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Assessment of Plantar Arch Index and Prevalence of Flat Foot Among Adult Ikwerre Residing in Port Harcourt, Rivers State

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Abstract

Feet abnormality such as flat foot resulting from the collapse of the arches of the foot is of great clinical and anatomical importance. This study aimed to assess the plantar arch index and determine the prevalence of flat foot among adult Ikwerre residing in Port Harcourt, Rivers State Nigeria. A total of 100 subjects consisting of 50 males and 50 females were recruited for this study. The bilateral footprints of the subjects were obtained using stamping ink and A4 plain papers. Convenience sampling technique was used in collecting samples. Data were analyzed using statistical package for social science (SPSS version 23) and Microsoft Office Excel 2019. Staheli's plantar arch index method was adopted and the presence of flat foot was identified from the data collected by calculating the plantar arch index (PAI). If the value of PAI is >1.15, it is considered as flat foot. The result showed that the right plantar arch index of male participants was significantly higher than that of the left. About 4% flat foot on the right feet and 6%flat foot on the left feet were observed in males while no flat foot was recorded in right foot and 10% flat foot on the left foot were recorded in females. The findings in the study suggest a higher prevalence of flat feet in left foot than the right foot with females having higher rate of left flat foot than the males.

Introduction

The term flat foot is commonly used to describe a nebulous mixture of anatomical variations as well as a small core of pathological conditions (Rose et al., 1985; Igbigbi et al., 2002; Pranati et al., 2017; Akinlolu et al., 2021). Flat feet or pes planus is a postural deformity in which the arches of the foot collapses, with the entire sole of the foot coming into complete or near-complete contact with the ground. There is a functional relationship between the structure of the arch of the foot and the biomechanics of the lower leg. The arch provides an elastic, springy connection between the forefoot and the hind foot. This association safeguards the body such that a majority of the forces incurred during weight bearing of the foot can be dissipated before the force reaches the long bones of the leg and thigh (Franco, 1987).

Flat feet, also known as acquired flat foot disorder, result from collapsed arch. When standing, the sole of the foot should not touch the ground completely. However, a fallen arch causes the foot to roll inwards and the entire sole comes close to touching the ground. The feet are fundamental to the mobility of the body, flat feet can cause problems throughout the skeletal

structure and can even bring the joints out of alignment (Donatelli et al., 2024).

In pes planus, the head of the talus bone is displaced medially and distal from the navicular. As a result, the spring ligament and the tendon of the tibialis posterior muscle are stretched, so much so that the individual with pes planus loses the function of the medial longitudinal arch (MLA). If the MLA is absent or non-functional in both the seated and standing positions, the individual has rigid flatfoot. If the MLA is present and functional while the individual is sitting or standing up on their toes, but this arch disappears when assuming a foot-flat stance, the individual has supple / flexible flatfoot. This latter condition can be correctable with well-fitting arch supports (Snell, 2012; Hayley et al., 2017; Rithanya et al., 2018).

The appearance of flat feet is normal and common in infants, partly due to "baby fat" which masks the developing arch and partly because the arch has not yet fully developed. The human arch develops in infancy and early childhood as part of normal muscle, tendon, ligament and bone growth (Pina-Diaz et al., 2024). Training of the feet, especially by foot gymnastics and going barefoot on varying terrain, can facilitate the formation of arches during childhood, with a developed arch occurring for most by the age of four to six years. Flat arches in children usually become proper arches and high arches while the child progresses through adolescence and into adulthood (Umar and Tafida, 2013; Gregory, 2020; Solanki et al., 2020).

The arch of the foot demonstrates two extremes of anatomical structural position the high arch characteristic of the pes cavus and the flat arch the pes planus. Although there are three distinct arches whose function is to support the foot, the medial longitudinal arch (MLA) has been found to be the arch of clinical significance. Problems and mal-alignments originating involving the MLA ultimately affect the functioning of the muscles and joints of the ankle, knee, hip, and low back, all of which depend on the base of support provided by the MLA (Karataş & Karasu 2024).

