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Association between flatfoot and age is mediated by sex: A cross-sectional study

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ABSTRACT

Introduction: Flatfoot (*pes planus*) is one of the most frequently encountered pediatric foot deformities. In spite of the numerous evidences for adverse implications of flatfoot to the locomotive system and musculoskeletal health of patients, in the continuum of developmental milestone, the age to which patients should be monitored for flatfoot remains debatable.

Aim: We investigated the prevalence and pattern of flatfoot in a Nigerian population ranging from 6 to 25 years of age in order to describe the triad of age-sex-flatfoot preponderance.

Material and methods: This was a cross-sectional study among 620 participants using the footprint method and the planter arch index – Staheli arch index criteria for flatfoot diagnosis.

Results and discussion: Flatfoot prevalence in the study population was 27.4%; children had the highest prevalence (28.3%) and adults had the lowest (20.0%). Most of the flatfoot was unilateral (60.0%) and was the flexible form (73.8%). The transition from childhood to adulthood was associated with a significant decrease in prevalence of flatfoot among the male participants, but there was no association between prevalence of flatfoot and age beyond 9 years among the female participants.

Conclusions: The incidence of flatfoot in the Nigerian population is high. Monitoring for flatfoot into adulthood is advisable particularly for the male patients.

1. Introduction

Concern over flatfoot is a common reason for frequent clinical consultations.[1] There is also controversy over the clinical characterization of flatfoot, the degree of disability it causes in adulthood, and the requirement and choice of treatment.[2,3] Additionally, there is evidence that flatfoot may cause gait disorders in adulthood.[4–7]

Increased age is associated with a decreased prevalence of flatfoot.[8–11] However, whether this decrease differs between the sexes, particularly as patients approach adulthood, is

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unknown.[12] In addition, reports of sex predisposition to flatfoot have been inconsistent.[11–15] Although this inconsistency could be due to ethnic variations, some studies of patient populations of uniform ethnicity have produced contradicting findings. In a Nigerian population, for instance, Eluwa et al.[14] reported a higher prevalence of flatfoot in female patients, but male patients had a higher prevalence in a study by Ezema et al.[11] Interestingly, participants in the study by Eluwa et al. were much older, raising the question of whether a change in gender predisposition to flatfoot truly occurs between children and adults. At what age does this occur, if there is indeed a change?

A study in a population composed of children, adolescents, and adults may provide information regarding age and sex differences associated with flatfoot prevalence and guide a hypothesis regarding a possible change of sex prevalence between children and adults.

2. Aim

The aim of this study was to investigate the prevalence and patterns of flatfoot in a representative Nigerian sample including children and adults. Our secondary aim was to determine the triad of age-sex-flatfoot preponderance.

3. Material and methods

3.1. *Study design and participant*

We employed a cross-sectional design with 620 participants. Participants were voluntary sample of children, adolescents, and adults in age ranging from 6 to 25 years of age recruited from public schools in Enugu metropolis. Physical examinations and subjective assessments, as well as discussions with the students, were done in order to rule out those who had foot deformities or other criteria excluding them from participating in this study. Students with evidence of previous foot operations or who had injuries requiring a non-weight-bearing period at the time of the study were excluded. Students with lower limb paralysis or paresis were also excluded. Subjective assessments included queries regarding diagnoses of metabolic syndrome or any other conditions that could impair objective measurement of any of the anthropometrics of interest, thus forming exclusion criteria.

Physical examinations included inspection for open injuries, foot ulcers, lower limb fractures or dislocations, previous foot surgeries, swelling or inflammation, neurological sequelae, or any other conditions that could impair the objective diagnosis of flatfoot and form exclusion criteria. Included were participants without any lower limb disorder that would hamper accurate measurement of the plantar arch. The presence of symptomatic flatfoot was not an exclusion criterion if an accurate footprint could be obtained.

3.2. *Procedure for data collection*

Following ethical approval by University of Nigeria Teaching Hospital Research Ethics Committee, visits were made to the various schools on prescheduled days during which the purpose, procedures, and relevance of the study were explained to the participants before their informed consent was requested and obtained. All adult participants signed a voluntary informed consent form appropriate for the study. The school guardians of the children and adolescents gave consent for those who voluntarily agreed to participate. Participants' privacy and confidentiality were maintained by secluding the assessment areas, using code numbers instead of names in data presentation, and keeping the records confidential.

