Flatfoot in the neglected age group of adolescents

Ananya Priya[1], Ravi Kant Narayan[2], Sanjib Kumar Ghosh[3]

[1] *Department of Anatomy, All India Institute of Medical Sciences, Patna, Bihar, India*

[2] *Department of Anatomy, Dr. B. C. Roy Multi-Speciality Medical Research Centre, IIT Kharagpur, West Bengal, India*

[3] *Department of Anatomy, All India Institute of Medical Sciences, Patna, Bihar, India*

SUMMARY

The foot arches in humans are the complex musculo-skeletal-ligamentous structure that helps in shock absorption because of the elasticity and provides stability while transmitting the muscle force for walking. Primarily we observed the prevalence of flatfoot among adolescents going to college. Thereafter we determined the correlation of flatfoot with the body mass index and gender of the adolescents being studied. Footprint analysis of undergraduate students was obtained based on Harris – the Beath mat principle. Clarke's angle, Chippaux-Smirak index, and Staheli arch index were observed in the footprints. Subsequently, the correlation between the flatfoot, body mass index, and gender of the participants was assessed. The prevalence of flatfoot in college-going adolescents was 18.28% by footprint analysis, presenting a female predilection (20% of the footprint analysis) for the condition. The most valid and reliable plantar arch index for diagnosing flatfoot was the Staheli arch index, followed by the Chippaux-Smirak index having a moderate to strong correlation (R = 0.7, 0.95; $p < 0.05$). Only 1.1% of females and up to 2.2% of males were observed to have flatfoot and were obese. Eighteen out of a hundred (approximately one–fifth) adolescents in the studied group had flatfoot. The gender predilection for females was observed. Contradictory to the findings of the previous study, obesity was not observed as a foot arch-altering factor in adolescents.

Key words: Flatfoot – Adolescents – Body mass index – Gender – Prevalence

INTRODUCTION

The foot arches in humans are the complex musculo-skeletal-ligamentous structure that helps in shock absorption because of the elasticity and provides stability while transmitting the muscle force for walking (Aenumulapalli et al., 2017). The medial longitudinal arch (MLA) is the most prominent of all the foot arches, the height of which, when lowered, leads to flatfoot or pes planus. One of the most typical foot deformities, flatfoot, is characterized by medial rotation and plantar flexion of the talus, eversion of the calcaneus, collapsed medial longitudinal arch, and forefoot abduction (Ezema et al., 2014; Neeraj et al., 2020).

In infants, the flatfoot is observed because of the plantar pad of fat, which disappears between 2-10 years of age, and subsequently, the arch becomes prominent (Gould et al., 1989). The flatfoot in children is mostly of flexible form, which appears on

Corresponding author:
Dr. Ravi Kant Narayan. Department of Anatomy, Dr. B. C. Roy Multi-Speciality Medical Research Centre, IIT Kharagpur, West Bengal, India. Phone: 91-9234896343. E-mail: narayanintouch@gmail.com

Submitted: September 15, 2022. **Accepted:** October 17, 2022

https://doi.org/10.52083/UEAM4094

weight bearing, while in adults, the condition is of the rigid type, which is present irrespective of the weight (Benvenuti et al., 1995; Atamturk, 2009; Medina-Alcantara et al., 2019).

The prevalence of flatfoot in children varies inversely with age (Pauk et al., 2012). As per literature, this variation is based on factors such as age, gender, weight, family history, body mass index (BMI), type of footwear, physical activity, and population being studied, and is associated with hypermobility, heel valgus, and genu valgum. The prevalence of flatfoot varies between 21% and 77% in children until six years of age, whereas in primary school children, the same decreases to 13.4-27.6% (Pfeiffer et al., 2006; Chen et al., 2009, 2011; Chang et al., 2010; Ezema et al., 2014; Pourghasem et al., 2016).

In adults, the prevalence of the pathological entity was observed to vary between 13.6% to 26.62% (Benvenuti et al., 1995; Pita-Fernández et al., 2015). The literature on flatfoot presents a bias of bimodal age group representation.

Adolescence traverses the age of biological growth period to the one with an active social role. The World Health Organization (WHO) mentions adolescence as the age group of 10-19 years, which also includes a few years of *a child* (as adopted by the Convention on the *Rights of the Child*), a few of the *youth* (15-24 years), and much of the *young people* (10-24 years) (WHO, 2014). While the beginning of adolescence has been shifted to an early age due to early puberty, the end of the same has continued into the third decade of life as per the paradigm shift in the perception regarding the beginning of adulthood based on the elongation of the education period and delayed marriage. Thus, redefining the age of adolescence as 10-24 years of age (Sawyer et al., 2018).