The prevalence of pes planus declines with age, being higher in children with ligament laxity and early shoe wearing which impairs longitudinal arch development (Hernandez et al., 2007; Gianmarco et al.,2015; Gavin et al.,2020). The lower limb, and particularly the foot, is amongst the most distinctive characteristics of human anatomy (Hernandez et al., 2007). Footprint of hominoids already demonstrated the existence of plantar arch 3.7 million years ago (Hernandez et al., 2007). The orthopaedic examination served to recognize disorders that are known to change feet consistency. The identification of congenital problems, particularly involving the feet; postural abnormalities of the spine, pelvis, hips, knees, Achilles Tendon shortening, and restraint to subtalar joint movements are essential for ruling out the possibility of secondary pes planus. (Hernandez et al., 2007; Chiamayee et al.,2020; Samuel &Tun,2020; Sergey et al.,2020).

The medial longitudinal arch of the foot is of great importance because it helps protect the foot from injuries (Yalfani et al., 2024). It is an important highly variable structure characteristics of the human foot which provides necessary shock absorption for the foot during activities. Traditionally, feet are classified as being high, normal or low arched. A high arched foot is supposed to be at increased risk of injuries to the bony structures on the lateral aspect of the foot (over-supinated), whereas a low arched foot can be at greater risk for soft tissue damage on the medial part of the foot (over pronated) (Gehlen & Märdian, 2024).

In Europe and America flat foot is a common reason for attendance at a children's orthopaedic clinic, but in India and most low-income countries, children are seldom brought for treatment for flat foot (Rao et al., 1992). This shows that there is lack of awareness about flat foot among the uneducated and economically backward people.

Materials and methods

This study was conducted on adult subjects (18-40) from Ikwerre ethnic group residing in Port Harcourt. A total of hundred (100) Adult subjects, fifty (50) male and fifty (50) who met the inclusion criteria were randomly selected. Their footprint was obtained by instructing the subject to place the foot in a mode which contained a rectangular piece of foam of the mode size.

The foam was wet with ink, the foot was then placed on a clean A4 paper placed on a flat smooth surface. After the plantar surface was printed on the paper, the subject was asked to raise his/her leg while cotton wool soaked in methylated spirit was used to wipe the stained ink on the plantar surface. The same procedure was repeated for the both feet.

The plantar arch index (PAI) of each foot was obtained according to Staheli's method. For calculating PAI, a tangential line was drawn connecting the edge of the medial forefoot and heel region. The mid-point of this straight line was calculated by dividing the full length by half. From this marked point, a perpendicular line was drawn crossing the footprint (Figure 1). The same procedure was repeated at the heel region for heel tangency point. The width of the central region of the footprint was considered as 'A' and that of the heel region is considered as 'B'. All measurements were taken in centimeters (cm). Plantar arch index (PAI) was obtained by dividing the A value by B value (Hernandez et al., 2007). Plantar arch index (PAI) = A/B. PAI greater than 1.15 was considered as flat foot.

Figure 1: Foot print of subject

The subjects were randomly selected. Sample size determination was done using Cochran's formula for population infinite or large population and the sample size used for this study was 100.

Figure 2: Foot print showing how measurements were derived

Mathematically, it is represented as:

$$\frac{z^2pq}{d^2}$$

Sample Proportion=Total Research Population/Total Nigeria Population

Results

Table 1 shows the summary of all measured foot parameters in both right and left. The right and left foot of all study participant had approximately the same length (24.54cm). The right width, A and B were slightly more in the right foot than in the left foot.

The Table 2 shows the comparison of the left plantar indexes with the right plantar arch indexes. The left foot had slightly higher plantar arch index, however this difference was not significant (t=1.093; p-value=0.227).

Table 1: Descriptive statistics of measured foot parameters of all subjects in the study

Foot parameter (cm)	Mean ± SEM (N = 100)	SD	Min	Max
Right Foot				
Length	24.54 ± 0.14	1.43	21.5	27.5
Width	8.99 ± 0.05	0.52	8.0	10.5
A	4.42 ± 0.14	1.37	2.0	8.5
B	5.33 ± 0.08	0.75	4.4	7.6
Left Foot				
Length	24.54 ± 0.14	1.44	21.5	27.8
Width	8.90 ± 0.05	0.54	7.5	10.5
A	4.29 ± 0.12	1.23	2.5	8.0
B	5.20 ± 0.07	0.72	3.9	7.3

