Proportion of flatfoot among primary school children and its association with Body Mass Index: a cross-sectional sample study

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ABSTRACT

INTRODUCTION

A flatfoot is common during childhood and is regarded as a part of normal foot development. Nevertheless, the persistence of flatfoot beyond early childhood may affect the biomechanics of lower limb, causing discomfort and pain. Although increased body weight has been identified as a potential contributing factor, evidence from Nepal remains limited. The study aims to determine the prevalence of flatfoot among children aged 6-10 years and assess its association with body mass index (BMI).

MATERIAL AND METHODS

A cross-sectional study was carried out among 361 children aged 6–10 years from selected schools in Ward 10 of Suryabinayak Municipality, Bhaktapur. Participants were recruited using a multistage cluster sampling technique. Body mass index was calculated and categorized using Centers for Disease Control and Prevention (CDC) age- and sex-specific percentiles. Flat foot was assessed from inked footprints using Staheli's plantar arch index. Associations between flatfoot and demographic variables were analyzed using Chi-square test. A *p*-value of <0.05 was considered statistically significant.

RESULTS

The overall prevalence of flatfoot was 18.8%. Flatfoot was significantly associated with age ($p< 0.05$) and body mass index ($p<0.05$), with prevalence decreasing with increasing age and increasing across body mass index categories. Although flatfoot was more common in boys than girls, the association was not statistically significant ($p = 0.096$).

CONCLUSION

The prevalence of flatfoot is relatively high in primary school-aged children and is positively associated with body mass index. Promoting foot health screenings and healthy weight maintenance may help reduce potential biomechanical consequences of flatfoot.

KEYWORDS

Body mass index, Flatfoot, Staheli's plantar arch index

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INTRODUCTION

Flatfoot (pes planus) refers to reduction or absence of the medial longitudinal arch while weight-bearing. In infant and toddlers, presence of flat foot is considered normal. However, when it persists beyond childhood it can lead to altered foot biomechanics, increasing the risk of discomfort and pain in the knees, ankles, and feet,[1] as well as reduced mobility.[2]

Epidemiological studies have reported a higher occurrence of flatfoot among children with increased body mass, suggesting that excess body weight can raise plantar pressure and may hinder typical development of foot arch.[3] Understanding this association is crucial for early diagnosis and timely intervention, especially given the rising global prevalence of childhood obesity.

In Nepal, routine pediatric foot assessment has not been prioritized, and locally generated epidemiological data remain scarce. The present study was designed to determine the prevalence of flatfoot among primary school children aged 6–10 years and to evaluate its association with body mass index (BMI) within a community-based setting. Identifying the prevalence and risk factors of flat foot in children can help in designing targeted preventive strategies and raising awareness about its impact on overall musculoskeletal health. The findings will provide valuable insights for healthcare professionals, educators, and policymakers to improve foot health, promote early interventions, and prevent potential complications.

MATERIAL AND METHODS

A cross-sectional study was conducted among primary school children aged 6–10 years from both government and private schools in ward 10 of Suryabinayak Municipality, Bhaktapur after obtaining approval from IRC-PAHS (ref:bss2511282166). Children aged 6–10 years were included because during this period the medial longitudinal arch undergoes progressive development. Flat foot is a physiological finding in children younger than 6 years, and the arch is well established in most children by around 10 years of age.[4] Selecting this age range reduces the likelihood of including physiological flat feet and improves the accuracy of assessing true flat foot. Children whose parents provided written consent and who gave verbal assent were included in the study. Children with a history of foot trauma, fracture, surgery, or congenital foot deformities such as osteomyelitis or foot drop were excluded.

The sample size was calculated using the formula $n= Z^2pq / e^2$, where, Z=1.96 at 95% Confidence Interval (CI), q= 1-p, e = margin of error (5%) and p= prevalence of flat foot in obese children (30.8%).[5] The minimum required sample size was calculated to be 328 participants. After adjusting for a 10% non-response rate, the final sample size was increased to 361 participants.

