

Prevalence of Flexible Flat Foot in Adults: A Cross-sectional Study

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ABSTRACT

Introduction: Flat foot (pes planus) is a commonly observed disorder in clinical practice. The height of Medial Longitudinal Arch (MLA) determines the degree of pes planus. Majority of the previous studies on prevalence of flexible flat foot were done among children.

Aim: The present study was undertaken to determine the prevalence of flexible flat foot among 18-21-year-old Indian adults using Navicular Drop Test (NDT) which is regarded as reliable and valid method to characterise MLA.

Materials and Methods: The present study was a cross-sectional study in which Brody's Navicular Drop Test was performed in five hundred healthy subjects (250 males and 250 females) aged 18-21-year-old. Navicular Drop (ND) of ≥ 10 mm was regarded as flexible flat foot. Statistical analysis was done using SPSS version 23.0.

Results: The 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.

Conclusion: The present study quantified the prevalence of flexible flat foot and gender wise normative values of ND among 18-21-year-old Indian adults. The information obtained by this study will be useful in field of orthopaedics.

Keywords: Medial longitudinal arch, Navicular drop, Pes planus

INTRODUCTION

The structure and dynamicity of foot arches are essential for functions of foot like shock absorption, body weight transmission and to act as a lever for propelling the body forward during locomotion [1,2]. Medial Longitudinal Arch (MLA) of foot is higher than the Lateral longitudinal arch and its curvature flattens to variable degree during weight bearing [3-6]. Pes planus is a medical condition where the curvature of MLA is more flat than normal and entire sole of the foot comes into near complete or complete contact with the ground [7]. The height of MLA is most important measurement in determining the degree of pes planus [8].

The feet appear to be flat in infants due to presence of fat. The arches become prominent when the child starts walking and the foot starts bearing the weight [9]. The arches of foot rapidly develop between two to six years and become structurally mature around 12-13 years [10]. Prevalence of flat feet is higher in children due to ligament laxity and declines with age. Early shoe wearing in children impairs the development of longitudinal arches [11].

Flat foot deformity was classified into three subtypes by Harris RT and Beath T, viz. rigid flat foot, Flexible Flat Foot (FFF) and Flexible Flat Foot With Short Tendo-Achilles (FFF-STA) [12]. FFF is generally asymptomatic while FFF-STA gives rise to pain and functional disability. Rigid flat foot is often symptomatic and associated with tarsal coalitions and reduced range of motion at subtalar joint.

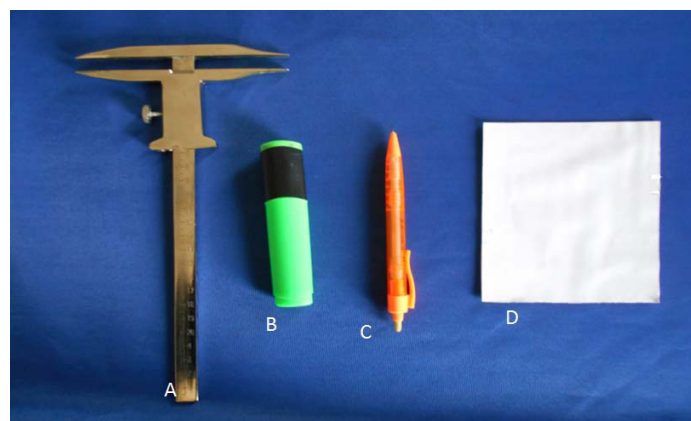
The true prevalence of flat foot is uncertain due to lack of exact clinical or radiographic criteria for defining flat foot [13]. The prevalence of flat feet has been investigated by many researchers in different parts of the world. Higher prevalence (21 to 57%) is reported among children of two to six years which declines (13.4% to 27.6%) in primary school children [14]. In adult population, it is reported to be approximately 5 to 14% by different researchers [10,15,16].

