RESEARCH REPORT

Flat foot and associated factors among primary school children: A cross-sectional study

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KEYWORDS
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Abstract Prevalence of flat foot and its associated personal characteristics among public primary school students was investigated. This cross-sectional study involved 474 public primary school students (253 females and 221 males) between the ages of 6 and 10 years. Flat foot diagnosis was made using Staheli plantar index (PI), where values >1.15 were indicative of flat foot. The number of children diagnosed with flat foot was 106, yielding a prevalence rate of 22.4%. Flexible flat foot accounted for 93 (87.7%) of the positive diagnoses, whereas bilateral flat foot was present in 97 (91.5%) of the cases. There was a significant relationship between higher prevalence of pes planus and older age, with the 6-year-old group showing the highest prevalence. Boys were twice as likely to be diagnosed with flat foot as girls, and obese participants were three and a half times more likely to have flat foot compared with those of normal weight. In summary, about one in every five public primary school children aged 6–10 years would be diagnosed with flat foot anomaly, and obesity further increased the risk. Preregistration flat foot screening, and periodic observation for onset of symptoms of progression, should be made available for primary school children.

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Introduction

Foot posture is an established factor in determining the function of the lower limb and may therefore have a role in a predisposition to repetitive injury [1–3]. Flat foot deformity is frequently encountered in paediatric orthopaedic and rehabilitation practices. Flat foot (pes planus) is a biomechanical problem consisting of a constellation of physical features that includes excessive...
evolution of the subtalar complex during weight-bearing, with plantarfexion of the talus, plantar flexion of the calcaneus in relation to the tibia, dorsiflexion and abduction of the navicular, supination of the forefoot, and valgus posture of the heel [4,5]. Flexible flat foot tends to disappear when the lower limb is not weight-bearing and rarely causes disability or requires treatment, although overuse may cause pain [5]. In contrast, rigid flat foot is a pathological foot condition that may arise from acquired or congenital causes ranging from structural abnormalities, collagen disorders, musculoskeletal abnormalities, trauma, spastic conditions, or neurovascular conditions [5,6]. People with flat foot are at higher risk of foot pain, knee pain, foot injury, stress fracture, and poor exercise performance [7]. The prevalence of flat foot varies across different studies. Some researchers have shown that prevalence of pes planus decreases with age [8,9]. Others have pointed sex preponderance [10,11]. Therefore, paediatric flat foot remains a controversial topic in the clinical community [12–22]. Substantial knowledge gaps still exist in the field [23]. In particular, the controversy around whether or not and when it is necessary to treat a nondevelopmental asymptomatic flat foot in children is yet to be resolved [24]. Also, there is a dearth of research on the prevalence of flat foot among school-aged children in Nigeria. Such information will highlight the need for school-wide screening and continuous monitoring for school-aged children at risk. Similarly, since the critical time for the development of the plantar arch is just prior to the age of 6 years [25], a study sample of participants <6 years may overestimate the prevalence of flat foot. Therefore, this study was aimed at investigating the prevalence of flat foot and its associated personal characteristics in a sample of Nigerian primary school children aged 6–10 years.

Materials and methods

Research design

The study employed a cross-sectional descriptive design with 474 participants. A multistage sampling technique was used (Fig. 1). A list of all local governments in Enugu metropolis was drawn. This was followed by a list of every layout in each of the three local governments listed. Then, two layouts from each of the three local governments were chosen by the simple random technique, bringing a total of six layouts. This was followed by another simple random sampling selecting one school from each of the six layouts. A list of all children aged 6–10 years who met the eligibility criteria described.

Participants

A total of 474 primary school children between the ages of 6 years and 10 years, attending public primary schools in Enugu metropolis and who met the inclusion criteria, participated in the study. Ethical approval was obtained from the Enugu State Education Board. Participants were fully informed about the data collection procedures and protocol, after which the headmasters/mistresses gave their informed consent on behalf of the students who volunteered to participate. Only those who volunteered to participate in the study were recruited. To be included, an individual had to be a student of one of the six primary schools selected, be between 6 years and 10 years of age, and not have any lower limb disorder that would hamper accurate measurement of the foot plantar arch. Students with evidence of foot deformity or previous foot surgery, or those with injuries that require a period of non-weight-bearing at the time of the study, were excluded from participating. Students with lower limb paralysis or paresis were also excluded.

