RESEARCH ARTICLE

STUDY OF FOOTPRINTS TO DETERMINE THE INCIDENCE OF PES PLANUS IN SOUTH-INDIAN POPULATION USING STAHELI'S PLANTAR ARCH INDEX

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ABSTRACT

Introduction: Pesplanus is one of the most common foot problems. It is characterized by-fatigue during the gait, metatarsalgia, pain in the forefoot, rearfoot, ankle, medial edge of the foot, near the insertion of the posterior tibialis, dorsal part of the foot (in case of a rigid foot), The patient has difficulty in standing, walking, running, etc.

Materials & Methods: The main purpose of this study was to apply quantitative and qualitative analysis of the footprints to determine the incidence of pesplanus (flat foot) in South-Indian student population by Plantar Arch Index method and to grade the severity of pesplanus. A Sample size of 284 students from Vydehi Institute Of Medical Sciences & Research Centre Bangalore was selected comprising of 142 males and 142 females, aged between 18-24 years.Informed consent from the students and ethical clearance from the institute was obtained. Printing India ink was applied on the soles of both the feet of each student and dynamic footprints were obtained on A4 size papers. Analysis of the results was done.

Results: This study revealed that 113 out of 284 subjects had pesplanus. The overall incidence of pesplanus was 39.7% including 21.8% in males and 17.9% in females. Furthermore, the incidence of unilateral flat foot was 9.15% among males, 7.74% among females and a total of 8.45% in the study population and the incidence of bilateral flat foot was 25.3% among males, 20.4% among females and a total of 22.8% in the study population. Totally out of 568 feet (284 subjects) 178 feet were flat i.e. had pesplanus which included 52 Grade I flat foot, 53 Grade II, 32 Grade III and 41 Grade IV flat foot.

Conclusion: It may serve as an early warning sign of structural and functional defects of the foot in a young population and can provide help for making appropriate footwear for persons with pesplanus.

INTRODUCTION

The overwhelming development of human brain cortex, vocal apparatus, and lower limb and foot structure distinguish man from other mammalians. Reviewing the concepts about human foot evolution, we notice that the footprints of hominoids demonstrated the existence of a plantar arch 3.7 million years ago. (Morton, 1937) Humans are born with flat feet especially of the flexible type, but as they begin to walk, they start developing normal arches throughout childhood. Research suggests that the optimal age range for arch development is 4-6 years old and that arches are usually formed completely by age of 8 years. If the flatfoot persists or presents in adolescence or

adulthood, then it is considered as abnormal. (Chew *et al.*, 1987) The foot has two functions: to be a strong and stable support for the body, and the lever for ambulation. (Morton, 1937) This double function makes feet to present a unique behavior during ambulation, when it is submitted to a successive load and unload cycle. Presenting the highest level of variability is the medial longitudinal arch. The deformation experienced by the medial longitudinal arch during support makes feet to be the region suffering the highest variations in a human body. These functional features make clinical examination of this region important. (Cavanagh and Rodgers, 1987) Pesplanus or flat foot refers to a change in foot shape in which the foot does not have a normal arch when standing. (Canale, 1998; Rose, 2007) Pesplanuscan be of two types-Flexible and Rigid. The flexible type of pesplanus is relatively common and is due to soft tissue abnormalities. Rigid

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pesplanus is caused by a combination of bony or fibro cartilaginous and soft tissue abnormalities, and include tarsal coalition (The foot and ankle, 1972), congenital vertical talus, idiopathic tight heel cord, neuromuscular disorders (e.g. cerebral palsy and polio), tarsal fracture with secondary osteoarthritis and rheumatoid arthritis. Tarsal condition is the commonest type of rigid foot. (Eluwa *et al.*, 2009) Most flexible flat feet are asymptomatic, and do not cause pain. But persons with rigid flat foot may have disabling weight bearing symptomslike- pain in the lower limb, starting from the ankle and progressing up to the hip and back of the trunk. People with flat feet may also experience stiffness in one or both feet. One or both feet may be flat on the ground (either no arch, or very slight arch), shoes may fit unevenly.Staheli's Plantar Arch Index method is used to determine the incidence of pesplanus. It is defined as the ratio of the width of the central region of the foot to the width of the heel region of the foot. Many studies have been conducted in the world on pesplanusin the disciplines of anatomy, anthropology, forensic science, orthopedics, ergonomics etc.but only a very few have been conducted in India. Hence, this study aims at finding the prevalence of pesplanus in South-Indian population. (Canale, 1998; Rose, 2007)