Literature on the prevalence of adult flat foot in Indian population is limited and wherever it is available the methods employed

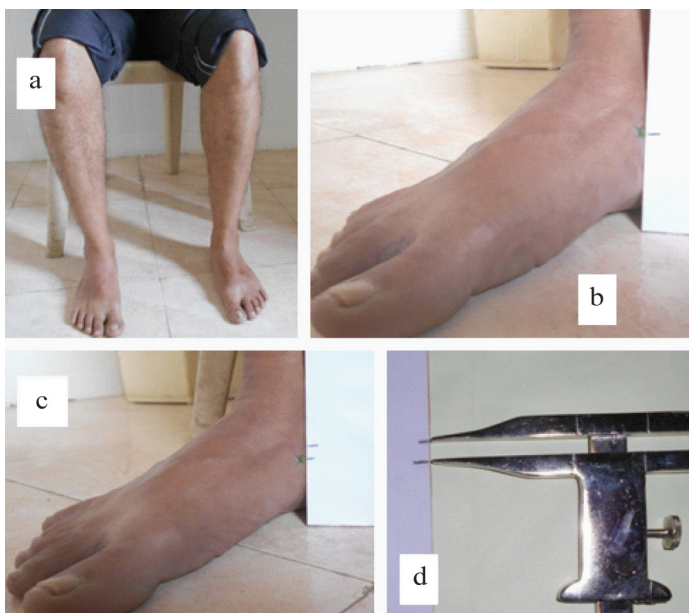
to determine the flat feet, such as Foot print method or Visual Assessment method, are less reliable [17,18]. So the present study was undertaken to investigate the prevalence of FFF among adults (18 to 21-year-old) by using NDT which has proven to be more valid. Additionally the study also aimed to find out the correlation of ND with demographic variables such as Height, Weight and Body Mass Index (BMI) of the individual.

MATERIALS AND METHODS

It was a cross-sectional study in which five hundred (250 males and 250 females) healthy subjects of age between 18 to 21 years from Gujarat region had volunteered. None of the participant had any lower extremity deformity, injury or neuromuscular disorder at the time of assessment. The author obtained ethical clearance from Institutional Ethical Committee and informed consent from the participants before undertaking the study. The materials used for this study were custom made index card and Vernier caliper [Table/Fig-1]. The demographic data such as gender, age, height, weight



A - Vernier caliper; B - Colour marker; C - Pencil; D - Custom made Index card
[Table/Fig-1]: Materials required for the study.



[Table/Fig-2]: Procedure for measurement of Navicular Drop for study participant; a) Subject in sitting position with hip and knee flexed at 90 degree and ankle in neutral position; b) Navicular height on an index card in sitting position (non weight bearing); c) Navicular height on an index card in standing position (weight bearing); d) Measurement of Navicular Drop by using Vernier caliper.

of each participant were recorded. The ND was measured applying Brody Method [3].

Each subject was asked to sit in relaxed position with hip and knee flexed at 90 degree and the foot gently placed flat on a firm supporting surface [Table/Fig-2a]. The observer ensured that the ankle and subtalar joints were placed in neutral position. The height of navicular tuberosity in this position was marked on the index card [Table/Fig-2b]. The subject was then asked to stand with equal weight on both the feet. Now the new height of Navicular tuberosity was marked on index card [Table/Fig-2c]. The difference between the marks on the index card (ND) was measured with Vernier caliper [Table/Fig-2d]. The ND was measured for both feet in each subject.

STATISTICAL ANALYSIS

SPSS version 23.0 was used for analysing the data. The normality of the data was tested using Shapiro-Wilk test. Median and Inter Quartile Range (IQR) were calculated for the demographic parameters and ND since the data was not normally distributed. The ND among males and females was compared using Mann-Whitney U test. The criteria to determine flat foot was ND of ≥ 10 mm. Using this criteria the prevalence was calculated separately for males and females and also for entire study population. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Participants in the present study were adults, in the age group of 18 to 21 years. The distribution of height, weight, BMI, Right Side Navicular Drop (RND), Left Side Navicular Drop (LND) amongst study population was calculated [Table/Fig-3]. The normality of distribution was tested with Shapiro-Wilk test. The data was not normally distributed. So we have also expressed Median and Inter Quartile Range (IQR) for descriptive statistics.

The ND between male and female groups was compared using Mann-Whitney U test. The difference was statistically not significant on right as well as on left side [Table/Fig-4].