Measurement

The height of the individuals (in cm) was measured with a height meter and their weight (kg) was obtained using a weighing scale. The feet were first cleaned thoroughly. The participant was placed in a sitting position and then asked to dip the foot to be studied into a tray filled with ink. The foot was then removed from the tray and the participant was asked to stand up to print the foot firmly on a sheet of paper attached to a wooden platform, while at the same time flexing the ipsilateral knee slightly (up to 30°). Each foot print was obtained in the standing position with the limb bearing about 50% of the body weight. The above procedures were repeated for the contralateral foot. The footprints were then used to calculate the plantar arch index (PI). Using a lead pencil, a line was drawn tangent to the medial forefront foot and the heel region. The midpoint of this line was determined. From this point, a perpendicular line was drawn crossing the footprint [28,29]. The same procedure was repeated for the heel tangency 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 measured. Also, 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 measured. The PI was then calculated by dividing the value of A by the value of B [29,30] (Fig. 2). An individual was considered to have flat foot, if his/her PI...
value was >1.15 [12]. This is a well validated method of measuring the PI [26,27].

**Differentiating between the flexible and the rigid pes planus**

A heel raise test (tiptoe standing) was conducted for all the participants diagnosed with pes planus from the foot impression test [4]. In the standing position, while bearing full body weight on the contralateral leg (the leg not being tested), the participant was asked to plantar flex (tiptoe) the ankle of the leg being tested. If the arch appeared, flexible pes planus was indicated. If the arch did not appear, rigid pes planus was diagnosed.

**Data analysis**

*A priori* power analysis was carried out to determine the minimum sample needed for the study utilizing the prevalence of flat foot reported by Chen et al [31] and based on the minimum sample calculation for infinite population [32], a 95% level of confidence and a precision of 5% [33,34]. Based on this analysis, a minimum sample of 322 participants was required.

The prevalence of flat foot and personal characteristics of the participants were presented in tabular form by using percentage frequencies. Body mass index (BMI) was compared with the values provided by the age- and sex-specific Centre for Disease Control (CDC) growth charts for Enugu metropolis.
Results

Prevalence and pattern of distribution of pes planus

A total of 474 children aged 6–10 years attending public primary school in Enugu metropolis participated in the study. Table 1 shows the demographic profile of the students. There were 253 (53.4%) girls and 221(46.6%) boys. A total of 153 (32.3%) of the students were underweight, whereas 160 (33.8%) students were either overweight or obese. The prevalence and pattern of distribution of flat foot observed in this study is shown in Table 2. One hundred and six (22.4%) students had flat foot, 93 (87.7%) of which were flexible, and 97 (91.5%) students had flat foot on both sides.

Association between personal characteristics and prevalence of pes planus

The association between demographic and anthropometric characteristics and the prevalence of pes planus is shown in Table 3. The prevalence of pes planus was highest (46.3%) among students in the 6-year-old group and lowest (7.1%) in the 10-year-old group. There was a significant association between increased prevalence of pes planus and advancing age ($p < 0.001$). While 64 (40.8%) of the male students demonstrated evidence of pes planus, only 42 (19.9%) of the females did. The association between sex and flat foot anomaly was found to be significant ($p < 0.001$). Increasing weight status was also significantly associated with a higher prevalence of pes planus ($p < 0.001$). The prevalence of flat foot was highest in the obese (53.4%) group and lowest in the underweight group (13.1%).

Table 4 shows the post hoc analysis of the significant association observed between age, weight status, and prevalence of pes planus. For the post hoc analysis of age, all results were significant, except that the prevalence of pes planus was not significantly different between the 7-year-old and 8-year-old groups ($p = 0.181$), and between the 9-year-old and 10-year-old groups ($p = 0.143$). For post hoc analysis of weight status, all comparisons were
significant, except that between the underweight and normal weight groups ($p = 0.640$).

**Discussion**

In this study, the overall prevalence of flat foot was 22.4% among students aged 6–10 years. We also found that pes planus occurred bilaterally in most cases and that the flexible form of pes planus was more common. The study demonstrated that medial arch development was associated with age, sex, and BMI.