The literature rarely presented data on flatfoot in adolescents before the second decade of the 21st Century. The present study aims to fill this gap by observing the prevalence of flatfoot in adolescent-aged individuals and the association of BMI and gender with flatfoot in this age group, as many orthopedic deformities are often associated with obesity (Pauk et al., 2012; Rivera-Saldívar et al., 2012; Woźniacka et al., 2015).

MATERIALS AND METHODS

The participants for this cross-sectional study were undergraduate students of the medical institute. After approval by the institutional ethics committee, the study was conducted in the Department of Anatomy between July 2021 to February 2022. Only students who gave their written agreement after being informed about the procedures and had no history of foot fractures, orthopedic procedures, congenital foot abnormalities, or neuromuscular problems were permitted to participate.

Out of 257 students fitting the age criteria and consenting to participate, a sample size of 175 (85 females, 90 males) in the age group of 17-21 years (as per the redefined adolescent age group by Sawyer et al., 2018) were included in the study as per the criteria. The demographic characteristics noted for these participants were age, sex, height, and weight.

Calculation of the plantar arch index

The footprint of all participants was taken using Harris and Beath's footprinting mat. The participants were asked to stand on the apparatus's hydrophobic mat, which transferred the image of the footprint onto the white sheet present underneath it.

As a universal definition of flatfoot is not present, we accepted the clinical diagnosis of the condition as per Pfeiffer et al. (2006) to be the gold standard.

Thereafter, Staheli's planter arch index (SAI), Chippaux-Smirak index (CSI), and Clarke's angle (CA) of each participant's footprint (Fig. 1) were calculated by two different investigators as per Chen et al. (2011).

Staheli Plantar arch index (SAI) = minimum support width of center of the arch (j)/ maximum support width of heel region (h); SAI = j/h×100%.

Chippaux-Smirak index (CSI) = minimum support width of center of the arch (j)/Maximum support width of the metatarsals (r); CSI = j/r×100%.

Clarke's angle (CA) = Defined as the angle obtained by a tangent line joining the medial edges of the first metatarsal head and the heel, and the second line that connects the first metatarsal head to the acme of the medial longitudinal arch concavity.

The validity of the above footprint parameters compared to the clinical diagnosis had been previously documented (Zuil-Escobar et al., 2018).

For measuring the weight, participants were asked to stand on a digital weighing machine (make - Philips device, Netherlands, sensitive to 100 g) without shoes and minimal formal clothing.

For measuring height, participants were asked to stand in an erect position under a stadiometer (make - Mowell, India; sensitive to 1 mm) without shoes and with the head in the Frankfurt plane.

Standard stationery was utilized to measure the lengths and angles of the footprint. To ensure the reliability of the measurements, the investigators took footprints of ten subjects (not participating in the study) of the same age group. They measured the parameters twice on two different days. The inter- and intra-class correlation coefficient values ranged from 0.77-0.94 and 0.81-0.93, respectively. Thus, a strong correlation confirmed the reproducibility of the measurements.

The data were entered in Microsoft Excel 2019 package and then transferred to Statistical Package for Social Sciences- SPSS 26.0 version for analysis. Mean and standard deviation was calculated for quantitative values, while categorical values were presented as percentages. Student paired t-test was applied to determine the p-value of the measurements on either foot. Thereafter, correlation coefficients were determined using bivariate analysis, and regression analysis was done to derive the regression equation between the pair of factors compared (y=mx + c, where m= slope, c= interception on 'y' constant).

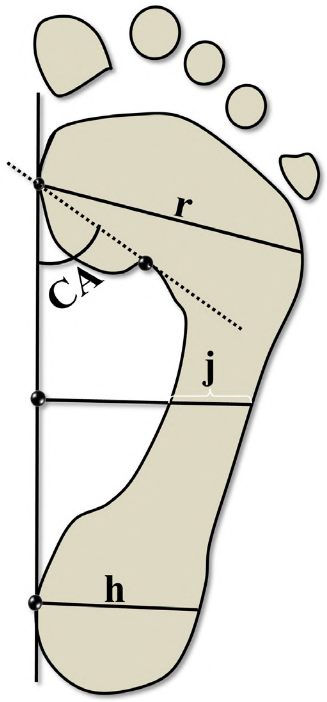


Fig. 1.- Schematic presentation of the footprint and the parameters measured. r = maximum support width of the metatarsals, j = minimum support width of center of the arch, h = maximum support width of the heel region, CA = Clarke's angle.