Table 2: Plantar index of right and left feet of all subjects of the study

	Right foot	Left foot
Mean	0.81	0.82
SEM	0.01	0.02
SD	0.18	0.20
Min.	0.44	0.48
Max.	1.27	1.33

t = 1.093; p-value = 0.227

Table 3: Comparison of right foot parameters of participants based on gender

	Male (N=50)		Female (N=50)			
Parameters (cm)	**Mean ± SEM**	**SD**	**Mean ± SEM**	**SD**	**t-test**	**p-value**
Length	25.43 ± 0.17	1.21	23.65 ± 0.15	1.04	7.837	0.001*
Width	9.30 ±0.06	0.45	8.70 ± 0.05	0.38	7.215	0.001*
A	4.70 ± 0.18	1.30	4.15 ± 0.20	1.40	2.044	0.044*
B	5.48 ± 0.10	0.74	5.19 ± 0.11	0.75	1.967	0.052*
PI	0.85 ± 0.03	0.19	0.76 ± 0.02	0.16	2.536	0.013*

Table 3 shows the comparison of the right foot parameters based on gender. The male right foot length was significantly higher than the female length (25.43cm as against 23.65cm). The width and the Plantar Index was also higher in males when compared to females (p=0.001 and p=0.013 respectively).

The result shown in table 4 displays the comparison between the left foot parameters in the male and female gender. The male foot length and width were significantly higher than females (p=0.001 and p=0.001). On the left feet the plantar arch index of males was higher (0.83) than that of females (0.81) though the difference was not significant.

Table 4: Comparison of left foot parameters of participants based on gender

Parameters (cm)	Male (N=50) Mean ± SEM	SD	Female (N=50) Mean ± SEM	SD	t-test	p-value
Length	25.49 ± 0.16	1.11	23.60 ± 0.15	1.06	8.699	0.001*
Width	9.16 ± 0.06	0.45	8.62 ± 0.07	0.48	5.882	0.001*
A	4.42 ± 0.16	1.16	4.16 ± 0.18	1.28	1.094	0.277
B	5.35 ± 0.12	0.77	5.04 ± 0.09	0.64	2.165	0.033*
PI	0.83 ± 0.03	1.19	0.81 ± 0.03	0.21	0.311	0.756

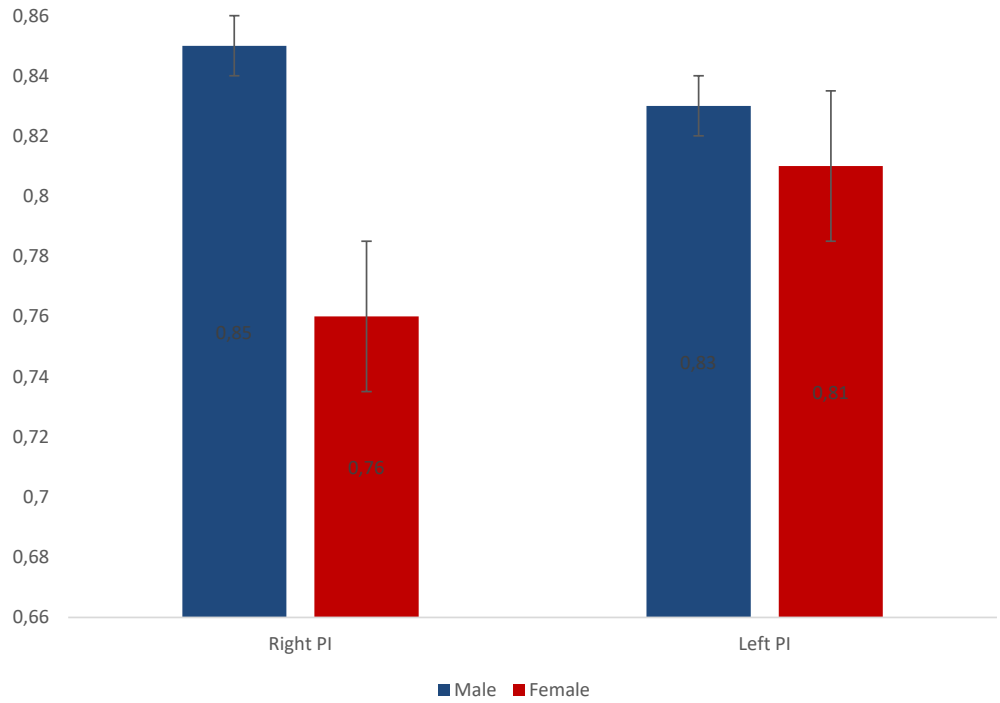

Figure 3: Bar chart showing average plantar arch index of both feet based on gender of the participants

