collected using the ink method with the following materials as described below:

- **Endorsing Ink:**Itwas used together with plain duplicating papers to obtain the footprints of the participants[1; 10].
- **Plain duplicating papers:** They were used together with endorsing ink to obtain the footprints of the participants[11].
- **Wooden platform:**This was used to create an even surface upon which the plain duplicating paper was placed[1].
- **Buckets of water and Towels:** They were used for washing, and drying the feet of the participants after the data collection.
- **Lead pencil:**This was used to trace the foot impression and meter rule and for the measurements of the selected foot dimensions.

The patterns of measurements were:

a. A sheet of plain duplicating paper was placed on a wooden platform. The participant remained seated in front of the platform on which the plain duplicating paper was placed. With the aid of one of the researchers, each participant placed the foot (already painted with endorsing ink) on the platform, with the contra lateral foot off the platform[1].

b. The participant was requested to stand up and perform a small flexion of the ipsilateral knee (about 30 degrees) and then to go back to the initial position, and remove the foot from the platform.

c. One of the researchers controlled the foot position on the platform, to prevent foot slip, a fact that could invalidate the test, which should show a clear foot print[1].

d. **Calculationof the plantar arch index**: Staheli's plantar index method was used. The Plantar arch Index (PI) establishes a relationship between central and posterior (heel) regions of the footprint, and it was calculated as follows:

i. A line was drawn tangent to the medial fore-foot edge and at the heel region[1].

ii. The mean point of this line was measured and marked off. From this point, a perpendicular line was drawn crossing

the footprint. The same procedure was repeated for the heel tangency point[1].

iii. The measurement of the support width of the central region of the foot (A), and the heel region (B) in centimeters was obtained. The Plantar arch Index (PI) was calculated by dividing the A value by B value: (PI = A/B)[1].

e. **Evaluation criteria**

A normal Plantar arch Index (PI), according to Hernandez et al[1], Engel and Staheli[5], is the one comprised within 2 standard deviations (2SD) of the population mean PI. This PI value equal to or above the sum of 2SD with the mean was considered as indicative of pes planus (flatfoot) and threshold index for this condition[1] in the population sample under study.

f. **Procedure for differentiating between the flexible and the rigid pes planus**

A Heel Raise test (tiptoe standing was conducted for all the participants)[8]. The appearance of the arch when the participant tiptoes (non-weight bearing posture), indicated a flexible pes planus, otherwise, rigid pes planus is indicated[12].

Data Analyses

Data collected were summarized and analyzed using descriptive statistics of mean and standard deviation, percentage, Pearson's Chi-square, and independent T-test. Alpha level was set at 0.05.

RESULTS

The point prevalence of pes planus was 3.8% with a higher prevalence amongst the female participants (5%) than the male participants (2.5%) (Table 1). The mean value for the Plantar arch Index (PI) of the male participants was 0.907± 0.213 (for the right foot) and 0.901 ± 0.199 (for the left foot) while that of the female participants was 0.825 ± 0.226 (for the right foot) and 0.828 ± 0.225 (for the left foot) (Table 2). The Plantar arc Index (PI) for the Normal Foot Population (NFP) was 0.85 ± 0.199 (for the right foot) and 0.85 ± 0.199 (for the left foot), while those of the Flat Foot Population (FFP) was 1.38 ± 0.161 (for the right foot) and 1.31 ± 0.106 (for the left foot) (Table 3).A significant difference (P = 0.004) existed in the scores of the right foot Plantar arch Index between male and female participants and also in the left foot Plantar arch Index (P = 0.008). The male participants had significantly higher scores in the Plantar arch Index than the female participants for both sides of the foot. There was no significant difference in the scores of the mean Plantar arch Index between the right and the left foot within the general population as sampled (Table 4). There was a high prevalence of the rigid type of pes planus (55.6%) than the flexible type (44.4%). Also, there was a high prevalence of unilateral pes planus (77.8%) than the bilateral type (22.2%). Rigid pes planus was more common among the male participants (66.7%) than the female participants (50%) while the flexible type was more common among the female participant (50%) than the male participants (33.3%). Unilateral pes planus was more common among the female participants (83.3%) than the male participants (66.7%) while the bilateral type was more common among the male participants (33.3%) than the female participants (16.7%) (Table 5).

Table 1: Point Prevalence and Gender Distribution of Pes planus

VARIABLES	PERCENTAGE (%)	
	Males (n=120)	Females (n=120)
NFP	117(97.5%)	114(95.0%)
FFP	3(2.5%)	6(5.0%)

Point prevalence of pes planus (n=240) = 3.8%.