To have representative samples of different age groups, recruitment involved two sampling techniques. For the children and adolescents, a stratified multistage sampling was used. Final inclusion from each school was by proportional random sampling based on the population of students aged 6–17 years who met the eligibility criteria. For the adults, a convenient sample was drawn from two representative institutions of higher education in Enugu metropolis.

3.3. *Measurement*

Participants' height (cm) was obtained using a height meter, while their weight (kg) was measured with a weighing scale. BMI was obtained through a mathematical calculation based on height and weight (weight/height^2, kg/m^2). For participants 15 years of age and younger, an age-and sex-specific BMI calculation was used.

To obtain the arch measurement the footprints method was used. Participants' feet were first cleaned thoroughly. Each participant was seated and asked to dip the foot to be studied onto a cyclostyling ink pad. The foot was removed from the cyclostyling ink and the participant was asked to stand and print the foot firmly onto a sheet of paper attached to a wooden platform, at the same time flexing the ipsilateral knee slightly (up to 30°).[11,13,16] Each footprint was obtained with the participant in the standing position with the limb bearing about 50% of the body weight. These procedures were repeated for the contralateral foot.

To calculate the plantar arch index (PI), the Stahelli arch index crieteria[16] was employed. A pencil line was drawn tangential to the medial forefoot edge and the heel region. The midpoint of this line was determined. From this point, a perpendicular line was drawn crossing the footprint.[17,18] The same procedure was repeated for the heel tangent point. The perpendicular distance (A, the perpendicular line representing the width covered by the ink from the medial edge to the lateral edge of the midfoot) was noted. A second perpendicular distance (B, the perpendicular line representing the width covered by the ink from the medial edge to the lateral edge of the rearfoot) was also obtained. The PI was derived by dividing the value of A by the value of B (Fig. 1). A PI value greater than 1.15 was considered evidence of flatfoot.[16]

A heel-rise test (tiptoe standing) to differentiate between flexible and rigid pesplanus was conducted for all participants diagnosed with flatfoot by the foot impression test.[19] Participants stood with their full body weight borne on the leg not being tested and held the ankle of the leg being tested in plantar flexion (tiptoe position). If an arch appeared, flexible pesplanus was indicated. If an arch did not appear, rigid pesplanus was diagnosed.

Fig. 1 – Analysis of a footprint to determine the plantar arch index (PI). The arrows indicate the boundaries of: (A) the width of the narrowest part of the midfoot; and (B) the width of the widest part of the rear foot. PI was calculated as length of A divided by the length of B.
Adapted from Ezema et al.[11]

3.4. Data analysis

A power analysis for the minimum sample was performed following the formula described by Daniel,[20] using the mean of prevalence (17.5%) of two reports of flatfoot among children[11] and adults.[14] A 95% level of confidence and a precision of 5%[21] were used to derive the sample size. By this calculation, a minimum sample of 601 participants was required. Associations between personal characteristics and flatfoot prevalence were analyzed with the χ^2 test. All data were analyzed using SPSS version 15 (SPSS Inc., Chicago, IL, USA) with all inferential statistics two-tailed and the level of significance set at $P \leq 0.05$.

4. Results

Slightly more than half (322; 51.9%) of participants were male. The majority were 10–21 years of age (65.9%) and were either underweight or of normal weight (92.9%). Approximately 27% had flatfoot, most of which (73.8%) was flexible and unilateral (60%). Details of the demographic characteristics, prevalence, types, and pattern of flatfoot are presented in Table 1.

Table 1 – Personal characteristics of participants and prevalence of flatfoot.

	n	%
Age, years		
6–9	128	20.6
10–15	211	34.0
16–21	198	31.9
22–25	83	13.4
Gender		
Male	322	51.9
Female	298	48.1
Weight Status		
Underweight	287	46.29
Normal Weight	289	46.61
Overweight	36	5.58
Obese	8	1.29
Flatfoot present		
Yes	169	27.35
No	449	72.65
Laterality of flatfoot		
Left	55	32.4
Right	47	27.6
Both	67	40.0
Type of flatfoot		
Rigid	39	23.1
Both	5	3.1

We could not analyze foot print for two participants because their prints got damaged.

In total, 48 (7%) of the participants reported foot pain; 41 of these had flatfoot (16 flexible, 25 rigid). Participants who had flatfoot and reported pain were distributed among the age groups as follows: 6–9 years (18/36; 50%), 10–15 years (12/72; 16.7%), 16–21 years (6/51; 11.8%), and 22–25 years (5/10; 50%). All of the participants 16–25 years of age with foot pain had rigid flatfoot; however, only 9 (50%) of the 6–9 years old with foot pain had rigid flatfoot. Generally, there were no significant associations of flatfoot with either of weight, or sex (Table 2).

