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# Effect Of Body Mass Index On Arches Of Foot

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***Abstract:***
***Background:*** *The human foot possesses a special intricate mechanism responsible for bipedal gait. The plantar arches of the foot are the most distinctive feature of a human being which can be normal, high arch or low arch.*
***Materials and Methods:*** *A cross-sectional study was conducted on 398 subjects (164 males and 234 females) in the Department of Anatomy, RIMS, Imphal from May 2023 to November 2023.Staheli's Index was used for classification of foot arches.*
***Results:*** *The mean value of body mass index (BMI) was 24.31±3.84 and mean value of Staheli arch index on left and right foot was 0.68±0.22 and 0.67±0.19. One way ANOVA analysis of bilateral Staheli arch index in five groups of underweight, normal, overweight, obese I and obese II showed a statistically significant difference with a progressive increase in values from underweight to obese II. Gender wise comparison of Staheli Index of the five groups was not found to be statistically significant (p>0.05).*
***Conclusion:*** *The present study showed a positive correlation between BMI and foot arches. The result of this study suggests a preventive intervention to improve the quality of life for overweight and obese persons*
***Key Word:****BMI, Staheli Index, Arches of foot*

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## I. Introduction

The human foot is a very complex anatomical and biomechanical structure, having different components working together to provide balance, flexibility, mobility and support to the body. It possesses a special intricate mechanism responsible for bipedal gait. The plantar arches of the foot are the most distinctive feature of a human being. Osteo- ligamentous plates in the foot act like springs to propel the body forwards. The arches of the foot are important in protecting the internal structures of the body from impact forces while it mainly help in transferring the internal forces to the ground, are also involved in lifting the body weight, and mainly shock absorption.

The development and changes in human foot shape begin from the postnatal developmental stage. Human feet contain 52 bones comprising of seven tarsals, viz, calcaneum, talus cuboid,navicular and three cuneiform bones. The metatarsals provide stability during standing while the phalanges stabilize and support the body posture when walking.During walking or standing, the body weight or pressure will be passed and distributed to the heel (calcaneum) and head of first and fifth metatarsal.[1]

A segmented structure can hold up weight only if it is built in the form of an arch. The foot has three such arches, which are present at birth: medial longitudinal, lateral longitudinal and transverse arches. The tarsal and metatarsal bones of foot are together shaped like half a dome.When the feet are placed together, the two half domes form one single dome. The rim of each half dome consists of the heel, lateral border of the foot and heads of the metatarsal bones. It is these parts of the foot which imprint the ground and form the footprint of a bare foot.[2,3]

Medial longitudinal arch is maintained by bony as well as ligamentous structures. The rounded head of the talus is the keystone in the centre of the arch.The inferior edges of the bones are tied together by the plantar ligaments. The most important ligaments are the plantar calcaneonavicular ligament and plantar aponeurosis. Next is the spring ligament which supports the head of the talus.

Similarly, lateral longitudinal arch is maintained by both bony and ligamentous structures. The cuboid forms the highest point of this arch.The inferior edges of the bones are tied together by the long and short plantar ligaments.Tying the ends of the arch together are the plantar aponeurosis, the abductor digiti minimi and the lateral part of flexor digitorum longus and brevis.Suspending the arch from above are the peroneus longus and brevis.The peroneus longus makes the most important contribution for the maintenance of this arch.

The transverse arch is also maintained by both bony and ligamentous structures.The inferior edges of the bones are tied together by the deep transverse ligaments, the strong plantar ligaments and the origins of the

plantar muscles from the forepart of the foot. The dorsal interossei and the adductor hallucis are particularly important in this respect. Suspending the arch from above are the peroneus longus tendon and peroneus brevis.[2,4]

Of the three arches, the medial longitudinal arch is the largest and clinically the most important. The shape of the bones, the strong ligaments especially on the plantar aspect of the foot, and the tone of the muscles all play an important role in supporting the arches. It has been shown that in the active foot the tone of muscles is an important factor in arch support. When the muscles are fatigued by excessive exercise as in case of a long route march by an army recruit or by standing for long periods (waitress or nurse), by overweight, or by illness, the muscular support give way, the ligaments are stretched, and pain is produced.

