Research article

Assessment of flat foot using plantar arch index in young adults

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ABSTRACT

Introduction and Aim: Flat foot or pes planus results from collapse of the arches of the foot. Etiology, however varies in different age groups. As anthropometric measurements are age dependent, their correlation with different foot postures should be age specific. Our study aimed at using Plantar arch Index (PAI) to identify prevalence of flat foot in a young student population and find any association of obesity with flat foot.

Methods: A prospective study was conducted on 150 medical students of a medical college. Staheli's method was used to calculate PAI after collecting the footprints of students by ink method.

Results: Prevalence of type III flat foot deformity was 6%, with a male preponderance. The PAI values ranged from 0 to 1.818. No association was found between obesity and PAI.

Conclusion: Obesity was not associated with flat foot in the age group 18-25 years probably indicating different etiology for acquired flat foot in this age group. Our study also suggests that simple ink print method is a simpler method to diagnose flat feet deformity clinically using PAI.

Keywords: Plantar arch index; Flat foot; BMI; Staheli's method.

INTRODUCTION

Humans by virtue of being bipeds, bear the weight of the whole body on their feet which stabilizes the body during a change in posture (1), facilitated by the medial longitudinal arch, the lateral longitudinal arch and the transverse arch (2). The arches help in proportional distribution of body weight. Abnormalities in the arches of foot lead to various kinds of foot deformities like pes planus, pes cavus, congenital talipus equinovarus etc. Pes planus (flat foot) has a much higher prevalence compared to other forms of foot deformities.

Flat foot can be congenital or acquired. Acquired flat foot develops due to injury, prolonged stress to the foot, obesity, illness, faulty biomechanics (3). It is a postural deformity in which the arch of the foot collapses. This has a significant impact on the foot function of the individuals and leads to the development of musculoskeletal pathologies (4) and negatively impacts quality of life (5).

Pathological flat feet can cause changes in muscle balance, gait, and alignment of joint motion (2) and predispose to injury (6). The etiology of pes planus differs in case of infants, children and adults. In infants the foot appears apparently flat due to presence of fat in the sole of foot (7). As age advances the etiology of flat foot shifts from normal physiological entity to a deformity caused by structural changes in foot anatomy. Studies have shown that overweight children tend to have flatter feet (8,9) and similar studies have been performed on children (10-12), however, data lacks in young adults.

As anthropometric measurements are age dependent, their correlation with different foot postures should be age specific. Hence, the need for this study in this age group. The assessment of the plantar arch development, by the relationship between the arch region and heel region, was proposed by Engel and Staheli(13).

In this study, we aim to assess and analyze flat foot among a young population, with reference to plantar arch index (PAI) using Staheli's Arch Index method and to identify any relation of flat foot with BMI.

METHODOLOGY

This cross-sectional study was conducted on 150 first year students of a Medical College in Mangalore of the age group 18-23 years, after procuring institutional ethical clearance.

Inclusion criteria: First year medical students of the age group of 18-23 years.

Exclusion criteria: Those with congenital foot deformities, callus or corn, unwillingness to participate.

The height and weight were calculated of each participant. Thereafter, BMI was calculated as weight in kg divided by square of the height in meter. They were then classified according to the WHO classification as underweight, normal, pre-obese, type 1 and 2 obesity.

The footprints of the 150 participants were taken by ink print method by a single examiner. A thin large piece of sponge (larger than the size of the foot) was placed on a tray and diluted ink was poured. The sponge absorbs the ink and when the foot is placed the ink sticks on the surface of foot. The foot was then immediately placed on a paper to obtain the print and then plantar arch index (PAI) was calculated using Staheli's method (Fig. 1).

First a tangential line was drawn from the medial forefoot edge to the mid-heel region. The mean point of this line was calculated. From this point, a perpendicular line was drawn crossing the footprint. The same procedure was repeated for heal tangency point.

The width of the central region of the footprint was considered as A and the width of the heel region is considered as B (Fig. 2).

Plantar arch index (PAI) was obtained by dividing the A value (in cm) by B value (in cm) (PAI = A/B) (14).