RESULTS

The mean age of the study population was 19.37 ± 0.87 years in males and 19.21 ± 0.69 years in females (Table 1).

Table 1. The mean (± standard deviation, SD) age and BMI of the study population.

Parameters	Total (n = 175) Mean ± SD	Males (n = 90) Mean ± SD	Females (n = 85) Mean ± SD
Age	19.29 ± 0.79	19.37 ± 0.87	19.21 ± 0.69
BMI (Kg/m^2)	22.42 ± 4.11	22.52 ± 4.11	22.32 ± 4.11

The frequency of flatfoot was observed as 18.28% (n = 32) by clinical diagnosis and later by comparing the same with their footprints. The gender distribution for flatfoots was slightly more prevalent in females, with a frequency of 20% (n = 17), while that in males was 16.6% (n = 15).

As per Clarke's angle, flatfoot was observed on the left side in 8.57% (n=15, female = 9, male = 6) participants, while that on the right side was observed in 6.28% (n=11, female = 7, male = 4). For CSI, flat left foot was observed in 23.42% (n=41, female = 25, male = 16), and on the right foot the observed value was 18.85% (n=33, female = 19, male = 14). Finally, SAI presented with a flatfoot frequency of 18.29% (n = 32, female = 17, male = 15), the same as that observed clinically in the present cohort. The plantar arch indices and angle had statistically significant differences concerning either foot, but gender-wise distribution was observed to be significant only for SAI (Table 2).

The Pearson's correlation coefficient (PCC) presented with significant but weak negative correlation between BMI and CA on either foots (PCC for left = -0.26, right = -0.13; p = 0.004, 0.02), while significant and weak positive correlation of BMI was observed with CSI (PCC for left and right = 0.26, p = 0.0003, 0.001) and SAI (PCC for left = 0.16 and right = 0.29, p = 0.02, 0.003) values of either foot irrespective of gender. The correlation coefficient was moderately positive for CSI and SAI on left side (PCC = 0.75, p < 0.001) and strongly positive for right side (PCC = 0.95, p < 0.001). The linear regression equation (y=mx+c) where m= slope, c= interception on 'y' constant was derived to assess the effect of SAI on CSI of both sides as the linearity could be observed between the two in the scatter plot shown in Fig. 2a, 2b. There was homoscedasticity and normality of the residuals on either side analysis. A few outliers were not significant and were included for analysis.

The present study population had 4.57% obese individuals (Table 3). When flatfoot was observed as per the BMI of the participants for the different plantar arch indexes and angles, the frequency was minimal for obese individuals (Table 4). For obese females, the frequency for flatfoot was 1.17% (n = 1) for CSI, SAI, and CA, whereas obese males had a frequency ranging from 1.1-2.2% (n = 1-2) concerning the parameters mentioned above. Comparatively, normal-weighed males (as high as 11.1%) and females (as high as 16.4%) suffered the most from flatfoot.

DISCUSSION

Prevalence of flatfoot in pediatric age-group

Flatfoot is a prevalent condition in pediatric (birth to 17 years) (Staheli et al., 1987; Gould et al., 1989; Echarri and Forriol, 2003; Pfeiffer et al., 2006; Chen et al., 2009, 2011; Coughlin and Kaz, 2009; Chang et al., 2010, 2012, 2014; Abolarin et al., 2011; Pauk et al., 2012; Rivera- Saldívar et al., 2012; Umar and Tafida, 2013; Ezema et al., 2014; Woźniacka et al., 2015; Pourghasem et al., 2016; Tong and Kong, 2016; Aenumulapalli et al., 2017; Banwell et al., 2018; Medina-Alcantara et al., 2019) and old (>40 years) age population [4,5,29]. In the age group of 3-6 years, Ecchari and Forriol (2003) reported a high flatfoot prevalence of 70%, while that observed by Pfeiffer et al. (2006) was 44%. The prevalence rate of flatfoot in the age group of 5-8 years was reported as 40% by Ecchari and Forriol (2003) and 78% by Gould et al. (1989). The high prevalence rate at a young age

Table 2. The mean (± standard deviation, SD) of different plantar arch index and angle on either foot.