Pes planus (flatfeet) is a condition in which the medial longitudinal arch is depressed or collapsed. It is likely to be secondary to dysfunction of tibialis posterior due to trauma, degeneration with age, or denervation. In absence of normal passive or dynamic support, the planter calcaneonavicular ligament fails to support the head of the talus. Consequently, the head of the talus displaces inferomedially. As a result, flattening of the medial longitudinal arch occurs along with lateral deviation of the forefoot. Flatfoot are common in older people, particularly if they undertake much unaccustomed standing or gain weight rapidly, adding stress on the muscles and increasing strain on the ligaments supporting the arches.[5]

It has been estimated that upto 23% of the public may be affected with flatfoot, depending on the diagnostic criteria. It is common in neonates and toddlers and are associated with physiologic ligamentous laxity. Fatty connective tissue on the plantar aspect may give the foot a flat appearance. The thickness of the medial midfoot plantar fat ranges from 3.1 to 4.9 mm. Improvement may be seen when the longitudinal arch develops between 5and 10 years of age.[4,6]

Pes cavus (clawfoot) is a condition in which the medial longitudinal arch is unduly high. Most cases are caused by muscular imbalance, in many instances resulting from poliomyelitis, hereditary motor and sensory neuropathies, Charcoat-Marie-Tooth disorder, spina bifida, post stroke.[6]

Balance is the process that maintains the centre of gravity within the body's support base and requires constantadjustments provided by muscular activity. Increase in the body weight interferes with the interaction of joints andmuscles that are crucial to the functional capacity andpostural balance. Inepidemiological studies, the body mass index (BMI) is thestandard measure used to characterize normal andoverweight. Obesity is excess body weight and BMI is considered as index of obesity. Gender, age, ethnic group and leg length are important variables. In populationbased studies, women generally have a BMI that is lower than that in men, even though their fat mass relative to their body build or BMI is considerably greater. Excessive increase in weight bearing forces caused by obesitymay adversely affect the foot arches ( Rohatgi et al[11] ). The structure and themovements of the foot are crucial for lower limb gaitkinematics. Although, this arch comprises of bony articulations, ligaments and muscles, it is primarily the ligaments that support and stabilize the longitudinal arch. Dowling and Steele[8] noted that ligaments rarely incur physiological fatigue and therefore offer a greater resistance to stress compared to muscles. However, repeated excessive loading may stretch ligaments beyond their elastic limit,damaging soft tissues and increasing the risk of footdiscomfort and subsequent development of foot pathologies like plantar fasciitis, ankle sprain etc. The foot arches are used to determine the shape or morphology of the foot, whether it is normal arch (normally aligned foot), high arch (supinated foot) or flat foot(pronated foot).[7]

The present study was performed, using Staheli arch index.Numerous studies have been published till date on the effect of overweight on the foot structure in different age groups. Studies have also shown the prevalence of flatfoot in general population but the distribution of flat foot problems are high in overweight and obese individuals. The perusal of review of literature supports the view that anthropometric status of the individual does influence the lower limb kinematics and foot arches.However, the reporting of association of foot arch index and BMI is found to be inconsistent. Some authors observed a significant correlation[9,10,11,12,13] while others could not find a significant association[14, 15, 16]. Thus there is an inconsistent association of foot arch with BMI.

The present study was undertaken to re-establish the effect of BMI on foot arch. The study population was a miniature representation of populace of Manipur which comprised of the students and staff of RIMS who were permanent residents of Manipur. The sample population belonged to all works of life and from different socio-economic background.

The result of the present study highlighted the different types of foot arch present among the adult population in Manipur. Gender variation as well as laterality of types of foot arch were also studied. Lastly, the result of the said study was of immense value not only from academic point of view but also a valuable predictor of impending risk factors of diseases related to obesity or high BMI.

## II. Material And Methods

This cross-sectional study was conducted in the Department of Anatomy, RIMS, Imphal from May 2023 to November 2023. A total of 398 subjects (164 males and 234 females) in the age range of 18 to 65 years were used for this study. Staheli's Index was used for classification of foot arches.

**Study design:**Cross-sectional study

**Study location:** Department of Anatomy, RIMS

**Study duration:** May 2023 to November 2023

**Sample size:** 398

**Sample size calculation:** Sample size (N) was calculated using the formula
$N=4PQ/L^2$
Where P =prevalence of flat foot taken from a previous study conducted by Vijayakumar Ket al[17] = 46.63
Q = (100 – P) = (100 46.63) =53.37
L = Absolute allowable error =5

**Subjects and selection method:**
**Inclusion criteria:**
a) Healthy subjects in the age group 18 to 65 years.
b) Subjects studying or working in RIMS, Imphal
c) Subjects who gave their written consent.

