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Original Research

A Study on Correlation between BMI and Morphometry of Medial Longitudinal Arch in Adults Using Navicular Drop Test

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ABSTRACT

Background: Obesity is related with health problems, involving high blood pressure, diabetes mellitus, and musculoskeletal disorders. In among all foot arches also can be affected because of obesity. Foot arch is made up of bony arch and soft tissues which are acts as a shock absorber and helps in transmission and distribution of body weight. Body mass index (BMI) is one of the indicators used to detect body weight and nutritional status. Excessive weight of an adult can affect the occurrence of flat feet compared with adults who have normal weight. Flat feet are a disorder of foot structures that does not form the medial longitudinal arch (MLA) . There are various studies who claim the association between high BMI and flat feet in adults. To know the association of flat feet and BMI in adult, this study was carried out.

Methadology: This is an analytical observational research with a cross-sectional design study. This study has done in National Institute of Medical Science & Research, Jaipur Rajasthan, India .1000 students who are under 18-25 age group of Medical, Paramedical & Physiotherapy of national Institute of medical Science & Research Rajasthan were taken .The research was conducted in between January 2020 to June 2022 (2 years).Various foot parameters for medial longitudinal arch taken in non weight bearing and weight bearing position . Data analysis was performed by pearsons correlation test were used the check association between BMI and foot parameters. Paired t test and independent student's t test were used to compare mean of foot parameters. The category of body mass index was classified into Normal, overweight and obese according to BMI INDEX.

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Result: We evaluated 486 male and 514 female with respect to the BMI, the arch height (AH), Total foot length (TFL), Anterior foot length (AFL), Hind foot length (HFL) of medial longitudinal arch of both foot. The obese female and male presented mean values for the all the parameters significantly greater than the normal and overweight women. There was a positive correlation between the BMI and the AH and all other parameters of medial longitudinal arch.

Conclusion: The result of the bivariate analysis conclude that there was a highly significant relationship between body mass index and parameters of Medial longitudinal arch (p = 0.00001).

Key Words: Medial longitudinal arch, flat feet, body mass index, foot parameters, and overweight, obese Arch height (AH) total foot length (TFL) , fore foot length (FFL), hind foot length (HFL).

INTRODUCTION

Human foot has been an object of interest of various specialists. Leonardo da Vinci, a Renaissance genius, painter, and architect, remarked that it was a most brilliantly structured machine and a true piece of art. The foot consists of 26 bones and more than 30 articulations enabling three fundamental functions: supporting, shock absorbing, and weight bearing. Many factors influence the structure and functioning of the foot, one of them being body weight. The problem of overweight and obesity and their influence on foot arches has been frequently dealt with, particularly in the context of an influence of excessive weight on flat foot incidence 1

Flatfeet is a very regular term that is been used in daily routine. Medically it is known as pes planus", it refers to the loss of the medial longitudinal arch of the foot. Though it is common problem in various age groups, negligence is often observed. Flat feet are always associated with heel pain, feet pain or even lower extremity pain. 2

The bone structure of the MLA is formed by the calcaneus, talus, navicular bone, medial cuneiform bone, and first metatarsal bone. The spring ligament complex is connected with the navicular bone of the foot, and thus the navicular bone serves as an important constructional factor for the MLA and has a role as an indicator and stabilizer determining height of the foot arch.

Normally arches of foot developed during first five year of life and if it is not developed then lead to congenital or acquired flat feet(pes planus).3

Many studies have stated and proved the association between the flat foot and high BMI. High BMI (>25) as a cause for the occurrence of flat feet. Increased body weight leads higher stress over the feet causing the arches to drop and lead to flat feet 4.

Now a day's Obesity is seen as the first wave of defined cluster of non communicable diseases called NEW WORD SYNDROME, creating an enormous socio economic and public health burden in poorer countries 5.

