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Assessment of Plantar Arch Index and Prevalence of Flat Foot Among Indigenes of Ikwerre Local Government Area, Rivers State

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Abstract

The arch of the foot provides an elastic, springy connection between the forefoot and hindfoot. The aim of this study is to assess the plantar arch index and prevalence of flat feet among indigenes of Ikwerre local government area, Rivers State aged 18-60. The study is a cross-sectional study using random sampling technique to select participants., Staheli's index was used to calculate the plantar arch index. Statistical analysis was done using SPSS version 25.0. A total of 107 males (53.5%) and 93 females (46.5%) were assessed to determine whether there were statistically significant gender differences in foot length, midfoot breadth, heel breadth, and arch index. The results show that males had a slightly higher mean foot length (25.17 cm) compared to females (24.60 cm). The t-test value of 1.99 and a p-value of 0.048 indicate that this difference is statistically significant at $p < 0.05$. This suggests the presence of sexual dimorphism in foot length, meaning that men in this population generally have longer feet than women. For midfoot breadth, males recorded a mean of 5.03 cm, while females had a mean of 4.89 cm. The t-test value (0.95) and p-value (0.34) show that this difference is not statistically significant, implying that both genders have similar midfoot widths. Regarding heel breadth, the mean values for males (7.96 cm) and females (7.93 cm) were nearly identical. The t-test value (0.37) and p-value (0.97) further confirm that there is no significant difference between males and females in heel width. Similarly, the arch index had a mean value of 0.83 for males and 0.80 for females. With a t-test value of 0.67 and a p-value of 0.49, the result shows no significant difference between genders. This suggests that both males and females in this population share similar arch structures and proportions. In summary, the only statistically significant gender difference observed was in foot length, with males exhibiting longer feet than females. However, no significant differences were found in mid foot breadth, heel breadth, or arch index. This indicates that while men generally have longer feet, the overall structural proportions and arch configurations of the feet are similar across both sexes in the studied population

Keywords: Foot, Planter arch index**,** Statistical analysis, length, midfoot breadth, heel breadth.

INTRODUCTION

Human foot is the region most affected by anatomical variations 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 measurement of the plantar arch, which can be compared to other measurements (Koirala *et al.,* 2021).

There is a functional relationship that exists between the structure of the arch of the foot and the biomechanics of the lower limb. The arch of the foot provides an elastic, springy connection between the forefoot and hindfoot. This relationship ensures that most of the forces incurred during weight bearing can be dissipated before reaching the long bones of the leg and thigh. (Xiong *et al.,* 2010)

The arch of the foot demonstrates two extremes of anatomical structural position—the high arch characterizes of the pes cavus and the flat arch the pes planus. Although three distinct arches function to support the foot, the medial longitudinal arch (MLA) has been found to be the arch of clinical significance in both these disorders. (Xiong *et al.,* 2010). Problems and mal-alignments originating specifically with 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. (Pranati *et al.,* 2017)

Reviewing the concepts about human foot evolution, we notice that the lower limb, and particularly the foot, is amongst the most distinctive characteristics of human anatomy. The overwhelming development of human brain cortex, vocal apparatus, and lower limb and foot structure make a triad distinguishing man from other mammalians. Footprints of hominoids already demonstrated the existence of a plantar arch 3.7 million years ago, and, during human evolution, feet - and not hands - experienced extraordinary changes (Hernandez *et al.,* 2007).The assessment of plantar arch development, by the relationship between arch region width and heel region width obtained on a footprint, is proposed by Engel and Staheli in the research work titled '*The natural history of torsion and other factors influencing gait in childhood'*. This relationship is greatly reduced up to 4 years old, and the standard deviation through this age group is very high, showing a large variation at the initial foot arch development. The longitudinal arch during childhood shows a wide variation, and, from 4 years old on, this relationship remains at about 0.75 in average (Hernandez *et al.,* 2007). The incidence of flat feet, as shown by footprints, reduces with age, reaching 4% at 10 years old. In Brazil, (Hernandez *et al.,* 2007). presents the results of footprints of 637 individuals between zero and 15 years old. The study reports that plantar arch shows a great deal of development up to the 6th year of life, increasing little after that age. It also reports the stabilization of flat foot incidence at around 2%.