**Exclusion criteria:**
a) Person with history of acute lower extremity injury or surgery within the last 6 months
b) Person with appreciable leg length discrepancy
c) Person with any existing neurologic and lower extremity chronic condition
d) Person with any congenital abnormality of lower limb
e) Person in possession of medical certificate on degree of disability.

**Sampling method**: convenience sampling was done

**Study variables:**
a) Dependent (outcome) variables: Height, weight, BMI, footprint type.
b) Independent variables: Age, sex.

**Study tools:**
1) Height: Height was measured by a portable stadiometer. Participants were required to stand straight on the floor board of a stadiometer with their backs to the vertical backboard of the scale. Height was recorded to the nearest 0.1cm.
2) Weight: Weight was measured by a portable weighing machine. The participants were requested to remove their shoes and socks and stand straight on a calibrated body weight scale. Weight was recorded to the nearest 0.1kg.
3) Body Mass Index (BMI) : BMI was measured using the formula as below:
BMI =Weight(kg)/Height($m^2$)

**BMI staging:**
WHO Asian BMI Classification

| **Nutritional Status** | **BMI ($kg/m^2$)** |
|---|---|
| Underweight | below 18.5 |
| Normal | 18.5 to 22.9 |
| Overweight | 23 to 24.9 |
| Obese I | 25 to 29.9 |
| Obese II | above 30 |

**Procedure methodology:**

The left and right footprints of the subject was taken. A graph paper was used to take the ink embossed foot imprints of the subject. A 1.5inch deep foam pad was designed and made from locally procured material. This pad was placed in a tray and soaked with routinely used office stamp ink. Written consent was taken from the subjects and procedure and purpose was explained to them completely beforehand. Each participant was asked to stand in a bipedal position (full weight bearing) on the paper on a flat horizontal area for 60sec (Fig.1).Then the footprint was studied using Staheli Arch index.

Staheli index is defined as the ratio between line drawn at the narrowest width of the midfoot to the line drawn at the wider zone of the hindfoot.The arches are defined as; high arch (0.1-0.4), normal arch (0.5 - 0.7) and flat arch (0.8-1.2) respectively (Fig.2,3)

**Figure 1: Taking footprint using ink soaked foam**

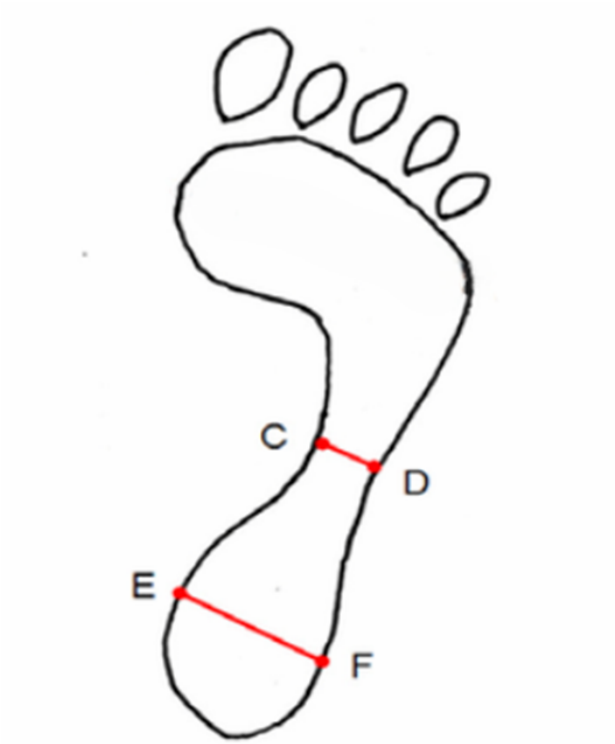


**Figure 2: Schematic diagram showing method of measuring Staheli Index**
CD = narrowest width of the midfoot
EF = widest width of the hindfoot


**Figure 3: Measurement of foot by Staheli Index showing normal arch**

**Statistical analysis:**

Statistical analysis was performed using SPSS statistical software (version 26.0 IBM). Descriptive statistics like mean, SD were used.Pearson's correlation coefficient(r) was used to determine the strength of relationship between BMI and Staheli arch index