According to the old literatures there are many techniques to measure medial longitudinal arch. The methods are divided into two groups: indirect and direct methods. Indirect methods include digital footprints or ink which can be static or dynamic and photographic techniques. Direct methods are, clinical assessment, ultra-sonography quantification radiographic evaluation, and, somato-metric measurements. One of the most popular clinical methods of assessing medial longitudinal arch is the Brody's navicular drop test which we have used to study the different foot parameters for correlation with BMI. In 1982 Brody's navicular drop test is a clinically validated tool which was determined by Brody in 1982. He classifies the foot arch into low arch (< 5mm), normal (6-10mm), high arch (> 10 mm) , by measuring navicular drop. 6

WHO guidelines for BMI classifies the individuals into underweight, normal weight, overweight, and obese, BMI< 18.5, 18.50 – 24.99, 25.00 – 29.99, > 30.00 respectively. Many research states that obesity lowers the medial longitudinal arch of foot. Hence this current study was intended to explore any significance changes were found in medial arch height of foot among normal, over weight and obese groups based on WHO Guidelines of BMI

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MATERIAL AND METHOD

The ethical clearance was obtained from the institutional ethical committee, to carry out the study**.** The NIMS University, Jaipur, Rajasthan students from different field specially medical, Paramedical, Physiotherapy students were targeted to obtain the subjects for carrying out the study. The inclusion criteria was to get the willingly, voluntary, informed consent participating subjects between 18-25 years of age including both genders, whereas the subjects with recent lower extremities surgeries, recent trauma, any limb length discrepancy, Lower limb pain at the time of data collection , Any Neuro-muscular disorder were excluded from the study. All the subjects included. The BMI was calculated and Flat feet were seen by using Navicular drop test method. The data was then collected and statistical analysis was done.

Brody's navicular drop test was done on all the subjects in both weight bearing and non-weight bearing positions. For non-weight bearing, the patient was made to sit in chair with hip and knee flexed at 90 degree and foot placed flat on custom made bronnack device.

Custom made Bronnack Device :- The Brannock Device is a measuring instrument invented by Charles F. Brannock for measuring a person's shoe size. A Brannock device measures foot length, foot width, and arch length. Here we have prepared a customized Bonnack device , in this we have taken a scale on a board where the subject's foot can be kept for measure vertical height from the device to navicular tuberosity.

The navicular tuberosity was palpated anteroinferior to medial maleolus and marked with color marker as shown in (Figure 1). The distance from navicular tuberosity to the custom made bronnack device (AH – Arch height) is measured with a sheet of paper as shown in (Figure 2)

Participant was asked to stand with shoulder width apart in weight bearing position. Same procedure was undertaken as seated position as shown in (Figure 3). The difference of navicular drop in non-weight bearing and weight bearing was calculated for all participants with the help of vernier caliper.

In other foot parameters TFL (Total foot length)- distance measure between head of first metatarsal and posterior most end of foot.

AH (Arch height) – vertical distance between bonnack device and navicular tubercle marked on medial side of foot by using a sheet of paper placed vertically as shown in figure

FFL (Fore foot length) – distance between head of 1st metatarsal and Navicular arch height .

HFL(Hind foot length) – distance between Navicular arch height and posterior most end of foot.

Similar measurements were carried for other foot of the participant in non weight bearing position.. Thus using these four parameters quantitative morphology of medial longitudinal arch of each individual was assessed.

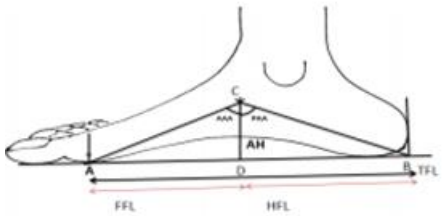

Figure 1 **Figure 2** **Figure 3**

Figure 1: Showing all measurement of medial longitudinal arch on custom made bronnack device.

Figure 1: Showing A) head of first metatarsal bone navicular tubercle B) Navicular tubercle c) Medial malleolus in Non weight bearing position.

Figure 3: Showing measurement of Arch height on custom made bronnack device in weight bearing position.

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RESULT

Measurements of body weight and height were taken to obtain a body mass index. Flat feet measurement were obtained by changes in different foot parameters. Navicular drop test is done

Table 1: shows the gender distribution of subjects were among 1000 subjects 486 (48.6%) were male , 514(51.4%) female.