Flatfoot prevalence was highest (34.3%) among participants 10–15 years old and lowest (11.4%) among those 22–25 years old. There was a significant association between age and flatfoot prevalence. When divided by sex, female participants 10–15 years old had the highest prevalence (36.9%), but the association between age and flatfoot was no longer statistically significant. Male sex consistently had a significant association with flatfoot; among male participants, the highest prevalence was in the group 6–9 years of age and the lowest was in the group 22–25 years of age. A post hoc analysis of the significant association seen among the male participants revealed that the prevalence of flatfoot decreased between those 6–9 years old and 10–15 years old, remained somewhat stable between those 10–15 years old and 16–21 years old, and decreased again between those 16–21 years old and 22–25 years old. The same pattern was seen when participants were categorized into children, adolescents, and adults using the World Health Organization (WHO) criteria.[22] Using the WHO criteria, there were no differences in prevalence among the three age groups for female participants ($\chi^2 = 5.672$, $P = 0.059$). For male participants, there was a significantly lower prevalence in adults than in children and adolescents ($\chi^2 = 22.219$, $P = 0.001$). See details shown in Table 2.

Table 2 – Association between age, gender, weight status and prevalence of flatfoot.

	Yes	%	χ^2	P
Age, years				
6–9	36	28.13	15.319	0.004*
10–15	72	34.29		
16–21	51	26.15		
22 and above	10	11.39		
Gender				
Male	84	26.25	0.509	0.473
Female	85	28.52		
Weight status				
Underweight	89	31.01	6.503	0.09
Normal weight	71	24.57		
Overweight	7	19.44		
Obese	2	66.67		

Association between age and prevalence of flatfoot by gender strata

Age	Female				Male				Post hoc (Male)			
	n	%	χ^2	P	n	%	χ^2	P	6–9	10–15	16–21	22–25
6–9	14/60	23.3	7.87	0.097	22/68	32.4	11.40	0.01*	–	0.001*	0.001*	0.001*
10–15	45/122	36.9			27/88	30.7				–	0.44	0.01*
16–21	17/64	26.6			34/131	26.0					–	0.008*
22–25	9/52	17.4			1/33	9.0						–

Association between age and prevalence of the male of flat foot by gender strata and post hoc analysis of the male

Differing	Ages, years	Female				Male				Post hoc (Male)		
		n	%	χ^2	P	n	%	χ^2	P	6–9	10–19	20 and above
Children	6–9	14	23.3	5.672	0.059	21	31.8	22.219	0.001*	–	0.997	0.001*
Adolescence	10–19	58	34.1			62	31.8				–	0.001*
Adults	20 and above	13	20.0			1	1.7					–

* Statistically significant ($P < 0.05$).

5. Discussion

In this study, the overall prevalence of flatfoot was 27.35%. Pes planus occurred unilaterally in most cases, and the flexible form was more common. Age but not BMI was associated with flatfoot. Pain was present in approximately 64% of the individuals with rigid flatfoot.

5.1. *Flatfoot prevalence*

The age-group-specific prevalence of flatfoot in our study is similar to that of recent reports in similar populations. In 2009, Eluwa et al. reported a prevalence of 13.4% among individuals aged 20 to 30 years, while Ezema et al. reported a prevalence of 22.7% among children aged 6 to 10 years.[11] The prevalence among children 6–9 years of age in our study is higher than that in a report from Asia.[23] In addition, the prevalence among participants 16–21 years of age in our study is about three times higher than that reported among a Saudi Arabian population of a similar age.[24] The higher prevalence found in our study could be explained by an ethnic variation in foot morphology, which has been well documented.[25,26] Our prevalence result is similar to that found in previous studies in this population.[11,14] The influence of shoe-wearing habits in medial arch development is still debated.[27,9] We did not inquire about footwear use among our participants; this constitutes a limitation of our study.