Fig. 1: Ink print method

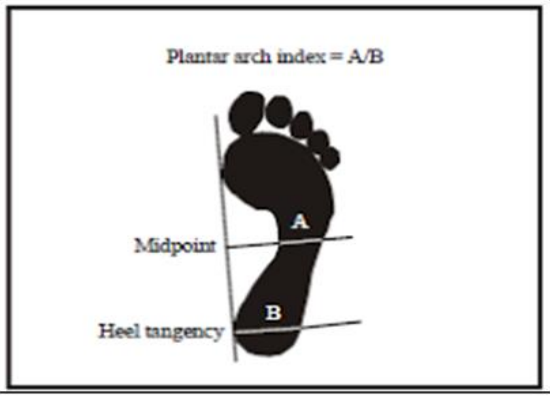

Fig. 2: Staheli's method of calculating PAI

According to Staheli's classification, the plantar arch index corresponds to Viladot's type III degree when the ratio is >1.15, to type II when it is within 0.9-1.15, and to type I when it is within <0.9(15).

Statistical analysis

Mean and standard deviation was used for statistical analysis along with the SPSS software.

RESULTS

This study was conducted on 150 students of the age group 18-23 years. There were 75 males and 75 females. The prevalence of Type III flat foot deformity was 6%.

Table 1: PAI among participants(n=150)

	PAI	Mean	SD
Male	Right Foot	0.72	0.28
	Left Foot	0.73	0.26
Female	Right Foot	0.58	0.21
	Left Foot	0.58	0.19

Table 2: Mean PAI(n=150)

	Mean PAI (In males)		Mean PAI (**In females**)	
	Right	Left	Right	Left
<0.9	0.618	0.6011	0.537	0.575
0.9-1.15	1.0504	1.023	1.096	0.975
>1.15	1.486	1.25	1.33	1.153

The PAI values ranged from 0 to 1.818. (Table2)

Among 150 subjects (75 male and 75 females), 9 participants had type III deformity (PAI >1.15). Out of these 8 had unilateral deformity and 1 had bilateral deformity (Table 1).

Table 3: Gender distribution with types of deformity

	Males		**Females**	
	Right	**Left**	**Right**	**Left**
<0.9	60	56	71	72
0.9-1.15	12	15	3	1
>1.15	3	4	1	2
Total	75	75	75	75

3 females and 5 males had a unilateral type III deformity, and 1 male had a bilateral Type III deformity. 25.33% males have a PAI >0.9 and 6.66% females have PAI >0.9; indicating males have a preponderance to flat feet (Table 3).

Table 4: Distribution according to types of deformity

PAI	No.	Percentage
Both feet Type I	126	84%
Both feet Type II	8	5.33%
Both feet Type III	1	0.66%
One foot I and other II	7	4.66%
One foot I and other III	2	1.33%
One foot II and other III	6	4%

The majority of participants had a normal PAI in both feet. Only 5.33% had a type II deformity in both feet and 0.66% type III deformity in both feet. 9.99% had a combination of deformities in both feet (Table 4).

Table 5: Distribution Based on Height, Weight and BMI

	Mean height (in cm)	**Mean weight (in Kg)**	**Mean BMI (in Kg/m^2)**
No Flat Foot	163.51	60.30	22.22
Bilateral Grade III	172	65	21.97
Bilateral Grade II	172.5	74.625	25.14
One foot Grade I, Other Grade II	168.85	66.85	23.87
One foot Grade I, Other Grade III	161	57	21.84
One foot II, Other Grade III	171.58	70.66	23.59

The mean height of participants in the normal arch foot group (Type I PAI<0.9) (n=126, M=56, F=70) was 163.5 cm while those who had Type II Bilaterally (PAI 0.9-1.15) was 172.5 cm and Type III Bilaterally (PAI >1.15) was 172 cm (Table 5).

The mean weight of participants in the normal arch foot group (Type I PAI<0.9) (n=126, M=56, F=70) was 60.30kg while those who had Type II Bilaterally (PAI 0.9-1.15) was 74.628kg and Type III Bilaterally (PAI >1.15) was 65kg (Table 5).

The mean BMI of participants in the normal arch group (Type I PAI<0.9) (n=126, M=56, F=70) was 22.22 while those who had Type II Bilaterally (PAI 0.9-1.15) was 25.14 and Type III Bilaterally (PAI >1.15) was 21.97(Table 5).

