The Foot and Ankle Online Journal
Official Publication of the International Foot & Ankle Foundation
faoj.com / ISSN 1941-6806

# Does BMI variation change the height of foot arch in healthy adults: a cross sectional study

**by A. P. C Udayamali Pathirana BPT[1], Dr. Watson Arulsingh PT[2*], Dr. Remya K.R PT[3], Joseph Oliver Raj PT[4]**

**The Foot and Ankle Online Journal 8 (4): 3**

Background: Many research give scatterlly distributed relationship between obesity and the medial longitudinal arch of foot. Among those studies, only two studies have stratified the samples in to underweight, normal weight, overweight and obese groups in the recent past, to explore the relationship of BMI to arch of the foot on the basis of gender variation. Yet these studies contradicted each other in their finding of associating BMI variation to foot arch height. Hence this current study was intended to explore any significance changes were found in medial arch height of foot among the stratified groups.
Design: Cross sectional observational study. For this purpose, 150 healthy adults were screened, out of which 100 were chosen and stratified into underweight, normal weight, overweight and obese group according to Asian guideline of BMI at convenient sampling method. Brody's navicular drop test was used to measure height of the foot arch of each person.
Results: Spss 16 version was used for statistical analysis. One way Anova analysis was tested across four groups. The P value for left navicular drop test between groups is 0.000 < 0.005. There is significant difference between the groups for left navicular drop test compared to the right navicular drop test with changes in BMI. The P value for right navicular drop test between groups was 0.304 > 0.005.
Conclusion: It is concluded that there was no statistical significance of difference found between the groups for height of foot arch. The current study concluded, navicular drop was more in overweight group and then in obese group of right and left foot against normal weight and underweight group. But there was statistical significance of difference found within the groups for left height of foot arch.

**Key words**: BMI, arch of foot, navicular drop, underweight, normal weight, overweight, obese



The human foot consists of 26 bones and more than 30 articulations enabling three fundamental functions of supporting, shock absorbing and weight bearing. The arches of the foot are formed by tarsals, metatarsals, ligaments and tendons.

**Address correspondence to**: **Watson Arulsingh***
1. Alva's college of physiotherapy and research center, Moodbidri, 574227, D.K, India. apcudayamali@gmail.com
2*. Associate Professor, Alva's College of Physiotherapy and research center, Moodbidri-574227 D.K
watsonarulsingh@yahoo.in.
3. Assistant Professor, Alva's College of Physiotherapy, Moodbidri-574227, D.K. remya.unni82@gmail.com
4. Professor, Alva's College of Physiotherapy, Moodbidri-574227, D.K. rushtojoseph@yahoo.co.in

They help to bear the weight of the body in standing and walking, and act as shock absorbers. Types of arches are the transverse arches which run across the midfoot from outside to inside. Longitudinal arches are the lateral and medial longitudinal arches. Medial longitudinal arch is higher than lateral longitudinal arch. Medial longitudinal arch (MLA) is made up of calcaneus, talus, navicular, three cuneiforms, and the 1st, 2nd, and 3rd metatarsals. Lateral longitudinal arch is made up of calcaneus, cuboid, and 4th and 5th metatarsals [1].

Types of the foot arches are pes cavus, pes planus, and normal arch. Arch function depends on the shape of the foot, bony structure ligamentous stability, and muscular fatigue while factors like race, footwear, age, and gender are found to influence the formation of MLA [2].

There are many techniques to measure MLA. The methods are divided into two groups: indirect and direct methods. Indirect methods include ink or digital footprints which can be static (standing) or dynamic (walking) and photographic techniques. Direct methods are somatometric measurements, clinical assessment, radiographic evaluation, and ultrasonography quantification. One of the most popular and widely used clinical methods of assessing MLA is the Brody's navicular drop test [3]. Brody's navicular drop test is a clinically validated tool determined by Brody in 1982 [4]. It classifies the foot arch into low arch, normal, high arch, measured by navicular drop of >10mm, 6mm – 10mm, < 5mm respectively. It was intended to represent the sagittal plane displacement of the navicular tuberosity from a neutral position to a relaxed position in standing. Muller et al 1993 explored the inter rater reliability (ICC) of navicular drop test 0.78 – 0.83, Sell et al 1994 explored inter-rater reliability (ICC) 0.73 and intra-rater reliability 0.83 [5].