**Prevalence of pes planus**

The prevalence of flat foot in our study differed from findings from earlier studies. Echarri and Forriol reported a prevalence of flat foot of 70% in children aged 3–4 years and 40% in those aged 5–8 years [9] whereas Pfeiffer et al reported a prevalence of flat foot of 44% and rigid flat foot $>1%$ among 3–6-year-old children [24]. In another study, Gould and colleagues found that hyperpronation was present in 78% of 5-year-olds [36]. The higher prevalence reported in these studies may be due to the younger age of their participants compared with the present study. Staheli et al found that flat feet of various types was invariably present in infants and common in children [12]. Rose has also shown that the critical age for development of plantar arch is just prior to the age of 6 years and the prevalence of flat foot evaluated prior to this age may result in overestimation of the problem [28]. This is further confirmed in a related study by El et al, in which a lower prevalence rate of 17% of moderate to severe flexible flat foot in a sample of 579 school-aged children (mean age $= 9$ years old) was reported [37]. Additionally, we cannot rule out the possibility of ethnic variations in foot morphology. In a study involving Spanish children aged 4–13 years, a prevalence rate of pes planus as low as 2.7% was reported [24].

A prevalence of $>22%$ in our study means that more than one in every five primary school children has flat foot,

**Table 3**

| Personal characteristic | Normal footed (PI $\leq 1.15$) | Flat footed (PI $>1.15$) | $\chi^2$ | $p$ |
|-------------------------|---------------------------------|--------------------------|---------|----|
| Age of participants (y) |                                 |                          |         |    |
| 6 ($n = 82$)            | 44 (53.7)                       | 38 (46.3)                | 50.927  | <0.001* |
| 7 ($n = 94$)            | 66 (70.2)                       | 28 (29.8)                |         |    |
| 8 ($n = 88$)            | 68 (77.3)                       | 20 (22.7)                |         |    |
| 9 ($n = 97$)            | 85 (87.6)                       | 12 (12.4)                |         |    |
| 10 ($n = 113$)          | 105 (92.9)                      | 8 (7.1)                  |         |    |
| Sex                     |                                 |                          |         |    |
| Male ($n = 221$)        | 157 (59.2)                      | 64 (40.8)                |         |    |
| Female ($n = 253$)      | 211 (80.1)                      | 42 (19.9)                | 10.377  | 0.001* |
| Weight status category  |                                 |                          |         |    |
| Underweight ($n = 153$) | 133 (86.9)                      | 20 (13.1)                |         |    |
| Normal weight ($n = 160$)| 137 (85.1)                      | 24 (14.9)                |         |    |
| Overweight ($n = 87$)   | 64 (73.6)                       | 23 (26.4)                | 54.161  | <0.001* |
| Obese ($n = 73$)        | 34 (46.6)                       | 39 (53.4)                |         |    |

Data are presented as n (%).

*Indicates statistical significance ($p < 0.05$).

**Table 4**

| Post hoc analysis of association between personal characteristics and prevalence of flat foot |
|---------------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|
| Age (y)                                     | 6                                           | 7                                           | 8                                           |
| 6                                           | 5.171 (0.018*)                              | 10.530 (0.001*)                             | 25.473 (<0.001*)                            |
| 7                                           |                                              | 1.167 (0.181)                              | 8.746 (0.003*)                             |
| 8                                           |                                              |                                              | 3.459 (0.048*)                             |
| 9                                           |                                              |                                              |                                              | 10.103 (0.001*)                            |
| 10                                          |                                              |                                              |                                              | 1.686 (0.143)                              |
| Weight status category (from BMI in kg/m²)  | Obese                                       | Overweight                                 | Normal weight                               | Underweight                                |
| Underweight                                 | 41.716 (<0.001*)                            | 6.736 (0.009*)                             | 0.219 (0.640)                              |                                              |
| Normal weight                               | 37.875 (<0.001*)                            | 4.888 (0.027*)                             |                                              |                                              |
| Overweight                                  | 3.645 (0.039*)                              |                                              |                                              |                                              |
| Obese                                       |                                              |                                              |                                              |                                              |

Data are presented as Chi-square value ($p$).