## III. Result

A cross-sectional study was conducted on 398 subjects which consisted of 164 males and 234 females. The subjects in the study were in five age groups i.e. lowest to 27, 28-37, 38-47, 48-57 and 58 and above years. The mean value of body mass index (BMI) was 24.31±3.84. and mean value of Staheli arch index left (SAL) and Staheli arch index right (SAR) was 0.68±0.22 and 0.67±0.19 (Table 1). Table 2, Fig. 4 shows the comparative mean and standard deviation (SD) values of Staheli left and right arch index in the five groups of subjects. One way ANOVA analysis of bilateral arch index in the five groups of underweight, normal, overweight, obese I and obese II groups showed a statistically significant difference with a progressive increase in values from underweight to obese II. Gender wise comparison of the Staheli arch index values of male and female subjects of the five groups of underweight, normal, overweight, obese I and obese II was not found to be statistically significant ($p>0.05$) (Table 3). The values of Staheli arch index were found to be statistically significant bilaterally ($p<0.05$) in the five groups. When we compare the mean Staheli Index of the right and left foot, it was observed that mean value was the same or higher on the left side with the most prominent difference being present in the underweight and obese II category (Fig. 5). A significantlypositive (P= 0.000) correlation was observed between BMI and Staheli index (left) and Staheli index (right) with correlation coefficient(r) of 0.177 and 0.183 respectively(Table 4, Fig. 6,7)

**Table 1: Comparison between Mean values of BMI and bilateral Staheli Index**

| | **BMI** | **SI (Left)** | **SI (Right)** |
|---|---|---|---|
| Mean ± Std. Deviation | 24.31 ± 3.84 | 0.68 ± 0.22 | 0.67 ± 0.19 |
| Minimum | 16.13 | 0.08 | 0.10 |
| Maximum | 39.44 | 2.22 | 1.73 |

BMI= Body Mass Index, SI (Left)= Staheli Index Left, SI (Right) = Staheli Index Right, S.D= Standard Deviation

**Table 2: Comparative Mean and S.D values of Staheli Index in the five groups of subjects**

| | **BMI** | **SI (Left)** | **SI (Right)** |
|---|---|---|---|
| | Mean ± S.D | Mean ± S.D | Mean ± S.D |
| Underweight (n=21) | 17.60 ± 0.72 | 0.64 ± 0.18 | 0.58± 0.12 |
| Normal (n=136) | 21.15 ± 1.41 | 0.64 ± 0.21 | 0.64 ± 0.20 |
| Overweight (n=83) | 24.01 ± 0.58 | 0.68 ± 0.23 | 0.66 ± 0.19 |
| Obese I (n=126) | 27.09 ± 1.42 | 0.69 ± 0.23 | 0.70± 0.20 |
| Obese II (n=32) | 32.04 ± 1.87 | 0.79± 0.17 | 0.73 ± 0.13 |
| p-value | | 0.005 | 0.008 |

BMI= Body Mass Index, **SI (Left)**= Staheli Index Left, **SI (Right)**= Staheli Index Right, S.D= Standard Deviation

**Table 3: Comparative mean and SD values of BMI and Sex in the five groups of subjects**

| | BMI | | Sex | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Underweight(n=21) | 17.60 | 0.72 | 1.67 | 0.48 |
| Normal(n=136) | 21.15 | 1.41 | 1.61 | 0.49 |
| Overweight(n=83) | 24.01 | 0.58 | 1.54 | 0.50 |
| Obese I(n=126) | 27.09 | 1.42 | 1.57 | 0.50 |
| Obese II(n=32) | 32.04 | 1.87 | 1.63 | 0.49 |
| P value | | | 0.764 | |

BMI= Body Mass Index

**Table 4: Correlations between BMI and Staheli arch index**

| | SI (Left) | SI (Right) | BMI |
|---|---|---|---|
| SI (Left) | 1 | 0.678** | 0.177** |
| SI (Right) | | 1 | 0.183** |
| BMI | | | 1 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | |

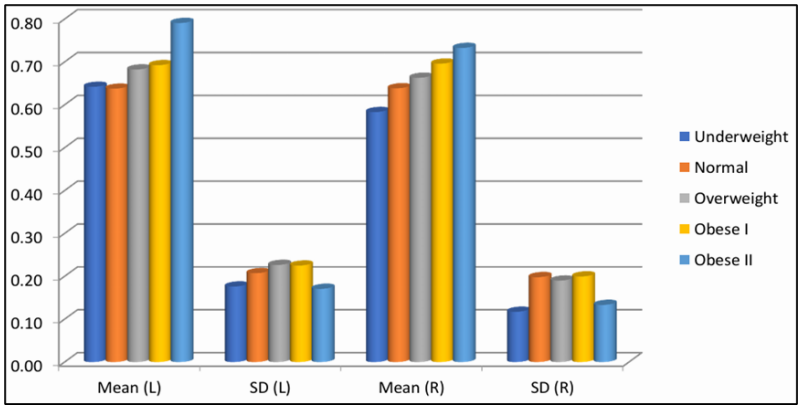


**Fig 4: Comparative mean and SD values of Staheli Arch Index in the five groups**

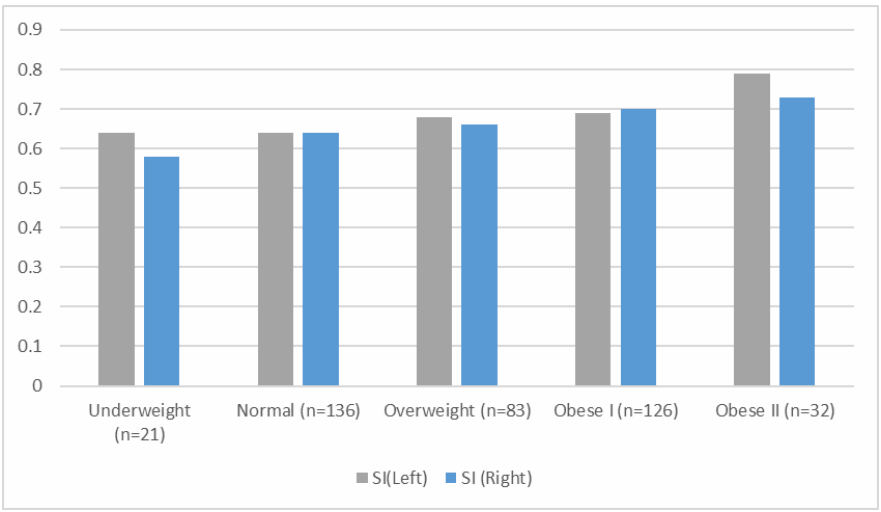


**Fig 5: Comparison between mean of left and right Staheli Index.**

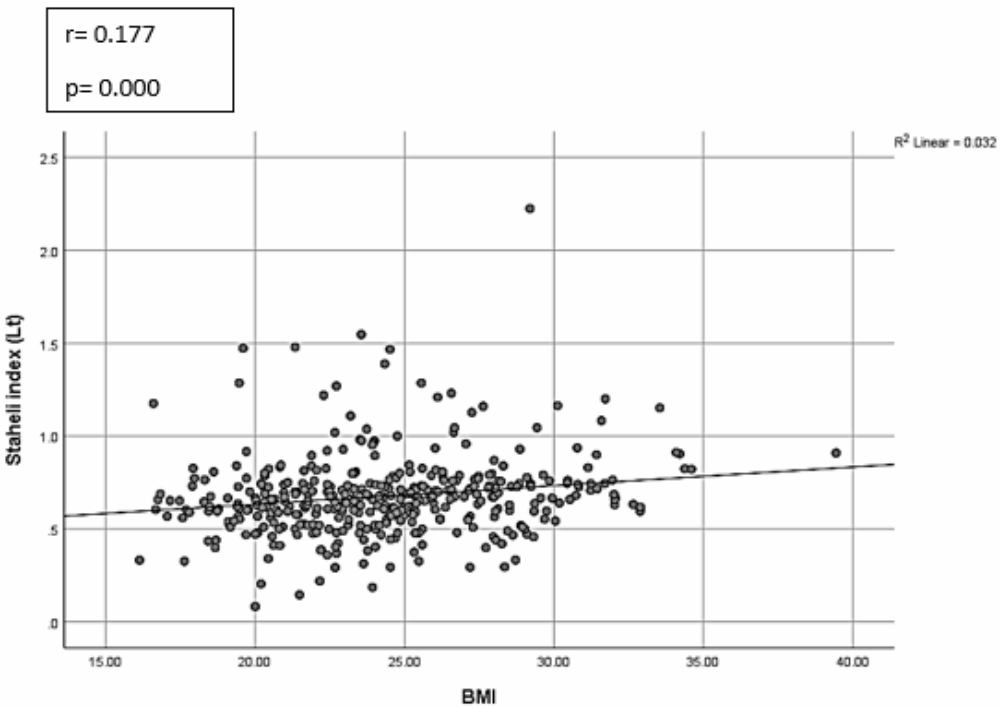


**Figure 6: Scatter diagram showing positive correlation between BMI and Staheli Index (left)**

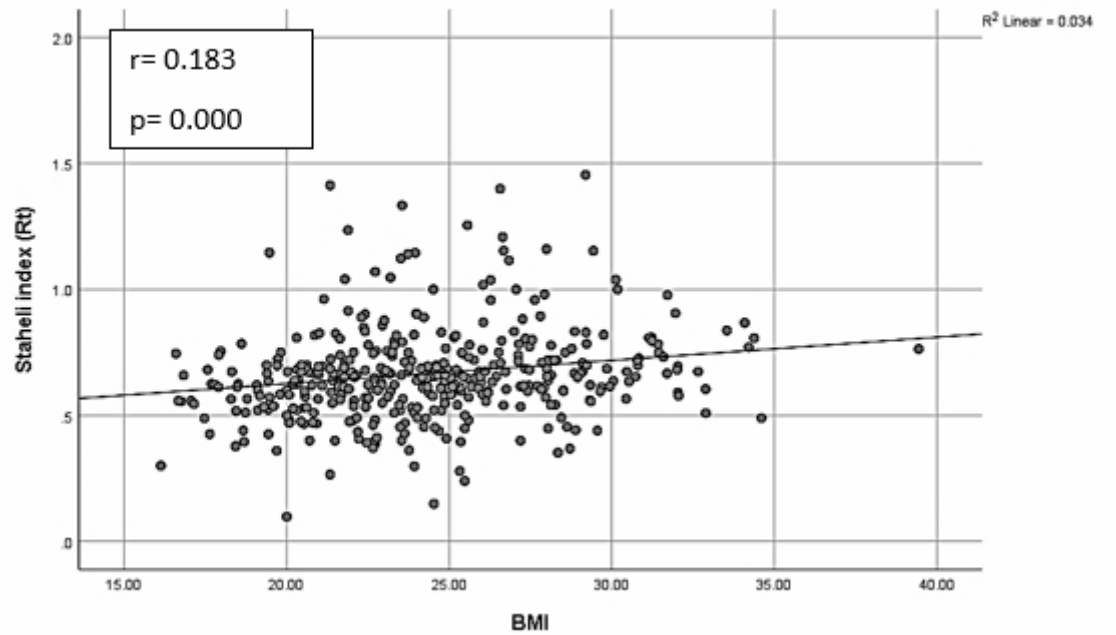


**Figure 7: Scatter diagram showing positive correlation between BMI and Staheli Index (right)**

## IV. Discussion

In this study, an increase in values of Mean Staheli Arch Index of right and left foot was observed with increasing BMI from underweight to obese II with p value of 0.005 and 0.008 respectively

Similar findings were found in studies done by Rachna Rohatgi[11], Karen J. Mickle[18] and Nagraraj Malashetty[19]. There was a positive correlation between BMI and Staheli ArchIndex left and right with r (Pearson's correlation Coefficient) values 0.177 and 0.183 respectively with p value 0.000

The results were also consistent with the findings between BMI and Staheli Arch Index by Ali Akbar Yousefi Azarfam[20] and K. Vijayakumar [17]

Gender wise comparison of Staheli Arch Index values of the five groups was not found to be statistically significant (p value=0.764).Similar results were obtained in studies done by Rachna Rohatgi [11] and Roy et al[21].In a study done by Shaliza Mohd Shariff[12], 22% of the participants possess different arches between the right and left feet. In this present studyalso it was observed in 24% of the participants. Disparity between left and right foot arches were also observed in a study done by Abdulaziz Almaawi et al [22]

## V. Conclusion

The result of the present study showed a positive correlation between BMI and foot arches. Gender variation of foot arches was not found to be significant. It suggests some preventive interventions to improve the quality of life for overweight and obese persons

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