There are few claims across the scientific world that BMI may influence the arch configuration of foot. Research has focussed to determine whether BMI has any correlation to arch of foot. Few among them concluded that there is a direct association of BMI to medial arch index [6, 7, 8]. Arulsingh et al [10] in their study tried to determine the impact of anthropometric measurements on medial arch height in half marathon runners. They reported minimum to moderate degree of inverse correlation between anthropometric measurements and navicular height on the left side and little correlation on right side, yet their sample size was small.

Two other studies reported that males were found to have higher prevalence of flatfoot than women in the age group of 18-25 years [6,8].

Only two studies in the past have stratified samples in to underweight, normal weight, overweight and obese groups in the recent past to explore the relationship of BMI to arch of the foot on the basis of gender variation [8]. Yet these studies contradicted each other in their finding of associating BMI variation to foot arch height and have utilized foot print method to characterize foot arch type rather than using navicular height a valid method for associating with variable [11].

ASIAN guidelines for BMI classifies the individuals into underweight, normal weight, overweight, and obese, BMI< 17.50, 17.50 – 22.99, 23.00 – 27.99, > 28.00 respectively [9]. 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 underweight, normal, over weight and obese groups based on ASIAN Guidelines of BMI.

## METHODS

### Procedure

For this study, nearly 150 healthy adults were screened from the age group of 18 to 25 years. 100 subjects fulfilled inclusion criteria and grouped into underweight (25), normal weight (25), overweight (25) and obese (25) based on ASIAN guidelines of BMI. Alva's Institutional ethical review board approval was obtained. Patient consent form was used before including subjects for this study. Subjects who fulfilled ASIAN Guidelines were fitted in to underweight, normal, overweight and obese. Subjects presented with recent ankle sprain, fracture, or any other foot injuries, cognitively impaired subjects, deformity of foot, inflammatory disease are excluded from the study.

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 to 90 degree and foot placed flat on ground. The subtalar joint neutral position was obtained by palpation method (Figure 1). The navicular tuberosity was palpated and marked with color marker (Figure 2). The distance from navicular tuberosity to the supporting surface is measured with metal scale (Figure 3).

**Figure 1** Palpation method to keep subtalar joint in neutral position.

**Figure 2** Marking the location of navicular tuberosity.

Participant was asked to stand with shoulder width apart in weight bearing position. Same procedure was undertaken as seated position (Figure 4). The difference of navicular drop in non-weight bearing and weight bearing was calculated for all participants with the help of vernier caliper.

**Figure 3** Measuring navicular height in sitting.

**Figure 4** Measure the distance from supporting surface to navicular tuberosity in standing.

## Outcome measures

Brody's Navicular Drop Test

Characteristic values for navicular drop are,
Normal arch = 6-10mm
Low arch = > 10 mm
High arch = < 5 mm

## Data analysis

Spss16 version was used to analyze data. Normality of data was checked. One way Anova was used to compare navicular drop values across groups.

## RESULTS

One-hundred healthy subjects were stratified into four groups according to ASIAN guidelines for BMI classification with 25 subjects in each group. Study results show that there is a significant difference of navicular drop in left foot with the BMI. Yet mean descriptive data of navicular drop test in all groups vary from one group to another regardless of right foot or left foot. The mean navicular drop values of right foot were for underweight group was 7.8±3.4, normal weight7.8 ±3.6, over weight group 8.84±3.9 and in obese group 9.5±3.7. Similarly the left foot readings of underweight group had mean navicular drop value of 8.32±3.11, normal weight group 6.4±3.0, overweight group 10.32±3.6 and obese group 9.6±2.9. The result shows that there is more navicular drop in left foot compared to right with increased BMI. On the basis of above observation, navicular drop was more in overweight group and then in obese group of right and left foot against normal weight and underweight group Table 1, 3 (see supplement, attached) show descriptive values of navicular drop test for four groups. Table 2, 4 show the p value when four groups were compared on navicular drop values. Figure 1-4 denote how navicular drop test was administered. Table 5,6 explains age, gender homogeneity across four groups. Figures 5 and 6 explain percentage of arch type across genders.