Flatfoot indices and angle		Total (n = 175) Mean ± SD	t-test	Males (n = 90) Mean ± SD	Females (n = 85) Mean ± SD	t-test
Clarke's angle (CA)	Left	45.45 ± 11.42	p = 0.002	46.21 ± 10.78	44.64 ± 12.02	p = 0.33
	Right	47.05 ± 10.58		47.83 ± 9.91	46.21 ± 11.18	p = 0.34
Chippaux-Smirak index (CSI)	Left	38.11 ± 14.23	p = 0.03	36.92 ± 12.81	39.36 ± 15.49	p = 0.05
	Right	35.97 ± 13.53		36.33 ± 11.51	35.59 ± 15.37	p = 0.45
Staheli's plantar arch index (SAI)	Left	67.87 ± 24.47	p = 0.01	66.87 ± 25.32	68.94 ± 25.58	p = 0.17
	Right	65.51 ± 25.26		66.75 ± 21.92	64.21 ± 28.31	p=0.035

Table 3. The frequency (percentage, %) distribution of BMI categories.

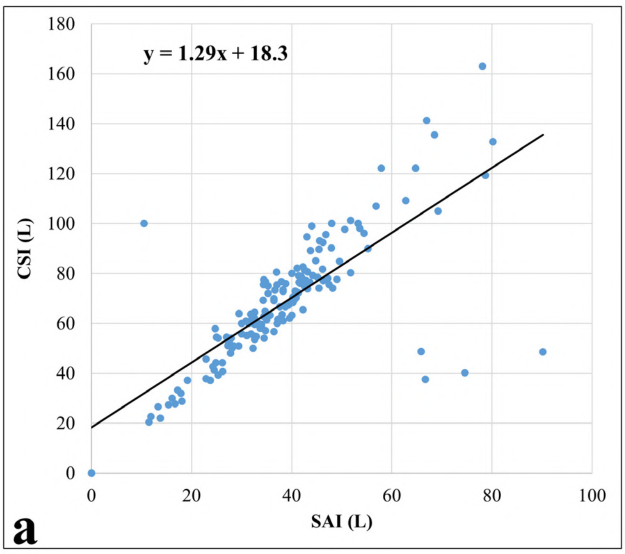
BMI categories	Total n (%)	Males n (%)	Females n (%)
Underweight (<18.5Kg/m^2)	29 (16.57)	15 (16.6)	14 (16.47)
Normal weight (18.5-25 Kg/m^2)	106 (60.57)	52 (57.7)	54 (63.52)
Overweight (25-<30 Kg/m^2)	32 (18.28)	20 (22.2)	12 (14.11)
Obese (≥30 Kg/m^2)	8 (4.57)	3 (3.33)	5 (5.88)

Table 4. Frequency of flatfoot as per BMI of the participants with respect to the different plantar arch index and angle.

Arch Parameters	Gender (n;F= 85, M= 90)		Underweight (<18.5 Kg/m²) [n (%)]	Normal weight (18.5-25 Kg/m²) [n (%)]	Overweight (25-<30 Kg/m²) [n(%)]	Obese (≥30 Kg/m²) [n(%)]	Total no. of flat foot
CSI	Female	Left	5 (5.8)	14 (16.4)	5 (5.8)	1 (1.17)	25
		Right	3 (3.5)	12 (14.1)	3 (3.5)	1 (1.17)	19
	Male	Left	3 (3.3)	10 (11.1)	1 (1.1)	2 (2.2)	16
		Right	3 (3.3)	9 (10)	0	2 (2.2)	14
SAI	Female	Left	4 (4.7)	9 (10.6)	3 (3.5)	1 (1.17)	17
		Right	4 (4.7)	9 (10.6)	3 (3.5)	1 (1.17)	17
	Male	Left	4 (4.4)	6 (6.6)	3 (3.3)	2 (2.2)	15
		Right	4 (4.4)	6 (6.6)	3 (3.3)	2 (2.2)	15
CA	Female	Left	0	5 (5.9)	3 (3.5)	1 (1.17)	9
		Right	0	4 (4.7)	3 (3.5)	0	7
	Male	Left	0	3 (3.3)	1 (1.1)	2 (2.2)	6
		Right	0	3 (3.3)	0	1 (1.1)	4

is attributed to the arch developing by six years, so estimating the prevalence in such age groups merely exaggerates the issue (Rose et al., 1985; Ezema et al., 2014). In addition, previous literature cites numerous reports regarding the decline in the prevalence of flatfoot with advancing age (Echarri and Forriol, 2003; Abolarin et al., 2011; Pauk et al., 2012; Ezema et al., 2014). Also, flatfoot in the pediatric age group is rarely reported to be associated with symptoms compromising the quality of life (Mosca, 2010).

