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THE STUDY OF FOOT ARCH INDEX IN RELATION TO BODY MASS INDEX AMONG INDIAN AND NIGERIAN YOUNG ADULTS: A COMPARATIVE STUDY

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Abstract

The human foot and ankle is a complex architectural marvel comprising of 26 bones and 33 joints which make it rigid for load bearing. The foot is efficiently and meticulously supported by muscles, tendon and ligaments which make it supple and pliable to manoeuvre uneven ground, provide stability, and propulsion in gait biomechanics. In activities of daily living work load forces are generated which are proportionally distributed to arches. Medial longitudinal arch of the foot is main arch for absorption and dissipation of forces generated during foot ground reaction. Foot arch index from 0.21 to 0.26 is for normal foot, foot arch index more than 0.26 is found in pes planus and less than 0.21 denotes pes cavus. Minimal research has been conducted to explore the long term effects of increased body mass on the musculoskeletal system especially the foot. Foot arch index is affected by increase in body mass index (BMI). The present study was done to correlate the effect of BMI on foot arch index in normal, overweight and obese young adults of Indian and Nigerian origin with comparative correlation. *Methodology*: This study was conducted in Department of Anatomy, SMS & R , Sharda University, Greater Noida, India, on total 60 subjects comprising of 30 Indians (18 females and 12 males)and 30 Nigerian (17 females and 13 males) between 18to 25 years of age. Weight and height of the subjects were measured and BMI calculated and subjects categorized into normal (BMI 19- 24.9 kg/m$^{2)}$), overweight (BMI 25-29.9 kg/m^2), and obese (BMI>30kg/m^2) Foot arch index was calculated from foot prints of subjects taken on graph paper. *Results: The* mean In our study mean arch index of left foot in Indian was 0.21±0.04 in Indian and 0.25±0.05 in Nigerian. Similarly mean foot arch index of right foot was 0.22±0.04 in Indian and 0.25±0.05 in Nigerian. No significant difference (p>0.05) was reported between male and female subjects. *Conclusion:* The Excess mass in overweight and obese subjects lowers the foot arch height which has an adverse impact on the functional capacity of medial longitudinal arch of foot, leading to foot dysfunction which interferes with daily and recreational activities of the individual. The resulting lack of mobility perpetuates the vicious cycle of obesity. Also the classification of foot depending on arch index from the present study may aid the clinicians and podiatrists to monitor the diagnosis, treatment and rehabilitation of different foot anomalies.

Keywords: Arch Index, Body Mass Index, Foot Print, Obesity.

Abbreviations: BMI – Body Mass Index, Arch index-AI.

INTRODUCTION

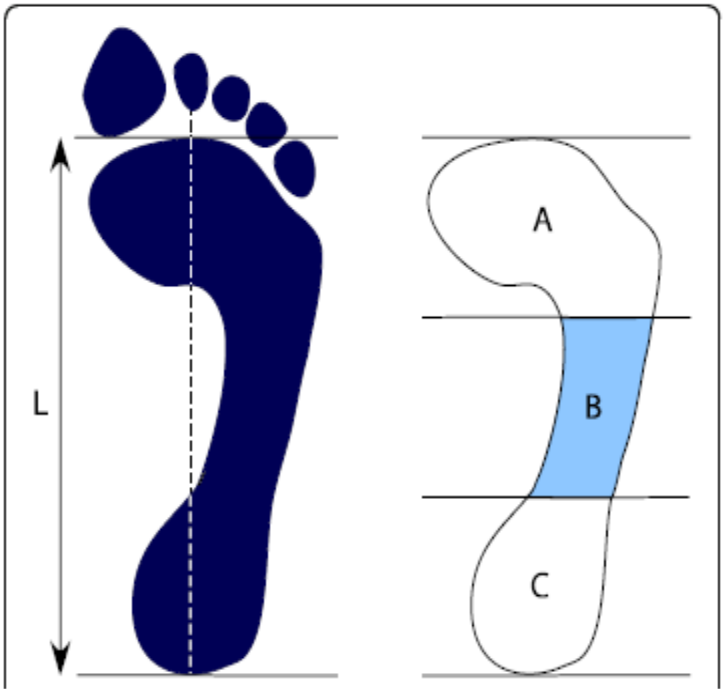
The human foot is considered as the foundation of body .The foot is a complex architectural marvel consisting of 26 bones, 33 joints which are efficiently and meticulously supported by muscles, tendons and ligaments. Human foot perform two basic functions, at first support the weight of body and secondly acts as a lever to propel the body forward during bipedal locomotion.