Similarly, the measurements of RND and LND for entire study sample were also compared using Mann-Whitney U test. The difference between RND and LND was statistically not significant [Table/Fig-4].

		Height (cm)	Weight (kg)	BMI (kg/m ²)	RND (mm)	LND (mm)
Male (N=250)	Mean (\pm SD)	169.6 (\pm 8.16)	68.1 (\pm 15.6)	23.62 (\pm 4.91)	6.7 (\pm 4.1)	6.9 (\pm 4.2)
	Median (IQR)	170 (165 to 175)	65.50 (57 to 77)	23.02 (20.14 to 26.22)	6 (4 to 8)	6 (4 to 9)
	Range	140-190	36-114	15.41 – 39.04	0-19	0-22
Female (N=250)	Mean (\pm SD)	156.5 (\pm 7.05)	52.7 (\pm 10.4)	21.5 (\pm 3.96)	7.2 (\pm 4.4)	6.3 (\pm 4)
	Median (IQR)	156.25 (155.5-160)	50 (45-58)	20.75 (18.38-23.28)	6 (4-10)	7 (3-8)
	Range	125.5-182	36-90	15.72 – 35.38	0-21	0-18
Total (N=500)	Mean (\pm SD)	163.07 (\pm 10.07)	60.41 (\pm 15.36)	22.56 (\pm 4.58)	7 (\pm 4)	6.6 (\pm 4.1)
	Median (IQR)	162.5 (155.5-170.5)	57 (49-69)	21.6 (13.14-25.28)	6 (4-9)	6 (4-9)
	Range	125.5-190	36-114	15.41 – 39.04	0-21	0-22

[Table/Fig-3]: Distribution of height, weight and Navicular Drop (ND) among study sample.

(RND = Right Navicular Drop; LND = Left Navicular Drop)

	RND (Males vs Females)	LND (Males vs Females)	RND vs LND (for total sample)
Mann-Whitney U test	28878.50	28431.50	119641.5
p-value	0.14	0.08	0.2

[Table/Fig-4]: Comparison of Navicular Drop (ND)

(RND = Right Navicular Drop; LND = Left Navicular Drop) *Mann-Whitney U test

	Correlation with	Spearman's rho	p-value
RND	Height	-.109	.014
	Weight	-.123	.006
	BMI	-.075	.095
LND	Height	.068	.127
	Weight	.033	.466
	BMI	-.002	.958

[Table/Fig-5]: Correlation between Navicular Drop with BMI, weight and height.

(RND = Right Navicular Drop; LND = Left Navicular Drop) *Spearman's correlation test

	Sample size	Right side	Left side	Bilateral
Males	250	53 (21.2%)	54 (21.6%)	32 (12.8%)
Females	250	71 (28.4%)	48 (19.2%)	36 (14.4%)
Total	500	124 (24.8%)	102 (20.4%)	68 (13.6%)

[Table/Fig-6]: Prevalence of flat foot in study sample.

The correlation of ND with weight, height and BMI was evaluated using Spearman's correlation test. The correlation of RND with height and weight was significant, but insignificant correlation was found between RND and BMI. The correlation of LND with height, weight and BMI of individuals was statistically not significant. [Table/Fig-5].

The criteria to determine FFF used by the present study was ND of ≥ 10 mm. In the study population, 13.6% individuals were found with ND of ≥ 10 mm in both the feet (Males=12.8% and Females=14.4%). The prevalence of FFF was calculated using the above mentioned criteria [Table/Fig-6].

DISCUSSION

Pes planus is a common condition found in adult population. Adult flat foot is defined as a foot condition that persists or develops after skeletal maturity and is characterised by partial or complete loss (collapse) of the MLA [19]. Adult flat foot is generally asymptomatic but can present with pain, functional disability and various degrees

of deformity. It can be constitutional or acquired. The causes of adult pes planus include posterior tibial tendon dysfunction, tarsal coalition, peroneal spastic flat foot, iatrogenic, post-traumatic arthritis, Charcot foot or neuromuscular flat foot [20].