As flatfoot prevalence is said to rise with age beyond age 40, it is anticipated that the elderly population would experience a reduced quality of life due to the condition. (Benvenuti et al., 1995; Pita-Fernández et al., 2015). Though the quality of life is not affected by the arch height (López-López et al., 2018), symptomatic presentation leading to



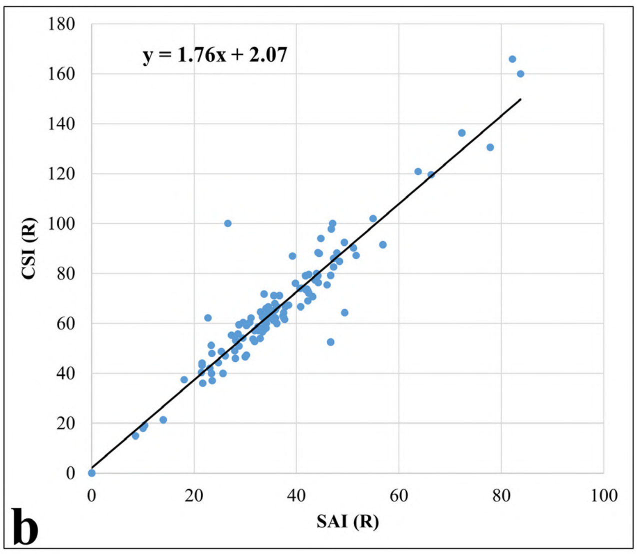


Fig. 2.- a, b - Graphs showing Linear regression correlation line derived from equation: y = mx + c, where y is CSI (L/R), m = 1.29 for a & 1.79 for b, x is SAI (L/R), and c = 18.3 for a & 2.07 for b.

discomfort due to flatfoot is often reported (Benvenuti et al., 1995).

The above explanations report the biased bimodal representation of variation in prevalence and association of flatfoot in pediatric (<17 years) and old age (<40 years) groups. This bias could be elucidated based on the fact that the arch is in the developing phase in the pediatric age, so the flatness is prominently visible as an abnormal feature, whereas in old age, the pathological effects of the condition highlight the situation (Ezema et al., 2014). Therefore, in light of the facts mentioned, it becomes necessary to study the prevalence of the condition in the adolescent age group.

Prevalence of flatfoot in adolescents

Accounts of data explaining the above findings and numerous others associated with flatfoot in the pediatric and old age groups could be found in previous literature. However, the absence of flatfoot data for adolescents (17-21 years) has had deleterious effects on the knowledge, awareness, and attitude of the masses regarding the condition (Aenumulapalli et al., 2017). The adolescents, though expected to have developed the plantar arches due to skeletal maturity, do suffer from flatfoot in considerable numbers (Tenenbaum et al., 2013). Apart from having aesthetic effects, this condition also hinders their professional prospect in security services. Lack of knowledge and awareness about flatfoot in adolescents leads to a torpid attitude to corrective attention, which could have a symptomatic presentation in old age (Ukoha et al., 2012; Tenenbaum et al., 2013).

The present study observed a flatfoot prevalence of 18.28% in adolescents 17-21 years which is much higher than that reported by previous literature in this age group, which ranges from 4.1-13.9% (Abdel Fattah et al., 2006; Atamturk, 2009; Ukoha et al., 2012; Bhoir et al., 2014; Aenumulapalli et al., 2017).

Prevalence in adolescents based on gender

The gender-based difference reported have contradictory evidence in the literature. Previous literature presents a predilection of flatfoot in males (Echarri and Forriol, 2003; Atamturk, 2009; Pauk et al., 2012; Woźniacka et al., 2015; Tong and Kong, 2016; Aenumulapalli et al., 2017). The present study observed statistically significant female predilection for flatfoot, which was previously mentioned by Umar and Tafida (2013). At the same time, the gender-based difference reported by Atamturk (2009) and Aenumullapalli et al. (2017) was statistically insignificant.