Table 1: Gender distribution of subjects

Gender	n = 1000	In %
Male	486	48.6%
Female	514	51.4%

Table: 2 shows frequency distribution of BMI in all subjects according to WHO guidelines those who were having BMI 18-24.9 are normal subjects were 282, those who are in category between 25-29.9 were 629 subjects and in 89 subjects BMI was more than 30 under category of obese.

Table 2: Frequency distribution of BMI of subjects

BMI	n = 1000	In %
< 25	282	28.2%
25 - 29.9	629	62.9%
> 30	89	8.9%

Table: 3 shows Descriptive statistics of non-weight bearing right foot of subjects where mean value for total foot length(TFL) is 17.63 ± 1.49, fore foot length (FFL) 8.92 ± 0.74 , hind foot length (HFL) 8.71 ± 0.75, arch height (AH) 5.02 ± 1.05.

Table 3: Descriptive statistics of non-weight bearing right foot of subjects

Variables	Minimum	Maximum	Median (IQR)	Mean ± SD
TFL	15.2	20.2	17.6 (16.4 , 18.9)	17.63 ± 1.49
FFL	7.7	10.2	8.9 (8.3 , 9.5)	8.92 ± 0.74
HFL	7.5	10	8.7 (8.1 , 9.4)	8.71 ± 0.75
AH	3.2	6.8	5 (4.1 , 5.9)	5.02 ± 1.05

Table: 4 shows Descriptive statistics of non-weight bearing left foot of subjects where mean value for total foot length(TFL) is 17.85 ± 1.61, fore foot length (FFL) 9.18 ± 0.84, hind foot length (HFL) 88.67 ± 0.78, arch height (AH) 5.25 ± 1.13.

Table 4: Descriptive statistics of non-weight bearing left foot of subjects

Variables	Minimum	Maximum	Median (IQR)	Mean ± SD
TFL	15.2	20.6	17.9 (16.4 , 19.2)	17.85 ± 1.61
FFL	7.8	10.6	9.2 (8.4 , 9.9)	9.18 ± 0.84
HFL	7.4	10	8.7 (8 , 9.3)	8.67 ± 0.78
AH	3.4	7.1	5.3 (4.2 , 6.3)	5.25 ± 1.13

Table: 5 shows Descriptive statistics of weight bearing right foot of subjects where mean value for total foot length (TFL) is 17.97 ± 1.54, fore foot length (FFL) 8.89 ± 0.83, hind foot length (HFL) 9.1 ± 0.83, arch height (AH) 4.72 ± 1.04.

Table 5: Descriptive statistics of weight bearing right foot of subjects

Variables	Minimum	Maximum	Median (IQR)	Mean ± SD
TFL	15.3	20.6	18 (16.6 , 19.3)	17.97 ± 1.54
FFL	7.24	10.71	8.86 (8.21 ,	8.89 ± 0.83

			9.56)	
HFL	7.344	10.92	9.1 (8.37 , 9.7)	9.1 ± 0.83
AH	2.8	6.4	4.7 (3.9 , 5.7)	4.72 ± 1.04

Table: 6 shows Descriptive statistics of weight bearing left foot of subjects where mean value for total foot length (TFL) is 18 ± 1.62, fore foot length (FFL) 9.01 ± 0.9, hind foot length (HFL) 8.99 ± 0.88, arch height (AH) 4.95 ± 1.01.

Table 6: Descriptive statistics of weight bearing left foot of subjects

Variables	Minimum	Maximum	Median (IQR)	Mean ± SD
TFL	15.3	20.7	18 (16.6 , 19.4)	18 ± 1.62
FFL	7.191	10.971	8.99 (8.28 , 9.68)	9.01 ± 0.9
HFL	7.191	10.971	8.97 (8.27 , 9.65)	8.99 ± 0.88
AH	2.9	6.8	5 (4.1 , 5.8)	4.95 ± 1.01

Table: 7 shows Association of BMI with different foot measurement of non - weight bearing feet, in right foot correlation in BMI and TFL is 0.3755, t test value 12.801 , p value 0.000001. Correlation in BMI and FFL is 0.3759, t test value 12.815, p value 0.000001. Correlation in BMI and HFL is 0.3749, t test value 12.774, p value 0.000001. Correlation in BMI and AH is 0.3760, t test value 12.819, p value 0.000001. These all parameters are show highly significance in all the parameters of medial longitudinal arch and BMI in weight bearing and non weight bearing foot.
In left foot correlation in BMI and TFL is 0.3734, t test value 12.715, p value 0.000001. correlation in BMI and FFL is 0.3748, t test value 12.773, p value 0.000001. Correlation in BMI and HFL is 0.3715, t test value 12.639, p value 0.000001. Correlation in BMI and AH is 0.3782, t test value 12.907, p value 0.000001. These all parameters are show highly significance in all the parameters of medial longitudinal arch and BMI in weight bearing and non weight bearing foot.