A previous study has established the metrics to quantify the arch as per the plantar contact area known as the arch index (AI), which is calculated from mid-foot area divided by the summation of forefoot area (excluding toes area), mid-foot area, and rear-foot area (Ekanem *et al.,* 2024). The arch index can be directly influenced by the foot contact areas, especially the mid-foot. (Wearing *et al.,*2004) believed that body fat mass could affect the arch index, and increased fat mass could increase the contact area of the mid-foot resulting in an increased arch index, which was reported as low arch or flat foot. Foot types, including high arch, normal arch, and low arch, were previously reported with different structures and functional performance (Hillstrom *et al.,* 2013). Foot arch height influences the quality of life (Lopez *et al.,* 2018; Lopez *et al.,* 2014). Low arch foot pronates excessively during running stance, while normal arch is characterized by an arch slightly raised from then ground during weight bearing.

Footwear companies designed functional shoes, such as arch support, for the cohort of different foot types, respectively. However, assigning shoes as per foot types were proven not helpful to reduce the injury risk during the military training among soldiers (Knapik *et al.,* 2014; Feng *et al.,* 2017).

Children with flat foot complained of frequent foot pain and difficulty while walking long and fast, running, maintaining balance, and walking on uneven ground. They are usually concerned about the appearance of their feet. They have difficulty in finding suitable footwear, an increased risk of falls, and other deformities in their future life, such as scoliosis and posture problems, as well as a reduced quality of life (Octavius *et al.,* 2020, Dabholkar & Agarwal, 2020). These factors have a significant influence on daily activities which demands appropriate interventions.

Hence, the present study assessed planter arches, of people in Ikwerre LGA, Rivers State.

MATERIALS AND METHOD

This study is a cross-sectional study using a random sampling technique conducted on 107males and 93 females (200) Adults between 18-60years who are indigenes of Ikwerre LGA, Rivers State, Nigeria. The selection of this population was based on the need to evaluate the presence of flat foot within this geographical and ethnic context.

Ikwerre LGA is predominantly occupied by the Ikwerre people, but its proximity to Port Harcourt means residents from multiple ethnic groups live there. This study primarily focused on the Ikwerre ethnic group while noting the diversity

Sample Size Determination:

To determine an appropriate sample size for this study, Taro Yamane's (1967) formula was used. This formula is suitable for finite populations and allows for the calculation of a representative sample size based on the population total and a desired margin of error.

$$n = \frac{N}{1 + N(e)^2}$$

Where:
n = sample size
N = population size (500 by assumption)
(e) = p. value
Population size N:500
p. value (e): 0.02
n= 1000/ (1+500 (0.02) 2
n= 200 approx.

Therefore, the required sample size used the Taro Yamane method for a population of 500 subjects is 200 participants in Ikwerre.

Inclusion criteria

- Male and female adults (18-60yrs)
- Participant must be a long-term resident of Ikwerre local government of Rivers state
- 3 Participants who provide informed consent.

Exclusion criteria

- Individuals with any recent fracture
- Individuals with neurological impairments
- Individuals not willing to participate and individual with trauma-like condition and bad ankle condition.
- Children and elderly individuals (below 18 and above 60) to account for fully developed arch index and exclude any age-related changes

The above-mentioned exclusion criteria is chosen to prevent any false positive or false negative results from being obtained throughout the period of this study.