MATERIALS AND METHODS

A Sample size of 284 students comprising of 142 males and 142 females of South Indian origin, aged 18-24 years was taken for the study based on prevalence of 25.3% with α error of 5%. Error in premium is 20%. After obtaining ethical clearance from Institutional Ethical Committee the subjects were screened based on the inclusion and exclusion criteria.
Inclusion criteria included students from Vydehi Institute of Medical Sciences &Research Centre in the age group of 18-25 years. Exclusion criteria included any congenital deformities of the foot, callus or corn, unwillingness for participation. The participants were briefed about the nature of the study and intervention and only those participants willing to take part were recruited for the study and informed consent was obtained. Following requirements were taken from each subject: Name, Age, Gender, and Date of birth. (Chougala *et al.*, 2015) All subjects underwent footprint screening. Printing India ink was applied on the soles of both the feet of each student and dynamic footprints were obtained on A4 size papers. Quantitative and Qualitative Analysis was done.

Figure 1. Steps performed to take the footprints

Quantitative analysis included calculating Staheli's Plantar Arch Index. It is defined as the ratio of the width of the central region of the foot (A) to the width of the heel region of the foot

(B). Thus, Staheli's Plantar Arch Index = A/B. It is used to determine the presence of pesplanus. The arch indices can range from 0.0-1.0 and are indicative of cavus and planus foot respectively though, the normal range of Plantar Arch Index is between 0.5-0.8. (Soper *et al.*, 2001)
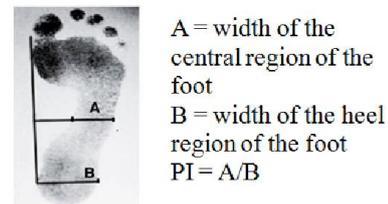

Figure 2. How the measurements of 'A' and 'B' are taken for calculating Staheli's Plantar Arch Index

Statistical Analysis

Statistical analysis for the present study was done manually as well as using the statistic software SPSS 16.0 version so as to verify the results obtained. For this purpose datawas entered in an excel spread sheet, tabulated and subjected to statistical analysis. In Qualitative Analysis, PesPlanuswas graded into 4 grades according to Moreno de la Fuente, (2003) based on the following criteria-

Table 1. Criteria for grading of pesplanus

PES PLANUS GRADING	DESCRIPTION	FLAT FOOT APPEARANCE
GRADE I	Mid foot support>1/3 of the total foot width (external supports lightly increased)	First grade
GRADE II	A contact of internal and external edges of the foot exists, but the plantar arch remains (it doesn't contact to the ground)	Second grade
GRADE III	Plantar arch disappears completely. The width of the arch support is equal to the metatarsal support width	Third grade
GRADE IV	Dominant internal protuberance on the footprint, and a wide area on the external anterior and middle zones does not appear on the footprint.	Fourth grade

RESULTS

This study revealed that 113 out of 284 subjects had pesplanus, which included 62 out of 142 males and 51 out of 142 females. Totally 178 out of 568 feet (284 subjects) were flat i.e. had pesplanus. Statistical analysis showed no significant difference between the incidence of pesplanus in males and females as well as between the right and the left foot. Furthermore, out of the 62 male subjects having pesplanus, 26 had unilateral flat foot and 36 had bilateral flat foot. Among the 51 female subjects with pesplanus, 22 had unilateral flat foot and 29 had bilateral flat foot. Statistical Analysis showed significant difference between the incidence of unilateral & bilateral flat foot by the method of Binomial test for Proportions.