Table 5: Plantar index classification of both feet of participants

	Frequency (n)	Percentage (%)
Right feet		
≤ 1.15 (Normal)	98	98.0
> 1.15	2	2.0
Left feet		
≤ 1.15 (Normal)	92	92.0
> 1.15	8	8.0

The table above displays the plantar arch index classification in both left and right foot of study participants. About 98% of study participants had a right plantar arch index that were normal (≤ 1.15) while about 2% of the subjects indicated abnormality in right plantar arch index (>1.15). The left foot plantar arch index of subjects indicated 8 abnormalities.

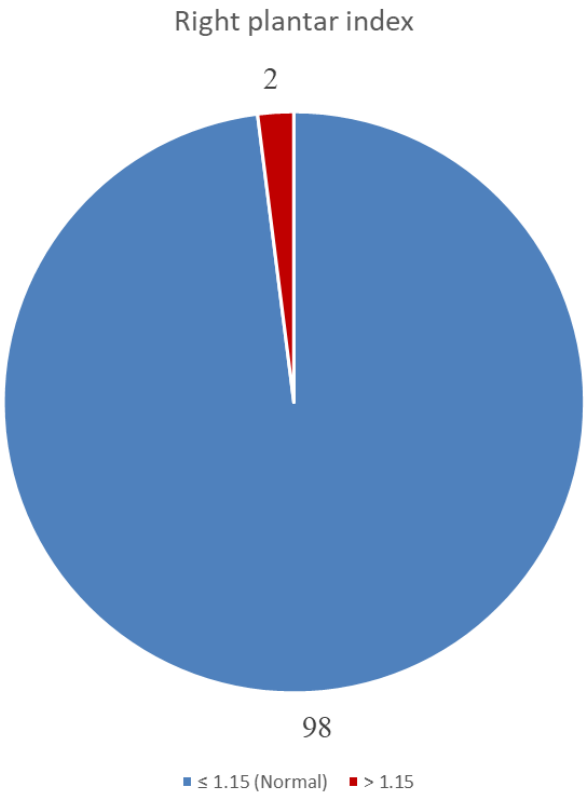

Figure 4: Pie chart showing proportion of participants with normal Right plantar arch index (normal PI ≤ 1.15).

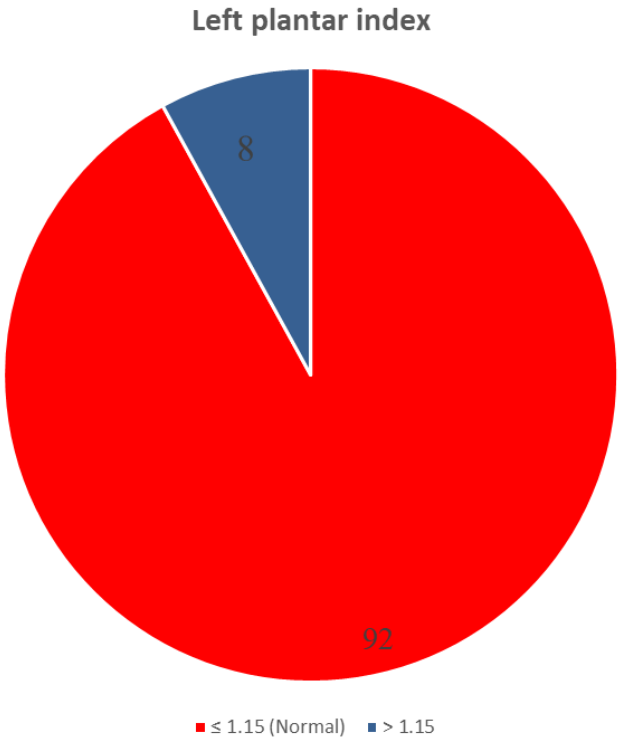

Figure 5: Pie chart showing proportion of participants with normal left plantar arch index (normal PI ≤ 1.15)