Sensitivity of various parameters for evaluation of flatfoot in all age-groups

For decades, footprints have been used to evaluate and diagnose flatfoot in all age groups. Banwell et al. (Banwell et al., 2018) reviewed articles using these parameters to evaluate flatfoot in children and observed that CSI and SAI were the only reliable and valid measurements for flatfoot estimation. The present study also observed CSI, SAI, and CA on footprints and deduced a moderate to strong positive correlation between CSI and SAI. The sensitivity was maximum for SAI, followed by CSI, and least for CA in predicting flatfoot in the studied age group. Chen et al. (2009) reported CSI as the most sensitive, followed by SAI and CA as the least.

Association of flatfoot and BMI in adolescents

While presenting the conundrum of the association between flatfoot and age, the literature also presented contradicting evidence regarding the association of flatfoot with BMI. The evidentiary support leans toward the positive correlation between flatfoot and BMI on many accounts (Pfeiffer et al., 2006; Chen et al., 2009; Chang et al., 2010, 2012; Tenenbaum et al., 2013; Ezema et al., 2014; Pita-Fernández et al., 2015; Woźniacka et al., 2015; Pourghasem et al., 2016; Gonzalez-Martin et al., 2017). Nonetheless, a study from the Turkish population reported no relationship between the two (Atamturk, 2009), while Wearing et al. (2012) mentioned that obesity has no effects on the bony alignment of the foot but distorts the reading of footprint-based arch indices and angle. The present study, too, observed the minimal impact of obesity on the plantar arch of adolescents. Most of the studies had reported the effect of obesity on children's foot without considering the pad of fat, which persists in these children and affect the footprint readings. In adults, obesity does play a part in foot deformity as the bones are weakened and ligaments are loosened. However, in adolescents, the ligaments are taut, and bones are strong; therefore, obesity cannot impose on the arch integrity (Wearing et al., 2012).

The variations related to the prevalence of flatfoot have been associated with numerous demographic and parametric features. Age group-related studies regarding flatfoots are necessary to differentiate between those requiring corrective measures or not. Non-invasive corrective techniques must be used at the right age to be effective. Data on the conditions' contributing elements and diagnostic characteristics are needed to comprehend the time-based therapeutic application (Mosca, 2010). The lack of data for adolescents regarding flatfoot deprives the derivation of specific and valuable information for diagnosing and treating the condition, like the diagnostic information extracted by Banwell et al. (2018) for the pediatric flatfoot.

The limited knowledge of flatfoot in adolescents calls for more research into the various variables that might impact the plantar arch height. The present study's findings have to be seen in the light of the meager sample size of obese adolescent individuals, which limits the appropriate derivation of the related facts. Further, a prospective comparative study between the footprint and radiological data of participants from the adolescent age group would provide more clinically relevant observations.

CONCLUSION

The present study helps us to understand that flatfoot in adolescents requires attention and that the findings of the pediatric and old age flatfoot reports should not be extrapolated to adolescents. The findings explain that approximately one-fifth (18.28% in the footprint study) of the adolescent population suffers from flatfoot. The gender-based analysis points out the female predisposition for the condition. The decade-old fact that obese individuals are more prone to flatfoot does not hold the ground for adolescents. We observed a moderate to strong positive correlation between CSI and SAI. The sensitivity was maximum for SAI, followed by CSI, and least for CA in predicting flatfoot in the studied age group.

ACKNOWLEDGEMENTS

The All India Institute of Medical Sciences, Phulwarisharif, Patna, India, and its residents and faculty members in the Department of Anatomy deserve the authors' sincere appreciation for their unwavering assistance throughout the research. We are thankful to the administrators of the All India Institute of Medical Sciences, Phulwarisharif, Patna, India, for their generous collaboration during this investigation.

REFERENCES

ABDEL FATTAH MM, HASSANIN MM, FELEMBANE FA, NASSAANE MT (2006) Flat foot among Saudi Arabian army recruits: prevalence and risk factors. *EMHJ - East Mediterr Health J,* 12(1-2): 211-217.

ABOLARIN TO, AIYEGBUSI AI, TELLA BA, AKINBO SR (2011) Relationship between selected anthropometric variables and prevalence of flatfoot among urban and rural school children in Southwest Nigeria. *Niger Q J Hosp Med,* 21: 135-140.