During the activities of daily living foot ground reaction causes generation of force and work load. These functions are carried efficiently due to arched skeleton of the foot both longitudinally and transversely. The arched foot is dynamic, pliable and acts as a spring board.[1]The concave shape of plantar arches serves to save the plantar nerves, arteries and veins from compression during weight bearing Medial longitudinal arch of the foot is main arch which helps in absorption and dissipation of force generated during foot ground reaction [2,3].

Apart from bony architectures, the coordination and cooperation between the muscles and ligaments is of paramount importance for arches of foot. The ligaments support and maintain longitudinal arches and acts as a powerful energy storing mechanism. [4, 5] Plantar ligament and plantar aponeurosis take the maximum stress in standing position and greatly contribute in arch support.

Failure of arch support depends upon the duration of stress and not upon the severity of the stress. So an overweight individual who stand immobile for long period ,exert excessive stress on the plantar ligaments compared to athletes who put great stress on foot arches intermittently. As a result obese person is prone to develop foot discomfort and flat foot compared to athlete who is able to maintain the arches.

Cavanagah et al [6] described the foot arch index is equal to the area of the middle third divided by whole area of the foot except the toes.



Foot Arch Index = B/A+B+C

According to his observation, In normal arch height the foot arch index is in between 0.21-0.2 , an arch index less than 0.21 is indicative of a high arched foot and more than 0.26 is indicative of flat foot.

Anthropometric status is governed by several factors such as age, race, gender, nutritional status and geographical area. So the foot arch index, body mass index and effect of body mass index over foot arch index vary in regard to different ethno-racial groups and geographical areas.

There are many publications over effect of body mass index on foot arch index in different region, but comparative correlation between different ethno-racial groups is very few Hence, our study is conducted to estimate the foot arch index, BMI and effect of BMI over foot arch index with comparative correlation between two different ethno-racial groups of Indian and Nigerian young adults.

Aim and Objectives:

Aim: To estimate and correlate the effect of BMI on foot arch index between Indian and Nigerian young adults.

Objectives

1. To calculate BMI from measurements of weight and height in Indian and Nigerian subjects
2. To measure the foot arch index
3. To correlate the effect of BMI on the foot arch index in Indian and Nigerian subjects

METHODOLOGY

The present study was conducted in the Department of Anatomy , SMS&R Sharda University , Greater Noida, India. **It was a cross-sectional study** comprising of **total** 60 subjects ,of which 30 were Indian students(18 females & 12 males) and 30 Nigerian students (17 females & 13 males) selected randomly from different academic courses of Sharda University in the age group 18-25 years fulfilling the inclusion criteria after obtaining their informed consent.

Inclusion Criteria: Healthy adults between age group of 18-25 years of either sex and willing to participate in the study. **Exclusion Criteria:** Subjects with Body mass index < 19Kg/m2, any neurological and lower limb disorders and anomalies, previous foot or leg surgery within six months of data collection, presence of any foot swellings/inflammations and ulcers **were excluded from the study.**

Approval for this work was obtained from Institutional ethics committee of Sharda University (Ref. No. SU/SMS&R/76-A/2O21 / 12O). The participating candidates were apprised of the procedure and intent of the study and their written informed agreement with their signatures for the study was taken on a consent form after explaining the details.

Methodology

The weight of the participants was measured to the nearest of 0.1 kg on standard weighing scale with participants wearing light clothes and without footwear.

Height of participants was measured from vertex of skull to foot standing erect in anatomical position.

Body mass index (BMI) was calculated as subjects weight in kilogram divided by square of height in meter[7]

BMI=Weight (in Kg) / Height (in Square meter)

Depending on BMI, the subjects were divided into Normal weight (BMI 18.5–24.9 Kg/ ^{2},overweight(BMI 25–29.9 Kg/m^2) and Obese (BMI > 30 Kg/m^2).

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Foot Arch Index:

On graph paper prints of Left and right feet of every participant were taken using ink and coded with name, age, sex, serial number and race (Indian or Nigerian). Imprint of full weight bearing foot was taken over graph paper in standard static position.

Foot Arch Index: On graph paper prints of Left and right feet of every participant were taken using ink and coded with name, age, sex, serial number and race (Indian or Nigerian). Imprint of full weight bearing foot was taken over graph paper in standard static position.