Study Procedure

This study was aimed to determine the prevalence of flatfoot by evaluation of the plantar arch index of indigenes of ikwerre L.G.A The following were the steps and procedures taken to ensure accurate and reliable results:

a. An ethical approval from Faculty of Basic medical science Rivers State University Ethical committee was obtained.
b. Informed consent was obtained from participants to ensure their understanding of the purpose and use of this study.
c. Their foot prints were taken thrice.

Fig. 1: Instruments for data collection: white paper, lead pencil, stamp pad ink, meter rule, ink tray

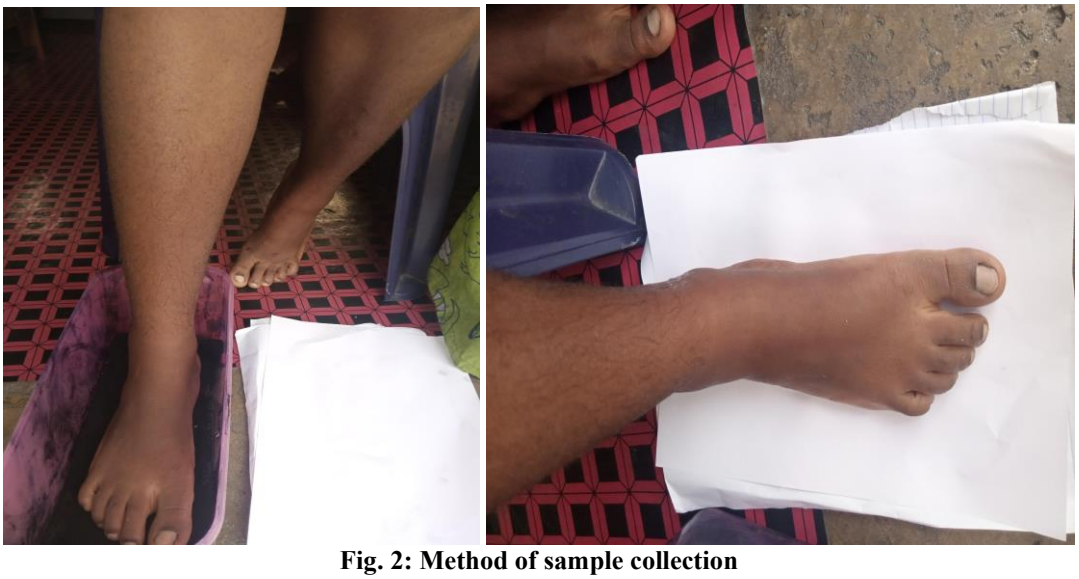
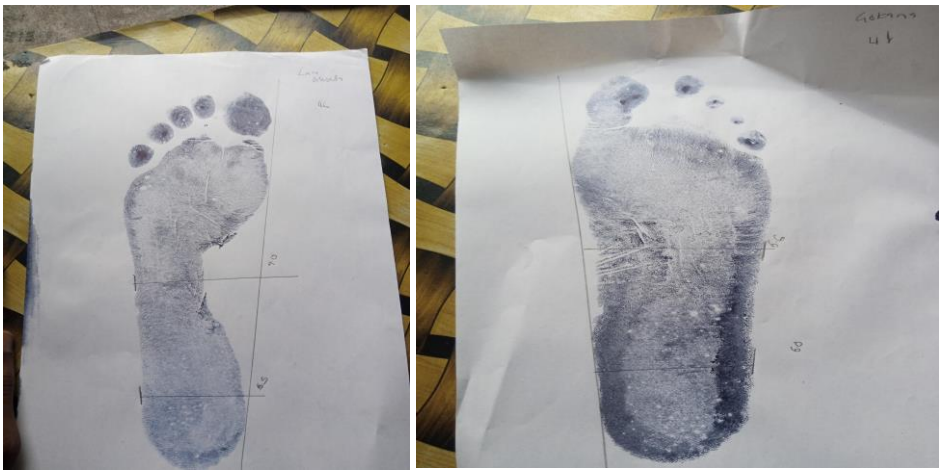