Table 7: Association of BMI with different foot measurement of non - weight bearing foot.

Variables		Correlation (r)	t-test	P - Value	Significance
Non - weight bearing right foot	**TFL**	0.3755	12.801	0.000001	**All are highly significant**
	FFL	0.3759	12.815	0.000001	
	HFL	0.3749	12.774	0.000001	
	AH	0.3760	12.819	0.000001	
Non - weight bearing left foot	**TFL**	0.3734	12.715	0.000001	
	FFL	0.3748	12.773	0.000001	
	HFL	0.3715	12.639	0.000001	
	AH	0.3782	12.907	0.000001	

Table: 8 shows Association of BMI with different foot measurement of weight bearing feet , in right foot correlation in BMI and TFL is 0.3819, t test value 13.056, p value 0.000001. correlation in BMI and FFL is 0.3615, t test value 12.247, p value 0.000001. correlation in BMI and HFL is 0.3483, t test value 11.738, p value 0.000001. correlation in BMI and AH is 0.1500, t test value 4.794, p value 0.000002.
In left foot correlation in BMI and TFL is 0.3758, t test value 12.810, p value 0.000001. correlation in BMI and FFL is 0.3455, t test value 11.630, p value 0.000001. Correlation in BMI and HFL is 0.3392, t test value 11.392, p value 0.000001. Correlation in BMI and AH is 0.1412, t test value 4.506, p value 0.000007. These all parameters are show highly significance in all the parameters of medial longitudinal arch and BMI in weight bearing and non weight bearing foot.

Table 8: Association of BMI with different foot measurement of weight bearing foot.

Variables		Correlation (r)	t-test	P - Value	Significance
Weight bearing right foot	**TFL**	0.3819	13.056	0.000001	**All are highly significant**
	FFL	0.3615	12.247	0.000001	
	HFL	0.3483	11.738	0.000001	
	AH	0.1500	4.794	0.000002	
Weight bearing left foot	**TFL**	0.3758	12.810	0.000001	
	FFL	0.3455	11.630	0.000001	
	HFL	0.3392	11.392	0.000001	
	AH	0.1412	4.506	0.000007	

We evaluated 486 male and 514 female with respect to the BMI, the arch height (AH) , Total foot length (TFL) , Anterior foot length (AFL) , Hind foot length (HFL) of medial longitudinal arch of both foot. The obese female and male presented mean values for the all the parameters significantly greater than the normal and overweight women. These results shows a positive correlation between the BMI and all foot (AH,TFL,FFL,HFL) parameters of medial longitudinal arch.

DISCUSSION

In the present study we investigated flat foot among 18 to 25 years age group by using NAVICULAR DROP method which was carried out in cross sectional population, in that we have found highly significant correlation of flat feet with obesity in age between 18-25 years. All morphometric parameters (AH,TFL,AFL,HFL) of medial longitudinal arch of foot were correlated with BMI. The various factors give rise to the flat foot and the bottom of the foot, including the age, sex, weight, race and some other anthropometric factors that make it one of the most serious and common problems in the 21st century. 7

On the basis of above observation, navicular drop was more in the high BMI subjects group of right and left foot. It shows that the overweight and obese population is at a high risk of getting low arched feet.