Ink Application on plantar surface of foot

Foot print taken on graph paper

Measurement of Foot Arch Index

As per Cavanagah et al description, Axis of the foot is measured as the straight distance from the center of the calcaneum (Point K) to the tip of the index toe (Point J) in the foot print. Then the most anterior point of the foot print was marked and a line at right angle was drawn tangential to this point to the axis of the foot (KJ). The point of intersection was marked as L. The line LK was divided into 3 equal parts and from lines were drawn perpendicular to the axis of the foot passing through these points. Thus main body of foot print were divided into anterior area **A**, middle area **B** and posterior area **C**. These areas were measured in sq. cm.

Foot Arch index was calculated as the ratio of the middle third of the foot to the entire area of the foot except toes

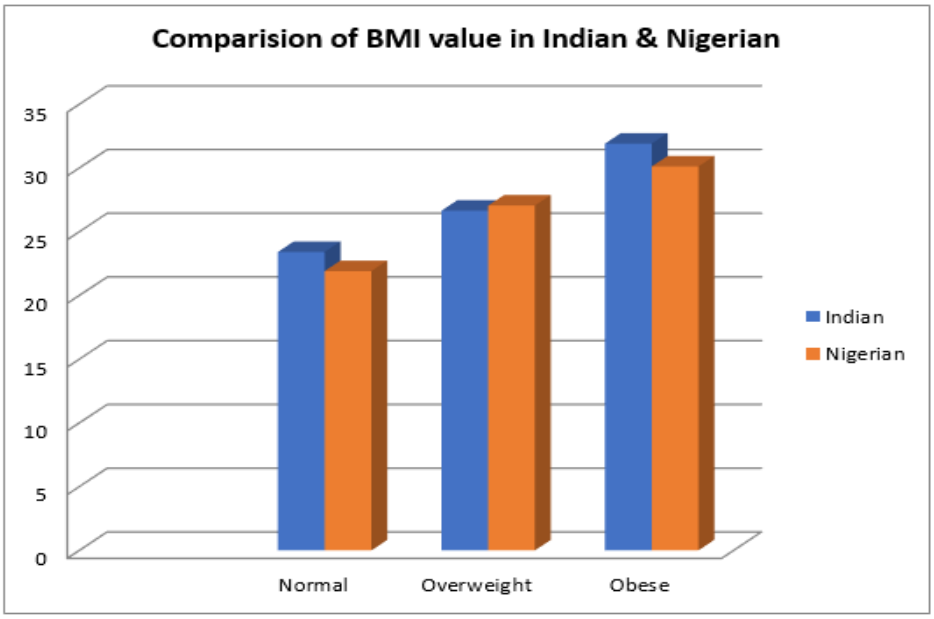
$$\text{Arch Index} = B/A+B+C$$

STATISTICAL ANALYSIS

Data was collected as per the Performa, tabulated and illustrated by appropriate photographs. All the data were collected with pre-informed consent and strict confidentiality of the participants was maintained. The data were analysed using Statistical Package for Social Sciences (SPSS) version 22. The statistical tool used was independent sample t-test for ascertaining gender differences and to compare foot arch index in Indian and Nigerian subjects. while paired sample test was used to test for differences between normal, high arched and flat foot. as well as right and left foot sides where P value lesser than 0.05 was considered significant. This was applied for the comparison of data in Indian and Nigerian among the normal weight, overweight and obese groups. The mean ± standard deviation was calculated for the Body Mass Index and Foot Arch index for the 3 groups (Normal, overweight and obese). One way Anova for multiple comparisons using a significance level of 0.05 (SPSS version 22) was used to test the difference between subject groups. A 5% level of probability was used to indicate statistical significance.