The prevalence of flat foot is very high in children which decreases with age as the skeletal maturity advances. Majority of previous studies on prevalence of flat foot were done in children. The purpose of this study was to determine the prevalence of FFF among 18-21-year-old age group through the NDT and to find out its correlation with demographic variables.

The ND is defined as the change in height of the navicular bone when the foot moves from subtalar neutral non weight bearing to a relaxed weight bearing stance [21]. The normal value for static ND has been suggested as lower than 10 mm by Brody DM and Muller MJ et al., [3,4]. So the present study considered a ND of ≥ 10 mm as FFF.

The prevalence of bilateral FFF was found to be 13.6% in our study sample. Inconsistent values for flat foot prevalence among adult population have been reported by various researchers [Table/Fig-7]. This can be attributed to the different methods used to assess the flexibility of the arches of foot. The present study applied 'NDT' to assess the flexibility of the MLA. The method of ND has proved to be more valid and reliable compared to foot print and visual assessment methods applied by other researchers [17,18]. Moreover, very few researchers have reported separate values of flat foot prevalence for male and female groups. Present study

Researchers	Sample Size	Age (Yrs)	Method Used	Prevalence of Flat foot
Ukoha U et al., [15]	649	18-27	Arch Index	13.9%
Bhoir MT [10]	80	18-25	FPI (Foot Posture Index)	11.25%
Ganapathy A et al., [16]	250	18-24	PAI (Plantar Arch Index)	5.2%
Present study	500	18-21	Navicular Drop Test (NDT)	13.6%

[Table/Fig-7]: Comparison of prevalence of flat foot of present study with previous workers.

observed the prevalence of FFF among males and females to be 12.8% and 14.4% respectively.

There is no consensus over normal values of ND among different researchers. Also, the researchers have employed different methods to measure the ND. Brody DM, Muller MJ et al., and Beckett ME et al., have reported the values of 15 mm, 13 mm and 10 mm respectively as the upper limit of range of ND in their study population [3,4,22]. Very few studies have reported gender wise separate values of ND for right and left foot. Current study found the median values with IQR for ND among male population as 6 mm (4-8) and 6 mm (4-9) on right and left sides respectively. The median with IQR for ND among female population were found as 6mm (4-10) and 7mm (3-8) for right and left sides respectively. The

Researchers	Method	Navicular Drop (mm)
Fiolkowski P [23]	Ruler	Mean (\pm SD) = 6 \pm 2
Nakhaee Z [24]	Cardboard card	Mean (\pm SD) = 5.3 \pm 2
Bandholm L [5]	Ruler (1mm resolution)	Mean (\pm SD) = 5 \pm 2.2
Chang YW [6]	Surface markers	Mean (\pm SD) = 7.38 \pm 3.04
Adhikari U et al., [25]	Vernier Caliper	Median (IQR): RND for Males= 6(3-8); RND for Females= 4(3-5); LND for Males= 4(3-6); LND for Females= 3(2-5);
Present study	Vernier Caliper	Median (IQR): RND for Males= 6(4-8); RND for Females= 6(4-10); LND for Males= 6(4-9); LND for Females= 7(3-8)

[Table/Fig-8]: Comparison of range of Navicular Drop reported in present study with previous workers.

mean/median values have been also reported by various authors in the past [Table/Fig-8] [5,6,23-25].

Fukano M and Fukubayashi have stated that normal values of ND are difficult to establish as ND is influenced by various factors like foot length, age, gender and BMI [26]. Present study evaluated the correlation of ND with weight, height and BMI. The correlation of RND with height and weight was significant, but insignificant correlation was found between RND and BMI. The correlation of LND with height, weight and BMI of individuals was statistically not significant. Also, the difference in ND between male and female group was statistically insignificant.

None of the participants of present study had any complaints related to their feet like pain, numbness, restricted mobility etc. We agree with the views of Milenkovic S et al., that in adults, the FFF may be considered as normal variant of strong and stable foot instead of deformity resulting from bony or muscular abnormalities [27].

CONCLUSION

The present study has quantified the prevalence of adult flexible flat foot in age group of 18 to 21 years. The study has estimated gender wise normative values for ND and influence of height, weight and BMI on ND. The information obtained by this study will be useful in the field of orthopaedics.

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