In 2016 Mohsen @ al found that Majority (83.9%) of respondents had normal feet. The prevalence of flatfoot was 16.1% with a decreasing trend with age. Boys had a higher frequency of flatfoot than girls; however the difference was not significant ($p > 0.05$). The prevalence of flatfoot was 17.5% in boys and 14.5% in girls. The percentage of overweight and obese children was 10.3%. A significant difference in the prevalence of flatfoot occurred between; under-weight (13.9%), normal-weight (16.1%), overweight (26.9%), and obese (30.8%); children.8

In 2017 Ashok Aenumulapalli @ al found prevalence of flexible flat foot was 13.6% (for males-12.8%; for females-14.4%). The median with Inter Quartile Range (IQR) for ND among males was 6 mm (4-8) and 6 mm (4-9) for right and left foot respectively. The median with IQR for ND among females was 6mm (4-10) and 7mm (3-8) for right & left respectively. The correlation of Right Side Navicular Drop (RND) with height and weight was significant, but insignificant correlation was found between RND and BMI. The correlation of Left Side Navicular Drop (LND) with height, weight and BMI of individuals was statistically not significant. The difference between the ND of males and female group was statistically not significant.9

In 2018 Jankowicz-Szymańska @ al stated that BMI significantly correlated with the height of the foot arch but their age did not. Excessive body weight contributes to the development of flat feet to a greater extent than age.10

In 2020 philipus @ al stated that Meta-analysis of 4 cross-sectional articles of obese individuals (aOR= 3.10; 95% CI= 1.80 to 5.32 p= 0.001); Meta-analysis of 2 case-control articles, obese individuals (aOR= 5.49; 95% CI= 1.33 to 22.61; p= 0.07). Meta-analysis of 3 cohort articles of obese individuals (aOR= 1.64; 95% CI= 1.34 to 2.02; $p<0.001$); Obesity is a risk factor that can increase the incidence of flat foot.11

In 2020 Samarakoon JN @ al stated that 403 participants enrolled, 53.8% were females. The mean arch index of right and left sides were 0.26883 ± 0.3477 and 0.26993 ± 0.03484 respectively. Overall prevalence of flat feet was 51.6%; it was right sided in 32% and left sided in 37.7%. Higher Body Mass Index was associated with presence of flat feet (p=0.001) and arch index (p<0.001). 12
In 2020 Cen X, Xu D @ al stated that there is No significant differences were observed for 10% BW compared to the normal weight condition ($p = 0.068 > 0.05$). However, when weight bearing increased to 20% and 30% BW, the subjects' AHI showed significant differences, decreasing by 0.006 ± 0.004 ($p = 0.004$) and 0.009 ± 0.005 ($p = 0.001$), respectively. 13
G. Pavan Kalyan Reddy@ al in 2021 have found in their study that BMI was highly significant with Prevalence of bilateral flat foot and Prevalence of bilateral flat foot was 11.6% (8.3% were females and 3.3% were males). Unilateral was 3% (2% were females and 1% were males) and the correlation of ND, AI, FPI with gender, age was not significant. 14
Many studies have found highly significance between BMI and all the parameters of medial longitudinal arch. All parameters of MLA have changed in weight wearing position. Maximum studies have done on children and those who did on adults clear stated that flat feet is highly significant with BMI. Because of less number of subjects, data was not clear but in our study we have taken more number of subjects (1000) to get accuracy.
In our data we have taken 18-25 age group students from different area of India and we found that all the parameters (AH,TFL,AFL,HFL,) are highly significant with BMI (p-0.000001).during the research we have observed obesity among the population has increased now a day's which is a life threatening disorder because in our study we found among 1000 subjects 282 normal (BMI between 19-24.9) 629 overweight (BMI 25-29.9) , 89 obese (BMI >30) . In this study in normal category those having (BMI between 19-24.9) 57 (20.21%) people were having positive flat feet and 225 (79.78%) were having normal medial longitudinal arch . In the category of overweight who has 25-29.9 BMI , there are 340 (54.10%) people were positive flat feet and 289 (45.94%) were having normal medial longitudinal arch. there are 89 subjects were included as obese who has BMI more than 30 in among 49 (55.1%) people were positive flat feet and 40 (44.94%) were having normal medial longitudinal arch.

CONCLUSION

The present study concluded that there are significant association between morphometric changes of medial longitudinal arch and BMI in Age group 18-25 year . The current study concluded, navicular drop was more in overweight group and then in obese group of right and left foot against normal weight group. The current study also conclude that tendency of overweight / obese has been increased.

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