Table 6a: BMI and RIGHT FOOT PAI

		Right			
		Type 1	**Type 2**	**Type 3**	**Total**
BMI	Underweight	16	1	1	18
	Normal	67	7	2	76
	Pre obese	24	3	2	29
	Obesity grade 1	14	1	0	15
	Obesity grade 2	9	3	0	12
	Total	130	15	5	150

pValue=6.003

Table 6b: BMI and LEFT FOOT PAI

		Left			
		Type 1	**Type 2**	**Type 3**	**Total**
BMI	Underweight	16	2	0	18
	Normal	66	7	3	76
	Pre obese	24	5	0	29
	Obesity grade 1	12	2	1	15
	Obesity grade 2	9	2	1	12
	Total	127	18	5	150

p Value= 4.725

It was noted that students with a Type II deformity in either or both feet had a higher BMI. However, the association between flat foot and BMI was not statistically significant (Table 6a, 6b).

DISCUSSION

Our study noted a 6% prevalence of flat foot in the study group. In a similar study done on 250 medical students by Ganapathy *et al.*, (16) the prevalence of flat foot was noted as 5.2%. In a study by Vijaykumar *et al.*, (17) on 412 individuals of the age group 18-27, the prevalence of flat foot was 8.9%. In a study by Rithanya *et al.*, (18) on 50 people aged from 50 to 70, the prevalence of flat feet was found to be 10% (12% in women and 8% in men). It can be inferred that as age advances the prevalence of flat foot increases.

In our study, a male preponderance to flat feet was noted which was contrary (18-21).

Our study did not find any significant association between obesity and flat foot. Redmond *et al.*, (22) also in a meta-analysis to find the relation between BMI and foot posture did not reveal any correlation.

Deshmandi *et al.*, (23) in a study on 1180 students based on a footprint-based analysis, showed significant correlation between BMI and flat foot in age group of 12-15 years but no correlation in 16-17 years age group. This difference could be attributed to an increase in body mass around puberty.

Fuhrmann *et al*., in their study reported an association between flat foot and obesity (24).

In the study by Ganapathy *et al.*, (16) the mean BMI of the normal and flat foot were 22.99±4.28 and 23.02±3.78 respectively. Our study also, showed a mean BMI of 22.22 in the normal group while those who had Type II Bilaterally (PAI 0.9-1.15) was 25.14 and Type III Bilaterally (PAI >1.15) was 21.97.

Staheli's method is suitable for calculation of PAI to identify normal and flat feet. It is not ideal to determine high arched foot, which is a limitation of our study.

CONCLUSION

Our study did not show any association between obesity and flat foot in the age group 18-25, indicating that probably the etiology of development of acquired flat foot varies with age. Our study also suggests that simple ink print method is a simpler method to diagnose flat feet deformity clinically using PAI. Flat foot is clinical condition which can be managed if diagnosed earlier. Identification and creating awareness about this condition in the younger population ensures earlier detection and may help those who want to pursue careers where the presence of skeletal deformities hinders them.

CONFLICT OF INTEREST

Authors declare that there is no conflict of interest among authors.