Table 2. Mean plantar arch index in the subjects

	Right foot			Left foot		
	Plantar Arch Index	Incidence of Pes Planus	% of Pes Planus	Plantar Arch Index	Incidence of Pes Planus	% of Pes Planus
Males	0.72±0.24	44	25%	0.75±0.26	54	30%
Females	0.70±0.23	36	20%	0.71±0.22	44	25%

Table 3. Overall mean and SD of arch indices in the left & right foot

	Left foot	Right foot	P Value
Average	0.72	0.71	
Standard deviation	0.24	0.23	0.45
Total number of feet	284	284	

Table 4. Overall mean and SD of arch indices in males & females

	Males	Females	P Value
Average	0.73	0.70	
Standard deviation	0.26	0.23	0.28
Total number of feet	284€	284	

Table 5. Incidence of unilateral & bilateralflat foot

	Unilateral Flat Foot	Incidence %	Bilateral Flat Foot	Incidence %	Total Feet
Males	26	9.15	72	25.3	284
Females	22	7.74	58	20.4	284
Total	48	8.45	130	22.8	568

Table 6. Total no. Ofunilateral & bilateral flat foot in the study population

Unilateral Flat Foot	Bilateral Flat Foot	P Value
48/284	65/284	0.037

Table 7. Incidence of pesplanus among males and females in various studies

Name of the study	No. of Subjects (N)	Age Criteria (Yrs)	Incidence in males	Incidence in females	Incidence of Pes Planus
Iqbiqbi *et al*. 2002	305	13-17	-	-	24.26%
Patrick S. Igbigbi *et al*, Kenyan, Tanzanian Population (2005)	1000	-	-	-	43.2% 20.3%
Mokutima A Eluwa *et al*, University of Calabar, Nigeria (2009)	1000	20-30	5.8%	7.6%	13.4%
Dare NW, Niger Delta University, Bayelsa, Nigeria (2012)	204	18-22	9.4%	15.9%	25.3%
Eluwa *et al*, Cross River State, Nigeria (Eluwa *et al*., 2008)	1000	20-30	8.80%	13.40%	22.2%
Lakstein *et al*, Israel (2010)			17.17	11.65	28.82
Aymelek, Turkey (Cetin, Aymelek *et al*., 2011)			35.5	28.5	64
Present study	284	18-24	21.8%	17.9%	39.7%
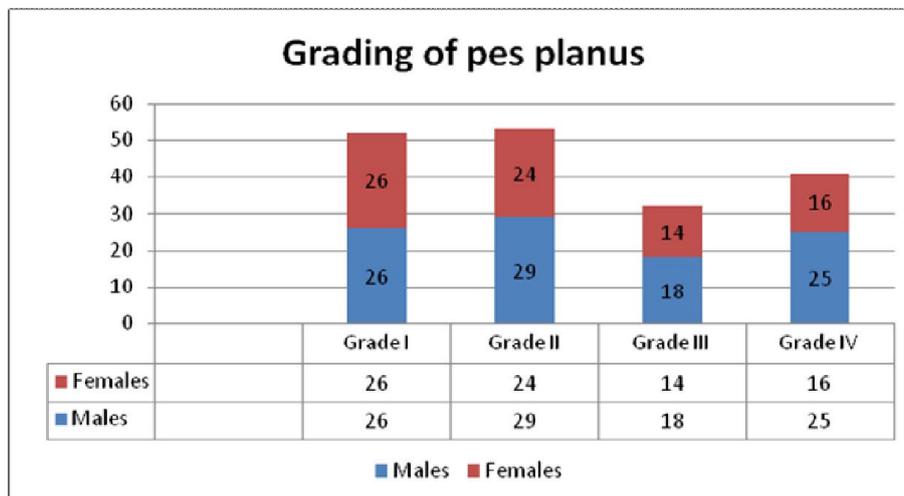
Graph 1. Grading of pesplanus

Out of 568 feet, 178 were flat which included 52 Grade I flat foot, 53 Grade II, 32 Grade III and 41 Grade IVflat foot. Statistical Analysis showed no significant difference between the incidences of pesplanus of different grades. The highest number of flat foot belonged to Grade II and Grade I.