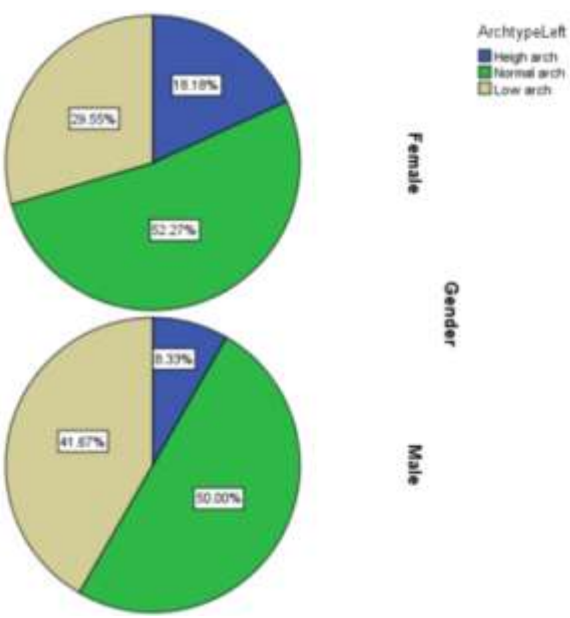


**Figure 5** Percentage of arch type across gender, left.

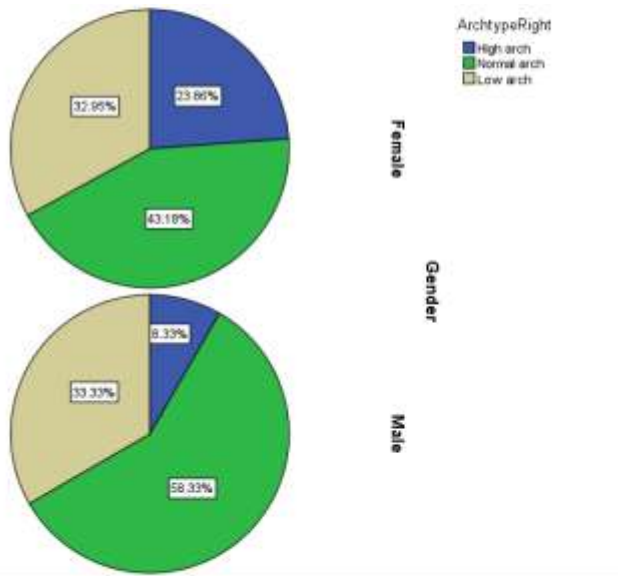


**Figure 6** Percentage of arch type across gender, right.

## DISCUSSION

On the basis of above observation, navicular drop was more in the overweight group and then in obese group of right and left foot against normal weight and underweight group. It shows that the overweight population and obese are at a high risk of getting low arched feet. It matches the report of two other researchers stating that body weight has a direct impact on the medial arch [7,9].Yet, MCID value was not yet determined for navicular drop test to report some clinical significance between groups. This is the first study to have used ASIAN BMI guidelines in stratifying samples. Out of 100 samples, only 12 were males. Figure 5a denotes the percentage of flat foot occurrence is more in male's left foot rather than right foot. Former studies have claimed that males have increased percentage of flat foot compared to their age matched females [6,8]. Yet none of these studies explored whether flat foot incidence are more in left foot to right foot in males. Age homogeneity was found across four groups.

Limitation of this study is that it did not take hand dominancy into account, as this study report that BMI has influence on left arch of foot. Sample size was small. Gender distribution in each group should be enhanced in future studies.

## Conclusion

It is concluded that there was no statistical significance of difference found between the groups for height of foot arch. The current study concluded, navicular drop was more in overweight group and then in obese group of right and left foot against normal weight and underweight group. But there was statistical significance of difference found within the groups for left height of foot arch.

**Acknowledgements**: I am grateful to my parents, my teachers and friends who helped me in a different way throughout my study