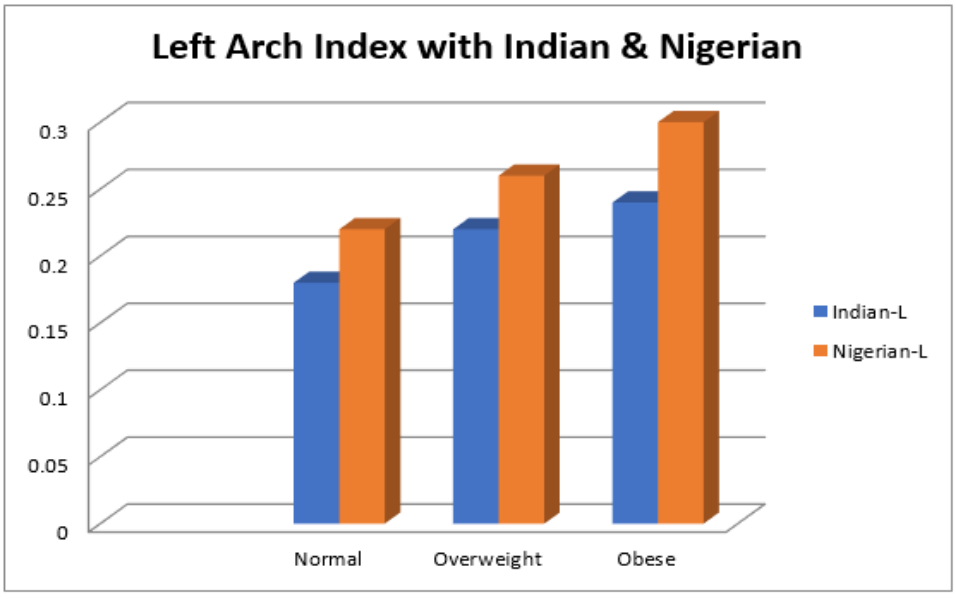
RESULT

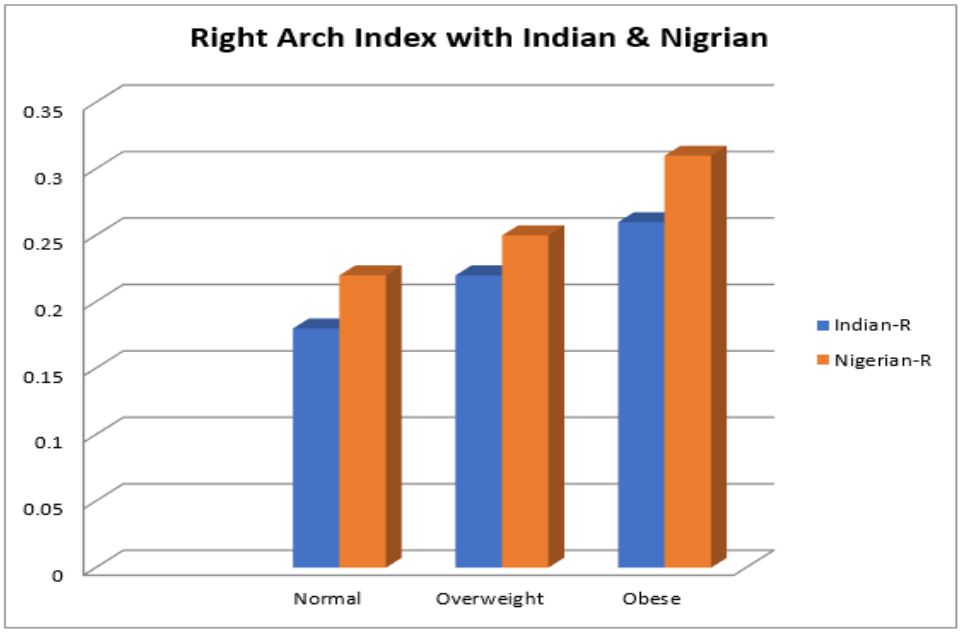
The Indian subjects were found to have a maximum and minimum body mass index of 41.01 and 19.86 with a mean value of 27.99+4.94. In Nigerian subjects the maximum and minimum BMI was found to be 30.86 and 18.17 respectively with a mean value of 24.99 +3.67.