DISCUSSION

The anatomy and shape of an individual's medial longitudinal arch dictates the types of injuries that person is susceptible to. The height of a person's arch is determined by the height of the navicular bone and collapse of this arch results in flat feet. Pesplanus (flat foot) is the most common foot pathology not only in patients of all ages in general but in pediatric, orthopedic practice in particular. (Lee, 2005) The present study has been conducted among 18-24 years age group considering the fact that the development of the longitudinal arches of the foot is complete by this age. Dynamic footprints obtained using printing India ink and A4 size papers was used. The technique employed for obtaining footprints in this study was simple, not expensive, easy to apply and satisfactory for routine clinical analyses. Footprints can be used for studies as they are simple, easily available, low-cost, and non-invasive, and without radiation. (Kanatli *et al.*, 2001) Although there are people who consider footprint as a poor evaluation approach, there is almost an unaccountable number of authors who advocate its use: Cavanagh and Rodgers (1987), Gervis, Engel and Staheli (1974), Viladot, Staheli *et al.* (1987), and Volpon and Chenare among some. The correlation between X-ray studies and footprint shows that the footprint is effective for individual studies and population-based investigations (Mathieson *et al.*, 2004), for large-scale studies (population-based), its practical application is more cumbersome. Any method showing a clear and homogenous footprint is, at first, worthy for assessing it. Cavanagh and Rodgers, have mentioned several cases. (Cavanagh and Rodgers, 1987)

The plantar arch index (PI) correlates foot central region, also called arch region, to the heel region, and has also been used by some other authors. (Mathieson *et al.*, 2004; Hogan and Staheli, 2002) The relationship between the areas of these regions was used by Cavanagh and Rodgers (1987) In the Present study, Plantar Arch Index (PI) method has been used for evaluation of the footprints. The mean plantar arch index in the male subjects was 0.72 ± 0.24 in the right foot and 0.75 ± 0.26 in the left foot, whereas it is 0.70 ± 0.23 in the female subjects in the right foot and 0.71 ± 0.22 in the left foot. The overall incidence of pesplanus was 39.7% including 21.8% among males and 17.9% in females. Furthermore, the incidence of unilateral flat foot was 9.15% among males, 7.74% among females and a total of 8.45% in the study population and the incidence of bilateral flat foot was 25.3% among males, 20.4% among females and a total of 22.8% in the study population. Thus, males had higher incidence of pesplanus than females and the incidence was more in the left feet than the right but it was not significant enough. This higher incidence among males may be due to the use of wrongly designed footwear, lack of exercise or excessive weight bearing. If the footwear is harder then it may cause flat foot. (Chougala *et al.*, 2015). Statistical Analysis of the results showed significant difference between the incidence of unilateral and bilateral flat foot with bilateral

flat foot being more common than the unilateral. This could be due to the fact that most congenital flat foot affects both the feet simultaneously and equally i.e. bilaterally. On the other hand most unilateral flat foot are acquired, thus affecting only the injured/target foot. Overall, a higher incidence (39.7%) of pesplanus was found in our population when compared to other studies. It was more than that seen in Tanzanian (20.3%) and Nigerian (25.3%) populations butless than that seen in Kenyen (43.2%) population which may be due to the fact that Africans are more taller and bulkier than Indians and also they are used to walking barefoot whereas Indians, especially the student population are exposed wearing closed shoes and shoes with improper designs from an early age. In the present study it was also found that the highest incidence of pesplanus belonged to Grade I and Grade II, suggesting that majority of them were of flexible type as compared to Grade III and Grade IV pesplanus, which are mostly bony type. With the help of footprint, the PI calculation was performed in a simple and practical way, and both can be done on an outpatient basis - in clinical cases - as well as in large groups, for population-based studies. The plantar arch index, as any other, must be applied in the light of clinical history and physical examination of the patient, and never in an isolate and absolute manner. (Hernandez *et al.*, 2007)

Conclusion

This study will prove highly useful for Orthopaedicions, anatomists, podiatrist, etc. for determining the incidence of pesplanus and possibly predicting pathologic foot conditions. It may serve as an early warning sign of structural and functional defects of the foot in a young population and can provide help for making appropriate footwear for persons with pesplanus.

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