AENUMULAPALLI A, KULKARNI MM, GANDOTRA AR (2017) Prevalence of flexible flat foot in adults: a cross-sectional study. *J Clin Diagn Res,* 11: AC17-AC20.

ATAMTURK D (2009) Relationship of flatfoot and high arch with main anthropometric variables. *Acta Orthop Traumatol Turc,* 43: 254-259.

BANWELL HA, PARIS ME, MACKINTOSH S, WILLIAMS CM (2018) Paediatric flexible flat foot: how are we measuring it and are we getting it right? A systematic review. *J Foot Ankle Res*, 11: 21.

BENVENUTI F, FERRUCCI L, GURALNIK JM, GANGEMI S, BARONI A (1995) Foot pain and disability in older persons: an epidemiologic survey. *J Am Geriatr Soc,* 43: 479-484.

BHOIR T, ANAP D, DIWATE A (2014) Prevalence of flat foot among 18-25 years old physiotherapy students: cross sectional study. *Indian J Basic Appl Med Res*, 3: 272-278.

CHANG JH, WANG SH, KUO CL, SHEN HC, HONG YW, LIN LC (2010) Prevalence of flexible flatfoot in Taiwanese school-aged children in relation to obesity, gender, and age. *Eur J Pediatr,* 169: 447-452.

CHANG HW, LIN CJ, KUO LC, TSAI MJ, CHIEH HF, SU FC (2012) Three-dimensional measurement of foot arch in preschool children. *Biomed Eng OnLine,* 11: 76.

CHANG CH, CHEN YC, YANG WT, HO PC, HWANG AW, CHEN CH, CHANG JH, CHANG LW (2014) Flatfoot diagnosis by a unique bimodal distribution of footprint index in children. *PloS One*, 9: e115808.

CHEN JP, CHUNG MJ, WANG MJ (2009) Flatfoot prevalence and foot dimensions of 5- to 13-year-old children in Taiwan. *Foot Ankle Int*, 30: 326-332.

CHEN KC, YEH CJ, KUO JF, HSIEH CL, YANG SF, WANG CH (2011) Footprint analysis of flatfoot in preschool-aged children. *Eur J Pediatr,* 170: 611-617.

COUGHLIN MJ, KAZ A (2009) Correlation of Harris mats, physical exam, pictures, and radiographic measurements in adult flatfoot deformity. *Foot Ankle Int,* 30: 604-612.

ECHARRI JJ, FORRIOL F (2003) The development in footprint morphology in 1851 Congolese children from urban and rural areas, and the relationship between this and wearing shoes. *J Pediatr Orthop Part B,* 12: 141-146.

EZEMA CI, ABARAOGU UO, OKAFOR GO (2014) Flat foot and associated factors among primary school children: A cross-sectional study. *Hong Kong Physiother J*, 32: 13-20.

GONZALEZ-MARTIN C, PITA-FERNANDEZ S, SEOANE-PILLADO T, LOPEZ-CALVIÑO B, PERTEGA-DIAZ S, GIL-GUILLEN V (2017) Variability between Clarke's angle and Chippaux-Smirak index for the diagnosis of flat feet. *Colomb Médica,* 48: 25-31.

GOULD N, MORELAND M, ALVAREZ R, TREVINO S, FENWICK J (1989) Development of the child's arch. *Foot Ankle*, 9: 241-245.

KOIRALA S, KHANAL GP, SHAH S, KHANAL L, YADAV P, BARAL P (2021) Calculation of Staheli's planter arch index, Chippaux-Smirak index, Clarke's angle prevalence and predictors of flat foot: a cross sectional study. *Austin J Anat*, 8(1): 1095.

LÓPEZ-LÓPEZ D, VILAR-FERNÁNDEZ JM, BARROS-GARCÍA G, LOSA-IGLESIAS ME, PALOMO-LÓPEZ P, BECERRO-DE-BENGOA-VALLEJO R, CALVO-LOBO C (2018) Foot arch height and quality of life in adults: a strobe observational study. *Int J Environ Res Public Health,* 15: E1555.

MEDINA-ALCANTARA M, MORALES-ASENCIO JM, JIMENEZ-CEBRIAN AM, PAEZ-MOGUER J, CERVERA-MARIN JA, GIJON-NOGUERON G, ORTEGA-AVILA AB (2019) Influence of shoe characteristics on the development of valgus foot in children. *J Clin Med*, 8: E85.