Table 6: Comparison of plantar index class among male and female participants in the study

Variable	Gender		Total	Chi square	p-value
	Male n (%)	Female n (%)			
Right PI					
≤ 1.15	48 (96.0)	50 (100.0)	98 (98.0)	2.041	0.495
> 1.15	2 (4.0)	0 (0.0)	2 (2.0)		
Left PI					
≤ 1.15	47 (94.0)	45 (90.0)	92 (92.0)	0.543	0.715
> 1.15	3 (6.0)	5 (10.0)	8 (8.0)		

Table 6 shows comparison of plantar index classification among male and female participants in the study. From the results 96% of males had normal right plantar index while 4% had higher than normal plantar index. All females had right plantar indexes that was normal. From the left 94% of males and 90% of females had normal left plantar arch index while 6% males and 10% of the female population had left plantar arch index higher than 1.15

Discussion

The human foot being an essential tool for motion is highly essential in bipedal species since any deformity in it could have far reaching consequences on the quality of life of the patient. High foot arches are associated with various musculoskeletal instability necessitating orthopedic intervention (Adler, 2024). Low foot arches also known as flat foot has been associated with gait abnormality and even spine deformity (Abbasi et al., 2024). Understanding the prevalences as well as foot parameters of the study population will aid clinicians as well as forensic scientists in taking informed decisions. In this, there was a significant difference in all measured right foot parameters of the study, when compared between males and females (length, width, plantar index). The male participants had higher values of all parameters ($p<0.05$) when compared with the females and this is likely due to some anatomical variations that exists between males and females. This may indicate that foot parameters exhibits sexual dimorphism in the study population. On the other hand, the left foot parameters showed significant difference only in length, width and A parameters between males and females.

Plantar index was higher in left feet of males than females although the difference was not statistically significant. The right plantar index of males in the study was slightly higher than that females; mean plantar arch index. The result show that the plantar arch index was determined to be 0.81 for the right foot and 0.82 for left foot, in the combined males and females.

There was a slight difference in mean value of the plantar arch index of the left and right feet as left foot had higher value (0.82) against right foot (0.81). Similarly, minor difference was noticed in value of the right and left foot width of the participants as right foot width stood at 8.99cm against left foot of 8.91cm value.

The prevalence of flat foot is low as only 8% of the participants have left flat foot while 2% of the participants have right and 92% of the participants have normal left foot and 98% have normal right foot. The result also reveal that flat foot can occur unilaterally or bilaterally. Also, this study reveals the males bilaterally have higher plantar arch index, foot length and foot width than females. Following the result of this study, it shows that males have more flat foot deformity compare to the females. This can be attributed to the out-door activities that many males are involved in.

The low level of prevalence in flat foot among Ikwerre adults residing in Port Harcourt can be attributed to their life style since the participants were engaged in little or no farming activities, less walking compared to rural dwellers. There is proper medical attention in city and proper medical facilities in case foot or ankle injuries, proper medical management of Rheumatoid arthritis which is one of the leading causes of flat foot. There is also proper surgical intervention in case of rupture of the posterior tibial tendon

It is also important to note that flat foot can be inherited (Yang and He, 2024) as some of the participants came from families where the gene of flat foot is dominant while some the participants acquired flat foot as a result of being athletic.

Conclusions

From this study, it can be deduced that the plantar arch index (PAI) of adult Ikwerre residing in Port Harcourt is 0.81 for the right and 0.82 for the left foot while the foot length is 24.54cm for the both foot and 8.99cm for right width and 8.90cm for the left foot width. It can also be deduced that prevalence of flatfoot among adult Ikwerre residing in Port Harcourt is very low.

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Conflicts of interest

All authors declare that there is no form of competing interests.

Authors' contribution

GSO was the lead researcher, designed the protocol, performed statistical analysis and wrote first draft. GOB, PC, BM and BKA participated in the writing of the first draft. NIO carried out the data collection and

statistical analysis. All authors discussed the results and agreed to submit the final manuscript for publication

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