## REFERENCES

1. Gray, Henry. Anatomy of the Human Body. "7j. 1918. Arches of the Foot". Bartleby.com. ISBN 0-8121-0644-X.
2. Rasmus G Nielsen, Michael S Rathleff, Ole H Simonsen, Henning, Langberg, Determination of normal values for navicular drop during walking: a new model correcting for foot length and gender, Journal of Foot and Ankle Research 2009, **2**:12 doi:10.1186/1757-1146-2-12.
3. R.Wozniacka, A Bac, S. Matusik R, E. Szczygie, E. Ciszek, Body weight and medial longitudinal foot arch: high arched foot, a hidden problem? Eur J Pediatr (2013) 172:683–691 DOI 10.1007/s00431-013-1943-5.
4. Evan Thomas, Navicular drop test, Physiopedia.
5. Arzu Erden, FilizAltug, UgurCavlak, Impact of body mass index and gender on medial longitudinal arch drop in young healthy population Sport medicine journal,2013, no.34.
6.Sneha Sameer Ganu,VrushaliPanhale**,** Effect of Obesity on Arch Index in Young Adults,
online journal of health and allied sciences, Online J Health Allied Scs. 2012;11(4):8. Available at URL:http://www.ojhas.org/issue44/2012-4-8.html
7. Ashwinichougala, Viditphanse, Erohitkhanna, Sudipta; Screening of body mass index and functional flatfoot in adult: an observational study; Journal of Physiotherapy and Research, Int J Physiother Res 2015, Vol 3(3):1037-41. ISSN 2321-1822; DOI:http://dx.doi.org /10.16965/ijpr.2015.133.
8. Tejashreebhoir, Deepak b. Anap, Abhijitdiwate; Prevalence of flat foot among 18 -25 years old physiotherapy students: cross sectional study, Indian journal of basic and applied medical research; September 2014: vol.-3, Issue- 4, p. 272-278.
9. Asian guideline for BMI by Joslin diabetes center, 2010
10. Watson Arulsingh, Ganesh Pai, Joseph Oliver Raj, Impact of anthropometric measures on medial arch height in half marathon Runners, scholars' research library, 2014 3 (3):37-41.
11.Piers LS, Soares MJ, Frandsen SL, O'Dea K, 2000. Indirect estimates of body composition are useful for groups but unreliable in individuals. Int. J. Obes. Relat.Metab.Disord 24;1145-1152.

**SUPPLEMENT: Data Tables**

Table 1
**Descriptive**
LeftNDT1

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| normal weight | 25 | 6.4800 | 3.01552 | .60310 | 5.2353 | 7.7247 | 2.00 | 13.00 |
| Overweight | 25 | 10.3200 | 3.64829 | .72966 | 8.8141 | 11.8259 | 2.00 | 19.00 |
| Underweight | 25 | 8.3200 | 3.11876 | .62375 | 7.0326 | 9.6074 | 4.00 | 14.00 |
| Obese | 25 | 9.5600 | 2.90230 | .58046 | 8.3620 | 10.7580 | 5.00 | 15.00 |
| Total | 100 | 8.6700 | 3.45843 | .34584 | 7.9838 | 9.3562 | 2.00 | 19.00 |

Table 2
Significance of LeftNDT1
**ANOVA**

LeftNDT1

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 210.830 | 3 | 70.277 | 6.932 | .000 |
| Within Groups | 973.280 | 96 | 10.138 | | |
| Total | 1184.110 | 99 | | | |

Table 3
**Descriptive**
RightNDT1

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| normal weight | 25 | 7.8400 | 3.60185 | .72037 | 6.3532 | 9.3268 | 1.00 | 16.00 |
| Overweight | 25 | 8.8400 | 3.91237 | .78247 | 7.2251 | 10.4549 | 2.00 | 16.00 |
| Underweight | 25 | 7.8800 | 3.40735 | .68147 | 6.4735 | 9.2865 | 3.00 | 14.00 |
| Obese | 25 | 9.5200 | 3.70945 | .74189 | 7.9888 | 11.0512 | 3.00 | 18.00 |
| Total | 100 | 8.5200 | 3.67487 | .36749 | 7.7908 | 9.2492 | 1.00 | 18.00 |

Table 4
Significance of Right NDT2

**ANOVA**

RightNDT1

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 49.360 | 3 | 16.453 | 1.227 | .304 |
| Within Groups | 1287.600 | 96 | 13.413 | | |
| Total | 1336.960 | 99 | | | |

Table 5. Results of age homogeneity test across groups

**One way ANOVA**

AGE1

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1.920 | 3 | .640 | .178 | .911 |
| Within Groups | 344.240 | 96 | 3.586 | | |
| Total | 346.160 | 99 | | | |

Table 6. Results of gender homogeneity test across groups.

**Chi-Square Tests**

| | Value | df | Asymp. Sig. (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 7.576a | 3 | .056 |
| Likelihood Ratio | 9.909 | 3 | .019 |
| N of Valid Cases | 100 | | |

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is 3.00.