A multi-stage cluster sampling method was employed. Of the eight schools in the ward 10 of Suryabinayak Municipality, Bhaktapur, five were government and three were private. Schools were first stratified by management type, and two schools from each stratum were randomly selected using simple random sampling to ensure representation from both government and private schools. The required number of students from each school was determined using probability proportional to size based on the number of primary students aged 6–10 years, and students were then randomly selected within each school.

Demographic details of the children such as age and sex were collected. Height was measured to the nearest 0.1 cm using a wall-mounted measuring scale with participants standing barefoot in an upright position. Body weight was recorded to the nearest kilogram using a calibrated digital scale with children wearing light clothing. Both measurements were taken twice, and the average was used to calculate BMI-weight (kg) divided by height squared (m^2) and categorized into underweight, normal weight, overweight, and obese according to age- and sex-specific Centers for Disease Control and Prevention (CDC) percentile criteria.[6]

Footprints of both feet were obtained using an ink method. The plantar surface of foot was painted with the ink and the subject was asked to stand and place their foot on A4-sized sheets of paper placed on a tool (3 inches high) to reduce wobbling during weight-bearing on one foot while standing. Each footprint is labeled with unique identification number. A midpoint of a line drawn tangent to the medial border of the forefoot and the heel regionis determined. From this midpoint, a perpendicular line is drawn across the footprint. The same procedure is repeated at the heel tangency. The widths of the narrowest part of midfoot (segment a) and the widest part of the rearfoot/ heel (segment b) of the footprint are measured in millimeters as shown in figure 1.

The Staheli'splantar arch index (SPAI) is then calculated as ration of midfoot width to heel width, i.e, SPAI = segment a/ segment b.

An individual was considered to have flat foot, if his/her SPAI scores was $\geq$ 1.15.[7] The data was collected by main author to minimize measurement bias and reduce errors in identifying anatomical landmarks during assessment. To reduce intra-observer variability, all footprints were analyzed by a single trained observer.

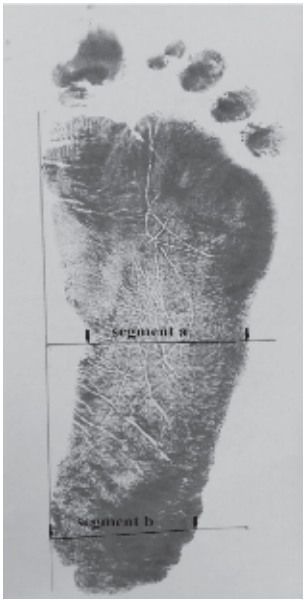

Figure 1. An image of a right footprint; the arrows indicate the boundaries of: the width of the narrowest part of the midfoot (segment a); and the width of the widest part of the rearfoot (segment b)

Data were entered into Microsoft Excel and analyzed using SPSS 16.0. Continuous variables were summarized as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. The prevalence of flat foot was determined as the proportion of children with flat foot in the study population.

The distribution of flatfoot was also determined separately by sex and across different age groups.

Associations between flat foot and categorical variables, including age, sex, and BMI, were assessed using Chi-square test. A *p*-value of <0.05 was considered statistically significant.

RESULTS

Table 1. Demographic characteristics of children aged 6–10 years

Variables	Category	N (%)
Age (years)	6	74 (20.5)
	7	71 (19.7)
	8	75 (20.8)
	9	70 (19.4)
	10	71 (19.7)
Sex	Male	178 (49.3)
	Female	183 (50.7)
BMI	Underweight	69 (19.1)
	Normal weight / Healthy	220 (61.0)
	Overweight	47 (13.0)
	Obese	25 (6.9)

Table 2. Distribution of flat foot and Crude Odds Ratios by age, sex, and BMI among children aged 6–10 years