Key:

NFP= Normal Foot Population
FFP = Flat foot population
n = Number of participants, according to sex

Table 2:Descriptive statistics of the mean and standard deviation of the measurement of Selected foot dimensions in centimeter (cm), according to sex

	VARIABLES	RIGHT FOOT Mean ±SD	LEFT FOOT Mean ±SD
Male (n=120)	A	5.55± 1.401	5.47± 1.293
	B	6.11± 0.573	6.09± 0.505

	PI	0.907± 0.213	0.901 ± 0.199
Female (n=120)	A	4.67 ± 1.307	4.63 ± 1.296
	B	5.65 ± 0.450	5.61 ± 0.442
	PI	0.825 ± 0.226	0.828 ± 0.225

Key:
SD = Standard Deviation
n = Number of Participants, according to gender.
A = Central width support
B = Heel width support
PI = Plantar Arch Index (A/B)

Table 3:Descriptive statistics of the mean and standard deviation of the measurement of selected foot dimension in centimeter (cm), for the general population sample

	VARIABLES	RIGHT FOOT Mean ±SD	LEFT FOOT Mean ±SD
NFP (n=231)	A	5.00 ± 1.344	4.95± 1.292
	B	5.89 ± 0.567	5.86 ± 0.537
	PI	0.85 ± 0.199	0.85 ± 0.199
FFP (n=9)	A	7.69 ± 0.799	7.46 ± 0.662
	B	5.49 ± 0.203	5.68 ± 0.331
	PI	1.38 ± 0.161	1.31 ± 0.106

Key:
SD = Standard Deviation
NFP = Normal Foot Population
FFP = Flat Foot Population
N = Number of participant, according to foot condition.
A = Central width support
B = Heel width support
PI = Plantar Arch Index (A/B)

Table 4:Comparison of the same side of foot plantar arch index between males and females and opposite sides of foot plantar arch index within the general population

VARIABLES	MEAN ± SD	T	p
Right FOOT PI			
General population (n=240)	0.866 ± 0.223	0.79	0.937
Male (n=120)	0.907 ± 0.213	2.883	0.004
Female (n=120)	0.825 ± 0.226		
LEFT FOOTPT			
General population (n=240)	0.865 ± 0.215		
Male (n=120)	0.901 ± 0.199	2.662	0.008
Female (n=120)	0.828 ± 0.225		

Key:
PI = Plantar arch index
n = Number of participants.
t = t-test value.
P is significant at < 0.05

Table 5: Types of pes planus and differences in gender distribution within the flat Foot population

	VARIABLES	PERCENTAGE (%)
Males (n=3)		
Type 1	Rigid	2(66.7%)
	Flexible	1(33.3%)
Type 2	unilateral	2(66.7%)
	Bilateral	1(33.3%)
Females (n=6)		
Type 1	Rigid	3(50%)
	Flexible	3(50%)
Type 2	unilateral	5(83.3%)
	Bilateral	1(16.7%)

Key:
n =Number of participants, according to gender in the flat foot population.

DISCUSSION

The foot has two functions which are to provide strong and stable support for the body, and the lever for ambulation. This double function makes the foot present a unique behavior during ambulation when it is subjected to a successive load and unload cycle[1]. The deformation experienced by the medial longitudinal arch during support makes the foot to be the region suffering the highest variations in a human body[1]. These functional features make a clinical examination of this region complex. The wide variability found in all concepts concerning the foot may be exemplified by the various names for flat feet. This condition has received many different names, not necessarily reflecting the characterization of different problems.There are a considerable number of authors who advocate for footprint as a good evaluation approach; Engel and Staheli[5], Cavanagh and Rodger[13], Staheli et al[14], Viladot[15], Volpon[16], Chen et al[11], Hernandez et al[1] and Eluwa et al[10]. The correlation between x-ray studies and footprint shows that the footprint is effective for individual studies and population-based investigations[17]. Some investigators could not find a correlation between footprint and clinical measurement of the plantar arch, regarding it as invalid to determine plantar arch height[18] others consider that footprint presents several approach facilities[19]. The plantar arch index and the navicular vertical height are correlated, but the latter is better because it directly measures navicular, which is the key to the medial arch, in addition to being easy to achieve[20]. Using a sophisticated methodology, such as strength platforms, graded scales[13], or Moire photopodometry[21]; increases measurement accuracy. The technique that employs footprint impression and plantar arch index calculation is simple, non-expensive, easy to apply, and satisfactory for routine clinical analysis[1]. The footprint impression test is simple, available, non-invasive, and does not use radiation as well[15].