Fig. 2: Method of sample collection

For calculating the plantar arch index, a tangential line is drawn connecting the medial forefoot edge and heel region. The mean point of this line is calculated. From this point, a perpendicular line is drawn

crossing the footprint. The same procedure is repeated for heel tangency point. The width of the central region of the foot print is considered as A and the width of the heel region is considered as B. The Plantar Arch Index (PAI) is obtained by dividing the A value by B value (PAI = A/B). If PAI is greater than 1.15, then it is considered as flat foot. (Hernandez *et al.,* 2007)



A B

Fig. 3: Calculation of plantar arch Index (A) normal feet. (B) flat feet

Ethical Considerations

Ethical research approval was obtained from the research committee of the faculty of basic medical sciences. Informed consent was obtained from participants; the consent form was obtained from the participants. The confidentiality information of the respondents was ensured and kept safe. The participants have the right to end participation at any time, following the human subjects rights enacted by the National Institute of Justice, in Nigeria in 2022.

Statistical Analysis:

In line with the nature of the research design, descriptive statistical methods of measures of central tendency such as the arithmetic mean, mean, standard error and percentage frequency was adopted for this study. Inferential statistics of paired t test was also adopted for the purpose of determining the statistical differences.

RESULTS

Presentation of Data and Analysis

The foundational analysis involved generating descriptive statistics for key foot parameters for the entire sample (N=200), as shown in **Table 1**. The mean arch index, a critical metric for assessing the plantar arch, was 0.81.

The statistical analysis of the foot parameters provides a detailed overview of the foot morphology within the study population of 200 individuals. The results show that the mean foot length was 24.91 cm, with values ranging from 21.00 cm to 28.50 cm. This indicates that most participants had moderately sized feet, with minimal variation as shown by the small standard deviation of 2.02 cm.

The midfoot breadth ranged from 2.40 cm to 7.50 cm, with a mean value of 4.98 cm. This suggests an average midfoot width typical of a normal adult foot. The standard deviation of 1.25 cm indicates a moderate degree of variation among individuals, possibly reflecting natural differences in body build or foot structure.

For heel breadth, the values ranged widely between 3.40 cm and 25.50 cm, with a mean of 7.94 cm. However, the very high maximum value and standard deviation of 6.15 cm suggest the presence of outliers or possible measurement inconsistencies. This implies that while most participants had heel widths close to the average, a few measurements deviated substantially, affecting the overall variability of the data.

The arch index ranged from 0.20 to 1.70, with a mean value of 0.81, which falls within the range classified as a high arch (pes cavus). This finding indicates that the majority of the participants exhibited a high-arched foot type. The standard deviation of 0.33shows some variation among individuals, meaning that while most had high arches, a smaller portion of the population displayed normal or flat arches.

In summary, the data reveal that individuals in this study population generally have moderate foot lengths, average midfoot widths, and a predominance of high arches. The results also highlight the need for cautious interpretation of heel breadth measurements due to the unusually wide variability observed. Overall, the consistency of the other parameters, as reflected by the low standard errors, indicates that the measurements were reliable and representative of the population studied.

Table 1: Descriptive Statistics of Foot Parameters (Total Sample, N=200)

Foot Parameters (cm)	N	Min	Max	Mean	SEM	SD
Foot length	200	21.00	28.50	24.91	0.14	2.02
Midfoot	200	2.40	7.50	4.98	0.08	1.25
Heel	200	3.40	25.50	7.94	0.43	6.15
Arch index	200	0.20	1.70	0.81	0.02	0.33

To investigate gender-based anatomical variations, an independent samples t-test was conducted, comparing the foot parameters of male (N=107) and female (N=93) participants. (**Table 2)**

Independent T-Test Comparison of Foot Parameters by Gender

A total of 107 males (53.5%) and 93 females (46.5%) were assessed to determine whether there were statistically significant gender differences in foot length, midfoot breadth, heel breadth, and arch index. **(Table 2)**

The results show that males had a slightly higher mean foot length (25.17 cm) compared to females (24.60 cm). The t-test value of 1.99 and a p-value of 0.048 indicate that this difference is statistically significant at $p < 0.05$. This suggests the presence of sexual dimorphism in foot length, meaning that men in this population generally have longer feet than women.