Variable	Category	Flatfoot present n (%)	Flatfoot absent n (%)	χ^2 value	*p*-value
Age (years)	6	25 (33.8)	49 (66.2)	22.9	<0.05
	7	15 (21.1)	56 (78.9)		
	8	12 (16.0)	63 (84.0)		
	9	10 (14.3)	60 (85.7)		
	10	6 (8.5)	65 (91.5)		
Sex	Male	40 (22.5)	138 (77.5)	2.76	0.096
	Female	28 (15.3)	155 (84.7)		
BMI	Underweight	7 (10.1)	62 (89.9)	21.8	<0.05
	Normal weight / Healthy	38 (17.3)	182 (82.7)		
	Overweight	11 (23.4)	36 (76.6)		
	Obese	12 (48.0)	13 (52.0)		
Total		**68 (18.8)**	**293 (81.2)**		

A total of 361 children aged 6 to 10 years were included in the study, comprising 178 males and 183 females. The overall prevalence of flatfoot was 18.8%. A significant association was observed between age and flatfoot prevalence. The prevalence decreased steadily with increasing age, from 33.8% at 6 years to 8.5% at 10 year. Flatfoot was more prevalent among male children (22.5%) compared with females (15.3%). However, the association was not statistically significant ($p = 0.096$). BMI was significantly associated with flatfoot ($p<0.05$). The prevalence of flatfoot increased progressively with higher BMI, from 10.1% in underweight children to 48.0% in obese children.

DISCUSSION

The prevalence of flatfoot varies widely across different populations worldwide. In the current study, the overall prevalence of flatfoot was 18.8% which is considerably lower than reported in other studies.[8,9] These differences may be due to the younger age of participants in those studies compared to the present study. The plantar arch develops most rapidly between two and six years of age, with a high prevalence of flatfoot present in toddlers, and assessing flatfoot prevalence prior to this age may result in an inflated estimation of the condition.[10] The results of the present study are consistent with findings from more recent studies, including Sadeghi et al., in Iran, which reported a prevalence of 17.1% among school children,[11] and a cross-sectional survey by Senadheera et al., in Srilanka, which found a prevalence of 16.06%.[12] On the contrary, Garcia et al., in Spain found a prevalence of 2.7%,[13] while Rao and Joseph in India reported a prevalence of 8.2% among children aged 6–10 years, both of which are lower than the prevalence observed in the present study.[14]

Arch development starts when a child begins to walk on their own, increases rapidly through the preschool age (around 3-6 years), is mostly formed by about 6-9 years,

and then continue to refine gradually across later childhood and the teenage.[4,15] In this study, a significant association was observed between age and flatfoot, with proportion of flatfoot declining with increasing age, from 33.8% at age 6 to 8.5% at age 10. This age-related decline in flatfoot prevalence aligns with the physiological development of the medial longitudinal arch, which becomes more pronounced as children grow. Both the magnitude and pattern of age-related diminution in flatfoot prevalence in the present study closely resemble findings reported in a Sri Lankan Cohort of children within the same age range, where prevalence rates were 26.35% at 6 years, 16.19% at 7 years, 12.75% at 8 years, 13.57% at 9 years, and 11.1% at 10 years.[12] Similarly, a cross-sectional study conducted on children aged 7–14 years in Saudi Arabia, revealed a significant relationship between age and the prevalence of flatfoot ($P = 0.050$). The study found that children aged 7–8 years had the highest prevalence of flatfoot compared with older age groups, indicating a reduction in flatfoot occurrence as age increased.[2] Li Xiaojun et al., reported fall of flexible flatfoot prevalence from 39.5% at 6 years to 11.8% at 12 years, and then stabilized at a plateau between the age of 12 and 13 years.[16] Overall, these results emphasize that early childhood is a critical period for foot arch development, suggesting that monitoring and early interventions should focus on younger children, while many cases may resolve naturally as children grow.