*Indicates statistical significance ($p < 0.05$).
adding to the body of evidence that paediatric flat foot is not an uncommon condition. This lends credence to the need for an approach towards preventing consequent problems later in life. Several authors suggested that flat feet in adults may be associated with a greater risk of injury or other problems. An Israeli study, for instance, showed that lower foot arches appeared to increase the risk of ankle sprains [38]. Moreover, midfoot morphometry predicted successful treatment of patellofemoral pain with orthoses [39]. A lower arch height of the foot has also been associated with fascia thickening and pain in an Australian study [40].

Association with age

In the present study, the prevalence of flat foot decreased significantly with advancing age. In particular, the prevalence quickly dropped between the ages of 6 years and 7 years, whereas the change between the ages of 7 years and 10 years was not as prominent, as revealed in the post hoc analysis (Table 4). Independent reports have also shown a decrease in the prevalence of flat foot with advancing age [12,24,29,36,41]. This may be attributed to the resolution and improvement of medial arch [25], as well as the reduction of rear foot angle [14] with age. Our results also concord with the finding that the critical time for the development of the plantar arch is around the age of 6 years [25]. Our results also showed that there was no significant difference in prevalence of pes planus between the ages of 9 years and 10 years, suggesting that paediatric flat foot may be likely to grow into adult flat foot if it is not resolved at the age of 9 years. However, a prospective cohort study is required to prove this hypothesis.

Association with sex

Our findings demonstrated that male children were twice as likely to be affected by flat foot than their female counterparts. This is consistent with previous reports [24,25,32,42], including a Taiwanese study involving 2083 children aged between 7 years and 12 years [42], and another study of 5866 Greek children aged between 6 years and 17 years [15]. The higher incidence of flat foot among male children could be explained by the greater rear foot valgus and retarded development of rear foot in boys compared with girls. Interestingly, Eluwa et al found a higher incidence of flat foot among females compared with males [11]. The discordance in results could be explained by the difference in age, with their participants at a much older age (20–30 years old). Also, as both the current study and the study by Eluwa et al were conducted in Nigeria, a question is raised regarding whether there is a real switch in sex preponderance to pes planus between the children and adult population, and at what age this occurs if there is indeed a switch. A prospective study is required to answer this research question.

Association with weight status

Our study showed that the weight status was significantly associated with flat foot. Obese children were three and a half times more likely to be diagnosed with flat foot compared with children of normal weight. A similar association has been reported by previous studies conducted in other countries [14,24,42,44]. Can this association be explained? The effects of temporary loading intensity on foot biomechanics have been examined [26] and obesity during childhood has been shown to relate to certain dimorphism of the foot, particularly flat foot [43]. However, not much has been reported on the long term loading effects of obesity on the developing longitudinal arch of growing children [45]. Nevertheless, it cannot be ruled out that the high prevalence of flat foot in overweight and obese children may be related to the continued pressure exerted on the longitudinal arch during gait.

Clinical implications

The findings of this study underscore the importance of school-wide screening, as well as preregistration physical examination and monitoring for flat foot, so as to engender early diagnosis and intervention strategies for children at risk. In particular, attention should be given to overweight/obese and male children, as these populations tend to have a higher risk of flat foot. Certainly, the problem of paediatric obesity needs to be tackled. Proper management strategies, including appropriate physical activity, dietary control, and education of children and parents are important. We also suggest that very close monitoring be given to individuals with flat foot between the ages of 8 years and 10 years, as it appears that arch development plateaus after the age of 9 years.

Limitations

This study has several limitations. First, we did not study the prevalence of flat foot among children older than 10 years of age. The results can only be generalized to those who are 6–10 years old. We did not gather information on potentially relevant factors, like parental income level, family history of flat foot, or dietary intake. Consequently, we could not compare our findings with children of older years; neither were we able to give a precise reason for the underweight and obesity problems in this population. Further study is required to determine conclusively the age at which the flat foot in a child will not resolve with growth. Finally, our report is cross-sectional and can only provide some insights into the association between the prevalence of pes planus and other factors (e.g., age, sex, and weight status). Causality, however, cannot be established. Therefore, the findings should be interpreted with caution. A prospective longitudinal study is needed to clearly demonstrate the influence of sex, varying BMI, and advancing age on the incidence of flat foot.

Conclusion

The prevalence of flat foot among Nigerian children is high compared to figures from many developed countries. Obese children, male children, and those of a younger age (<9 years) are at a higher risk and therefore, may require
closer monitoring. Prospective research is needed to unravel the interaction between foot arch and relevant risk factors.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

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