For midfoot breadth, males recorded a mean of 5.03 cm, while females had a mean of 4.89 cm. The t-test value (0.95) and p-value (0.34) show that this difference is not statistically significant, implying that both genders have similar midfoot widths.

Regarding heel breadth, the mean values for males (7.96 cm) and females (7.93 cm) were nearly identical. The t-test value (0.37) and p-value (0.97) further confirm that there is no significant difference between males and females in heel width.

Similarly, the arch index had a mean value of 0.83 for males and 0.80 for females. With a t-test value of 0.67 and a p-value of 0.49, the result shows no significant difference between genders. This suggests that both males and females in this population share similar arch structures and proportions.

In summary, the only statistically significant gender difference observed was in foot length, with males exhibiting longer feet than females. However, no significant differences were found in mid foot breadth, heel breadth, or arch index. This indicates that while men generally have longer feet, the overall structural proportions and arch configurations of the feet are similar across both sexes in the studied population.

Table 2: Independent T-Test Comparison of Foot Parameters by Gender

	MALE (N = 107 (53.5%))			FEMALE (N = 93 (46.5%))				
Foot Parameters	**Mean**	**SEM**	**SD**	**Mean**	**SEM**	**SD**	**t – test**	**P - value**
Foot length	25.17	0.19	2.01	24.60	0.20	2.00	1.99	0.48
Mid foot	5.03	0.12	1.28	4.89	0.12	1.21	0.95	0.34
Heel	7.96	0.61	6.32	7.93	0.62	5.98	0.37	0.97
Arch index	0.83	0.32	0.33	0.80	0.35	0.34	0.67	0.49

$P < 0.05$ considered significant

DISCUSSION

Data were collected from 200 participants: 107(53.5%) males and 93 (46.5%) females [Table 2]. The primary objective of this study was to investigate the plantar arch characteristics and determine the prevalence of pes planus. The analysis revealed a statistically significant gender difference only in foot length ($p = 0.048$), with males having longer feet on average. This finding is consistent with well-established principles of sexual dimorphism in human anthropometry, where males typically exhibit larger absolute skeletal dimensions (Kouchi, 2018*)*. The result supports more recent studies conducted on various populations which continue to confirm this fundamental anatomical difference (Manna & Pradhan, 2019).

This finding corroborates a previous Indian study (Inamdar et al.,2018) that had high arch as the most prevalent foot type. Moreover, other studies (Pourghasem *et al.,*2016) that had either flat foot has been prevalent contradict this finding. This study is therefore compliant with the established normal range as it has been said that flat foot is estimated to affect approximately 3.0-25.0% of the adult population globally (Cacace *et al.,* 2013). Other previous studies that reported low or lower percentages of flat foot included Nigerian, African and Asian studies (Igbinedion *et al.,* 2022) while those that reported higher percentages were few (Igbinedion *et al.,* 2022). These findings were not in line with a previous study (Eluwa et al.,2009) which determined the prevalence of pes planus among people of Akwa Ibom State of Southern Nigeria, with an overall prevalence of pes planus as 13.4% (a prevalence of 5.8% among males and 7.6% among females) and another (Ezemagu et al.,2018) that determined the prevalence of pes planus among people