MOSCA VS (2010) Flexible flatfoot in children and adolescents. *J Child Orthop,* 4: 107-121.

NEERAJ V, PUJA D, ACHLESHWAR G (2020) A new approach for medial longitudinal arch estimation by "foot print": A comparative study. *Natl J Clin Anat,* 9: 101.

PAUK J, EZERSKIY V, RASO JV, ROGALSKI M (2012) Epidemiologic factors affecting plantar arch development in children with flat feet. *J Am Podiatr Med Assoc*, 102: 114-121.

PFEIFFER M, KOTZ R, LEDL T, HAUSER G, SLUGA M (2006) Prevalence of flat foot in preschool-aged children. *Pediatrics*, 118: 634-639.

PITA-FERNÁNDEZ S, GONZÁLEZ-MARTÍN C, SEOANE-PILLADO T, LÓPEZ-CALVIÑO B, PÉRTEGA-DÍAZ S, GIL-GUILLÉN V (2015) Validity of footprint analysis to determine flatfoot using clinical diagnosis as the gold standard in a random sample aged 40 years and older. *J Epidemiol*, 25: 148-154.

POURGHASEM M, KAMALI N, FARSI M, SOLTANPOUR N (2016) Prevalence of flatfoot among school students and its relationship with BMI. *Acta Orthop Traumatol Turc*, 50: 554-557.

RIVERA-SALDÍVAR G, TORRES-GONZÁLEZ R, FRANCO-VALENCIA M, RÍOS-MONROY R, MARTÍNEZ-RAMÍREZ F, PÉREZ-HERNÁNDEZ E, DUARTE-DAGNINO D (2012) Risk factors associated with the conformation of the medial longitudinal arch and the symptomatic flat foot in a metropolitan school population in Mexico. *Acta Ortop Mex*, 26: 85-90.

ROSE GK, WELTON EA, MARSHALL T (1985) The diagnosis of flat foot in the child. *J Bone Joint Surg Br*, 67: 71-78.

SAWYER SM, AZZOPARDI PS, WICKREMARATHNE D, PATTON GC (2018) The age of adolescence. *Lancet Child Adolesc Health*, 2: 223-228.

STAHELI LT, CHEW DE, CORBETT M (1987) The longitudinal arch. A survey of eight hundred and eighty-two feet in normal children and adults. *J Bone Joint Surg Am*, 69: 426-428.

TENENBAUM S, HERSHKOVICH O, GORDON B, BRUCK N, THEIN R, DERAZNE E, TZUR D, SHAMISS A, AFEK A (2013) Flexible pes planus in adolescents: body mass index, body height, and gender--an epidemiological study. *Foot Ankle Int*, 34: 811-817.

TONG JWK, KONG PW (2016) Medial longitudinal arch development of children aged 7 to 9 years: longitudinal investigation. *Phys Ther*, 96: 1216-1224.

UKOHA UU, EGWU OA, OKAFOR IJ, OGUGUA PC, IGWENAGU VU (2012) Pes planus: incidence among an adult population in Anambra state, Southeast Nigeria. *Int J Biomed Adv Res*, 3: 166-168.

UMAR MBT, TAFIDA RU (2013) Prevalence of flatfoot and anthropometric comparison between flat and normal feet in the Hausa ethnic group of Nigeria. *J Am Podiatr Med Assoc*, 103: 369-373.

WEARING SC, GRIGG NL, LAU HC, SMEATHERS JE (2012) Footprint-based estimates of arch structure are confounded by body composition in adults. *J Orthop Res Off Publ Orthop Res Soc*, 30: 1351-1354.

WHO (2014) Health for the world's adolescents: a second chance in the second decade: summary. https://www.who.int/publications-detail-redirect/WHO-FWC-MCA-14.05.

WOŹNIACKA R, BAC A, MATUSIK S (2015) Effect of obesity level on the longitudinal arch in 7- to 12-year-old rural and urban children. *J Am Podiatr Med Assoc*, 105: 484-492.

ZUIL-ESCOBAR JC, MARTÍNEZ-CEPA CB, MARTÍN-URRIALDE JA, GÓMEZ-CONESA A (2018) Medial longitudinal arch: accuracy, reliability, and correlation between navicular drop test and footprint parameters. *J Manipulative Physiol Ther*, 41: 672-679.