The prevalence results of our study imply that nearly 3 of 10 people from 6 to 25 years of age in Nigeria have flatfoot. This proportion falls to approximately 1 of 10 when considering only individuals from 20 to 25 years old. Our findings suggest that Nigerians, and potentially Africans in general, have a higher prevalence of flatfoot than do Asians.[23,24] Our results provide evidence that flatfoot is common in Nigeria and support approaches to reduce potential consequences. Abnormal foot biomechanics related to flatfoot have been implicated in several foot and lower limb disorders, including the risk of ankle sprain,[28] fascial thickening,[29] and patellofemoral pain.[30]

5.2. *Types of flatfoot and their association with foot pain*

Our finding implies that more than 1 in every 5 cases of pesplanus in our population is the rigid form. This is a concern, given that rigid flatfoot does not resolve and increases the risk of numerous biomechanical and gait disorders.[31] Twenty five of the 39 individuals diagnosed with rigid flatfoot (64%) reported foot pain, as compared to approximately 13% of those with flexible flatfoot. While it is certain that flatfoot deformity is a problem in the Nigerian population, the high prevalence of the rigid form of the disorder in this population exacerbates poorer prognosis.

That the majority of the flatfoot diagnoses in this study were unilateral is surprising. A previous report has shown that most cases of flatfoot occur bilaterally;[23] this was similar to the findings of a recent study in a Nigerian population similar to ours.[11] This finding could have been caused by our foot print capture technique, but there are two arguments against this conclusion. First, we cannot attribute this finding to measurement error, because we used the approved standard methodology for obtaining foot arch measurements.[32] Second, the knee flexion used in our methodology is similar to that present during the double support phase of gait.[25,33]

No standard assessment of flatfoot subtypes (i.e., rigid, flexible, symptomatic, developmental) was available until the recent development of the flatfoot proforma (FFP), which is centered on accurate diagnosis of suggested subtypes of flatfoot (flexible, rigid).[1] Because many of the elements of the FFP were not included in our study, the proforma could not be used to classify flatfoot in our study population. Our finding of a higher prevalence of unilateral flatfoot arguably resurrects the debate regarding the laterality of flatfoot. Future research should address this study limitation by using the FFP to classify the subtypes of flatfoot.

5.3. *Interaction among age, sex, and the prevalence of flatfoot*

Several studies have reported that the prevalence of flatfoot decreases with age.[11,17,32–34] To our knowledge however, this is the first study that has shown the transition in flatfoot prevalence from children to adults within a population. Our findings suggest a selective male association of flatfoot with age. Among the male participants, prevalence decreased significantly after 9 years, plateaued between 16 and 21 years, and then decreased further. Classifying male participants into children, adolescents, and adults according to the WHO criteria,[22] a similar result was found, with the prevalence decreasing in adults as compared to the children or adolescents. There was no age preponderance to flatfoot in the female participants. This suggests that the foot arch in males may continue to develop into early adulthood. Volpon reported that, unlike the medial arch of girls, the feet of boys continue to grow beyond the age of 12 years.[12] The higher prevalence of female flatfoot in the adult population may be explained by the continued development of the male arch even into early adulthood. If this holds true, improvement in the medial arch as well as reduction of the rear foot angle may still be possible in young adults, particularly in young men.

Ankle-flattening force,[35] shown to increase with age, was not examined in our study population. However, we believe that an increase in ankle force would be unlikely to explain any difference in prevalence unless the increases were differentiated by sex. A study of possible sex mediation in ankle-flattening force and its influence on development of the foot arch between the sexes is warranted. Studies have also demonstrated a higher incidence of flatfoot among people who wore shoes in early childhood and have greater ligament laxity.[36,37] Strength is another possible influence on flatfoot outcome[35] that we did not investigate in our participants; this is an area of improvement for future studies. A prospective longitudinal study is warranted to clearly explain the sex-age-flatfoot triad. Such a study should also consider the possible influence of other factors that have been associated with age, including ankle-flattening force, ankle range, physical activity, strength, and footwear, and should consider using a methodology such as Chippaux-Smirak index for footprint measurement.

6. Conclusions

The high prevalence of underweight participants in our study population is a public health concern particularly applicable to Nigeria and potentially to all of Africa. Approximately 1 of every 5 cases of flatfoot is rigid, which is often associated with foot pain. Sex-mediated influences on foot morphology with age may have an impact on the differential prognosis of flatfoot in male and female patients from childhood to adulthood. Although female patients are at higher risk, monitoring for flatfoot into adulthood is advisable for male patients as well. Possible interventions might include routine compulsory flatfoot screening for new entrants to school. Close monitoring of patients diagnosed with flatfoot as well as symptomatic treatment should be made freely available. Screening and monitoring should be available for all children and adolescents at risk, regardless of their weight. Patients should also be screened for rigid flatfoot, because this condition commonly presents with foot pain.

Conflict of interest

None declared.

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