The procedure for obtaining the footprint impression employed in this study seems to be through a static manner, but the objective of the slight knee flexion (30^0) performed by the participant was to cause an inner rotation of the leg and increase foot pronation, similar to what happens during gait support phase, although with lighter load[22;23]. This present study employed the static footprint method and slight flexion of the ipsilateral knee, with the contra lateral foot off the ground (Monopodal support). The results obtained in this study showed no significant difference in plantar arch index between the right and the left foot ($P = 0.937$). This is consistent with some report which showed no significant difference between right-side and left-side plantar arch index[14;24]. However, it is in contrast with the findings of Hernandez et al[1] and Sa et al[25].

Hernandez et al[1] reported a highly significant difference in plantar arch index regarding sides, in a population sample of 100 children aged 5-9 years old. Sa et al[25], in a study on evaluation of plantar arch index with 302 children aged 3-10 years old, called attention to the differences between sides in the various feet measurements, although they emphasized that these are almost unnoticeable on plantar index dimensions. The observed variation could be either methodological or other factors such as the age bracket of the population sample used by different researchers. In the study by Hernandez et al[1], it was impossible to use monopodal support (as employed by the present study), due to balance problems in the age group they used. The same applied to the study by Sa et al[25]. Therefore, their result could depend on the fact that performance of measurements of foot impression with bilateral support could lead to differences if one side supported a heavier body load than the other, being subjected to a higher level of foot deformation[1].

This study also shows that the male participants had significantly higher scores in the right plantar arch index than the female participants (P = 0.004), and higher scores in the left plantar arch index than the female participants (P=0.008). These findings by the present study are in agreement with the findings by Igbigbi et al[6] and Eluwa et al[10]. However, these findings are at variance with the result reported by Hernandez et al[1] and Staheli et al[14], which showed no significant sex difference in the plantar arch index for both rights and left feet. This variation could be due to factors like ethnic and racial differences, population size, and age group used by these authors. The present study was carried out among students aged between 17-30 years.

Although the male participants had significantly higher scores in the plantar arch index than the female participant for both right and left feet, suggesting a higher risk of pes planus among them. In females, this present study shows a contrary situation. Males had a higher plantar arch index but the female group showed a higher pes planus prevalence of 6 per 120 (50%) within the total female population than the male group with a pes planus prevalence of 3 per 120 (2.5%) within the total male population. This situation is consistent with the findings of Eluwa et al[10], who reported that males had a significantly higher plantar arch index than females, however, females had a higher pes planus prevalence of 38 per 500 than males (29 per 500). This could be explained by some structural factors. Females tend to have smaller bones and less bulky muscles unlike males with larger and stronger bones and hypertrophied plantar foot muscles. Since these factors helps in the maintenance of the arches of the foot[10], females are therefore more prone to developing pes planus, though presented with a lower plantar index than males in this study.

This study found the point prevalence of pes planus in the population sample as 3.8% (9 per 240). The findings of this study also indicate that unilateral pes planus was more common (77.8%) than bilateral (22.2%) within the pes planus population. This agrees with the work of Didia et al[24] but in contrast with that of Didia and Asomugha[26], who reported an incidence of 7.5% bilateral flatfoot and 3.5% unilateral flat foot. Also, this study found that within the pes planus population, unilateral pes planus was more common among females (83.3%) than males (66.7%). This is consistent with the findings of Eluwa et al[10] among students of Akwa Ibom state origin, but at variance with their findings in another study among students of Cross River State origin, in which unilateral pes planus was more common in males (2.8%) than in females (2.20%) (Eluwa et al[10].

Also, this study found that bilateral pes planus was observed to be more prevalent among males (33.3%) than among females (16.7%) in the pes planus population. This disagrees with the findings of Eluwa et al[10], which reported that bilateral flat feet were common among females (11.20%) than males (6.00%). This study also found a higher prevalence of rigid pes planus (55.55%) than flexible type (44.4%). This is at variance with the findings of Collins etal[27], which reported flexible type more prevalent (91.4%) than rigid type (8.6%). Also, flexible pes planus was more common among females (50%) than in males (33.3%) while the rigid type was more common among males (66.7%) than among females (50%).

CONCLUSION

The findings of this study suggest that the point prevalence of pes planus is very low in this environment (3.8%). The results of this study also revealed that although males had a significantly higher plantar arch index, females had a higher prevalence of pes planus. Unilateral and rigid types of pes planus were more common than bilateral and flexible types, respectively.

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