REFERENCES

1. Saltzman, C. L., Nawoczenski, D. A., Talbot, K. D. Measurement of the medial longitudinal arch. Arch Phys Med Rehabil. 1995 Jan; 76(1): 45-49.
2. Standring, S. Gray's Anatomy.40th ed. Elsevier publications (UK); 2008. Pp. 1450.
3. Low, S. Shoes, Sitting, and Lower Body Dysfunctions Published: November 22, 2009.
4. Burns, J., Crosbie, J., Hunt, A., Ouvrier, R. The effect of pes cavus on foot pain and plantar pressure. Clin Biomech (Bristol, Avon). 2005; 20: 877-882.
5. López, D., Gracia-Mira, R., Alonso, F., López, L. Analogy of the pediatric prevention. A study through the Internet. Rev Int of Hundred Pedol. 2012; 6: 63-72.
6. Williams, D. S., Mc Clay, I. S. Measurements used to characterize the foot and the medial longitudinal arch: reliability and validity. Physical Therapy. 2009; 80(9): 864-871.
7. Halabachi, F., Mazaheri, R., Mirshahi, M., Abbasian, L. Pediatric flexible flat foot; clinical aspects and algorithmic approach. Iran J Pediatr. 2013; 23(3): 247-260.
8. Mickle, M. J., Steele, J. R., Munro, B. J. The feet of overweight and obese young children: are they flat or fat? Obesity. 2006; 14(11): 1949-1953.
9. Pfeiffer, M., Kotz, R., Ledl, T., Hauser, G., Shega, M. Prevalence of flat foot in preschool aged children. Pediatric. 2006; 118(2): 634-639.
10. Levinger, P., Lenz, H. B., Fotoohabaddi, R., Feller, J. A., Bartlett, J. R., Bergman, N. R. Foot posture in people with medial compartment knee osteoarthritis. Journal of Foot and Ankle Research. 2010; 3(29): 1-8.
11. Evans, A. M., Nicholson, H., Zakarias, N. The paediatric flat foot proforma (p-FFP): improved and abridged following a reproducibility study. Journal of Foot and Ankle Research. 2009; 2(25): 1-8.
12. Tudor, A., Ruzia, L., Sestan, B., Sirola, L., Prpc, T. Flat footedness is not a disadvantage for athletic performance in children aged 11-15 yrs. Pediatrics. 2009; 123(286): 386-392.
13. Engel, G. M., Staheli, L. T. The natural history of torsion and other factors influencing gait in childhood. A study of the angle of gait, tibial torsion, knee angle, hip rotation, and development of the arch in normal children. Clin OrthopRelat Res 1974; 99: 12-17.
14. Hernandez, A. J., Kimura, L. K., Laraya, M. H. F., Favaro, E. Calculation of Staheli's plantar arch index and prevalence of flat feet: a study with 100 children aged 5-9 years. Acta Ortop Bras. 2007; 15(2): 68-71.
15. Riccio, I., Gimigliano, F., Gimigliano, R., Porpora G., Iolascon, G. Rehabilitative treatment in flexible flatfoot: a perspective cohort study. MusculoskeletSurg. 2009; 93: 101.
16. Ganapathy, A., Sadeesh, T., Raghuram, K. Effect of Height, Weight and BMI on Foot Postures of Young Adult Individuals. Journal of Clinical and Diagnostic Research. 2018 Sep, Vol-12(9): AC06-AC08.
17. Vijayakumar, K., Senthil Kumar, S., Subramanian, R. A Study on the relationship between BMI and prevalence of flat foot among the adults using foot print parameters. Int. J. of Adv. Res. 2016; 4 (May): 1428-1431.
18. Rithanya, P., Babu, Y., Mohanraj, K. G. Assessment of flat foot by plantar arch index using footprint in aged population. Drug Invention Today. 2018; 10; 11.
19. Pita-Fernández, S., González-Martín, C., Seoane-Pillado, T., López-Calviño, B., Pértega-Díaz, S., Gil-Guillén V, *et al.*, 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. 2015; 25: 148-154.
20. Dunn, J. E., Link, C. L., Felson, D. T., Crincoli, M. G., Keysor, J. J., McKinlay, J. B., *et al.*, Prevalence of foot and ankle conditions in a multiethnic community sample of older adults. Am J Epidemiol. 2004; 159: 491-498.
21. Nguyen, U. S., Hillstrom, H. J., Li, W., Dufour, A. B., Kiel, D. P., Procter-Gray, E., *et al.*, Factors associated with hallux valgus in a population-based study of older women and men: The MOBILIZE Boston study. Osteoarthritis Cartilage 2010; 18: 41-46.
22. Redmond, A. C., Crane, Y. Z., Menz, H. B. Normative values for the foot posture index. Journal of Foot and Ankle Research. 2008; 1(6): 1-9.
23. Deshmandi, H., Rahnema, N., Mehdizadeh, R. Relationship between obesity and flatfoot in high school boys and girls. International Journal of Sports Science and Engineering. 2009; 3(1): 43-49.
24. Fuhrmann, R. A., Trommer, T., Venbrocks, R. A. The acquired buckling-flatfoot. A foot deformity due to obesity?. Orthopade. 2005; 34: 682-689.