of Ebonyi with an overall prevalence of pes planus as 4.2% on the right foot and 2.5% on the left foot (a prevalence of 3.7% among males and 2.5% among females). There were also other previous studies (Igbinedion *et al.,* 2022) with discrepancies from the present study. These variances could be ascribed to use of different footprint methods, differences in sample size, method of data analysis and of course, ethnicity could also be possible factors. However, the difference between flat foot of the right foot side and that of the left was not statistically significant. Furthermore, high arch and normal foot were more prevalent in the population. Moreover, all these differences were statistically significant ($p<0.05$). It was observed that male and female residents do a lot of trekking to their various businesses. The fact that physical activities (such as trekking), everyday habits such as shoe wearing (such as low slippers worn while trekking and cycling) as well as personal characteristics (body mass index and age) could affect the foot morphology of adults as stated in a 115 previous study (Igbinedion *et al.,* 2022) have been confirmed in this study. This finding does not agree with findings of some previous studies (Eluwa *et al.,* 2009; Parash *et al.,* 2013; Abtahian & Farzan 2016; Pranati *et al.,* 2017) who reported that majority of the subjects had flat foot and normal arch, respectively. Use of different index methods for flat foot determination, reduced sample size and of course, ethnic differences as shown in the previous studies could account for these differences.

Conversely, the analysis found no statistically significant differences between males and females in midfoot width, heel breadth, or the arch index ($p > 0.05$ for all). The arch index, being a direct measure of arch height, is particularly relevant for pes planus. The lack of a significant gender difference in the arch index (Male: 0.83 ± 0.34, Female: 0.80 ± 0.34) is a critical finding. It suggests that the structural architecture of the plantar arch is not inherently different between genders in this specific adult population. This aligns with several contemporary studies that have also reported no significant sexual dimorphism in arch height among adults, indicating that after skeletal maturation, arch morphology may be more influenced by factors other than gender (Uchenna *et al.,* 2019; Igbinedion *et al.,* 2022*)*.

The overall mean arch index of 0.81 provides a quantitative baseline for the Ikwerre population. When interpreted using the Staheli Plantar Index (where values ≥ 0.26 indicate pes planus), this mean value sits within a range that suggests a notable presence of lowered arches in the general sample, supporting the reported 41.5% prevalence of pes planus. This prevalence is higher than the 3.0-25.0% often cited for the global adult population *(*Cacace *et al.,* 2013*)* but finds parallels in other specific ethnic groups and studies. The variance can be attributed to several factors, including the specific footprint method used, as different indices can yield different prevalence rates (Igbinedion *et al.,* 2022*)*. Furthermore, lifestyle factors are significant. The observation that residents engage in considerable trekking is noteworthy, as physical activity levels and habitual load-bearing have been shown to influence foot morphology and arch stiffness in adults *(*Tong & Kong, 2016*)*. Therefore, the high prevalence may reflect a functional adaptation to the local environment rather than a pathological condition.

CONCLUSION

This study was conducted to investigate the plantar arch and determine the prevalence of pes planus among the indigenous Ikwerre population. From the comprehensive analysis of the collected foot parameters, several important findings were established.

The most notable result was the prevalence of foot types within the study population. The findings revealed that a high arch (pes cavus) was the most common foot type, as indicated by the mean arch index value of 0.81, which falls within the established range for a high arch (0.8–1.0). Consequently, the order of prevalence among the foot types in the population was determined to be High Arch > Normal Foot > Flat Foot (Pes Planus).

Furthermore, the study identified gender-based variations in foot morphology. There was a clear sexual dimorphism in foot length, with male participants exhibiting significantly longer feet compared to their female counterparts. However, no statistically significant differences were observed between the genders in midfoot breadth, heel breadth, or arch index. This indicates that although males generally have longer feet, the overall structure and proportions of the plantar arch remain consistent across both sexes. the findings of this study provide valuable baseline data for understanding foot morphology within the Ikwerre population. The results hold practical significance for orthopaedists and podiatrists in Nigeria, as they can inform the diagnosis, prevention, and management of foot deformities, particularly among young adults.

RECOMMENDATION

It is therefore recommended that further research on flat foot amongst adolescents should be carried out in other populations.

Conflict of Interest: Authors declare that they do not have any conflict of interest

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