In this study, male children demonstrated a higher prevalence of flatfoot (22.5%) compared with females (15.3%), however, the association was not statistically significant.The slightly higher frequency observed in boys may be related to developmental or morphological differences i.e., increased deposition of plantar fat in boys may obliterate the arch while taking footprint.[17] The findings of the present study are consistent with several previous studies reporting a higher prevalence of flatfoot among boys. Comparable results were reported by Senadheera et al., in a study conducted among Sri Lankan children aged 6–10 years, who found a higher prevalence of flatfoot in male children, with no significant association between flatfoot and sex.[12] Ezema et al., also reported that male children were more likely to have flatfoot than females among Nigerian primary school children, attributing this difference partly to delayed arch development,increased ligamentous laxity and differences in physical activities level in boys.[18] Similarly, Chang et al., reported a significantly higher prevalence of flexible flatfoot in Taiwanese boys compared with girls, suggesting that sex-related differences in musculoskeletal maturation may influence foot posture during childhood.[19] Conversely, some Cohort,[20] including elementary school students of Anatolia, the prevalence of flat foot was slightly higher in girls (girls-35.5%and boys-28.5%), without statistically significant gender differences.[21] Such discrepancies across studies may be explained by differences in age distribution, methods of assessment (footprint analysis versus clinical or radiographic evaluation), and environmental factors such as footwear and rural and urban residence.[3,19-21] Moreover, several studies have suggested that the association between flatfoot and gender is inconsistent; indicating that sex alone is not a strong determinant of flatfoot prevalence.[3,12,21]

Excess body mass increases mechanical loading across the foot plantar surface potentially influencing structure of the arch during its growth. Additionally, a thicker plantar fat pad in an obese children can obscure the arch during footprint-based assessments, potentially exaggerating the apparent prevalence of flatfoot.[22] In the present study, the prevalence of flatfoot increased progressively with increasing BMI. These findings indicate a positive association between body mass and flatfoot, with excess body weight emerging as a significant risk factor for developing flatfoot. Similar findings were reported in an Indonesian study, in which overweight and obese children had approximately 4.5 times higher risk of flatfoot compared with their non-overweight peers.[23] Likewise, a large Taiwanese study involving 2,083 children aged 7–12 years demonstrated a progressive increase in flatfoot prevalence across BMI categories, with prevalence of 48% in underweight, 57% in normal-weight, 65% in overweight, and 75% in obese children. These findings are comparable to those of the present study, further supporting a positive association between increasing BMI and flatfoot prevalence in children.[19] Pourghasem et al., and Fenget et al., further demonstrated distinct variations in foot morphology between underweight, normal-weight, and overweight children, with heavier children demonstrating flatter and broader feet, as assessed using footprints and three-dimensional measurements.[20,24] Overall, the present findings align closely with existing literature and underscore the importance of maintaining a healthy body weight to support normal foot arch development during childhood.

The findings of this study have important clinical and public health implications. Although flatfoot in younger children may be a normal developmental feature, several epidemiologic studies and systematic reviews reported a strong association between elevated BMI and flatfoot,[12,20] as well as increased discomfort and pain and limitation in physical activity among affected children.[25] Addressing excess body weight through early screening and timely lifestyle-based interventions may therefore help not only in reducing the risk or severity of flatfoot but also in preventing associated problems such as foot pain, fatigue, and limitations in physical activity.
The present study was conducted in children from a single

ward, aged 6–10 years, which may restrict the generalizability of the findings to the other populations. Furthermore, in this study, the flatfoot was assessed using the plantar index, which depends on visual assessment and potential confounders such as physical activity, footwear, and joint hyper mobility were not considered. Future research should include larger, more diverse populations, and incorporate objective assessment methods to better understand the development of pediatric flatfoot and its associated risk factors.

CONCLUSION

Flatfoot remains prevalent among primary school-aged children and reveals a clear positive association with increasing BMI. These findings indicate that excess body weight is a primary risk factor influencing foot posture and biomechanics during childhood. Incorporating foot health screening and strategies promoting healthy weight into school health programs may help reduce the burden of flatfoot and its associated musculoskeletal complications.

CONFLICT OF INTEREST

None

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