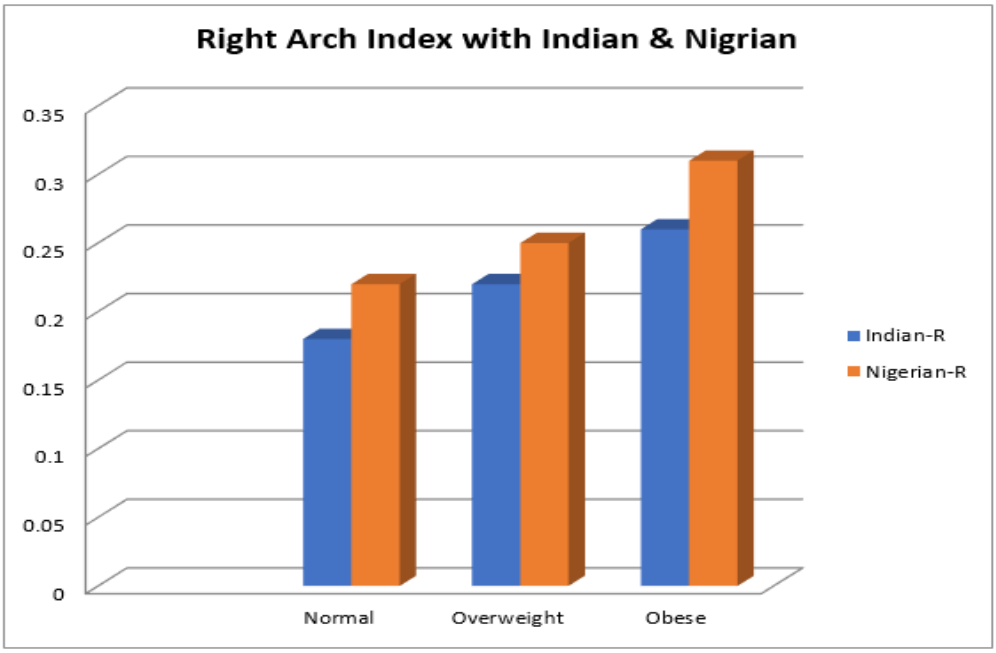
In Indian the maximum and minimum foot arch index was 0.32 and 0.15 with a mean value of 0.21+0.04 on left side while the corresponding values on the right side were 0.35 and 0.15 and 0.22 +0.04 respectively.

In Nigerian the maximum and minimum foot arch index on the left side was 0.33 and 0.15 with a mean value of 0.25+0.05.The corresponding values on the right side were 0.32 and 0.14 with a mean value of 0.25+0.05.





Analysis of data using paired t test with SPSS software version 22 between BMI and foot arch index of left and right side in Indian and Nigerian subjects was found to be statistically significant ($p<0.001$).



DISCUSSION

The body mass index is correlated with postural balance and functional stability of the individual. BMI is considered as the standard parameter to categorize the normal, overweight and obese.

In the present study the BMI of Indian participants was higher than their Nigerian counterparts in the three weight categories, which is in accordance with the ethno-racial category.

In our study, progressive increase in the foot arch index was reported from healthy weight to obese groups, with an increased value in obese signifying a flatter foot. (Table 3-8 Bar diagram 2).

The values of foot arch index (AI) showed a positive correlation ($r=0.78$ $p<0.05$) with BMI, which was in accordance with work of Ganu and Panahale [8] who had shown that medial longitudinal arch is lowered by obesity due to a rise in the load bearing capacity, thereby negatively affecting the foot arch index.

Medial longitudinal arch (MLA) is very crucial for supporting body weight in stance and swing phase of gait. [9] The abductor hallucis which plays an important role for stabilizing the medial longitudinal arch, is weakened in subjects with pes planus.[10,11]

Riddiford-Harland had conducted the study on obese children and found that obese children had significantly longer & flatter foot than normal weight children.[12.] C.L.Enema, U.S. Abaraogu, G.O.Okaforet et al had done the study on school children of age group 6 to 10 years in Enugu, Nigeria and they found that occurrence of flat foot was higher in obese group of students (54.4%) & lowest in underweight group of students (13.1%), which is similar to our study on Indian & Nigerian students.[13]

In our study increase in foot arch index value with increasing BMI was in accordance with the study conducted by Wearing, who measured the adult foot arch structure both radiographically and with foot print and evaluated the effect of BMI on foot arch structure.

Weaning found that increase in contact area of midfoot without change in bony arrangement and alignment of medial longitudinal arch components in obese person caused a relative distortion of foot print, and proposed adiposity as measure of body mass index.[14] Future studies should target the body composition of the individual and not rely only on body mass index as BMI is affected by both skeletal muscle mass and body fat percentage.[15]

Schie & Boulton had noted significant association between BMI and arch index ($r=0.36$, $p<0.05$) in their study of plantar pressure in diabetic and non-diabetic subject, which is similar to our study which observed that the subjects with lower arch (higher values of arch index) have a greater BMI.[16] But Cavanagah in diabetic with neuropathy and healthy controls found only weak correlation between peak pressure and foot arch index.[17] Thus higher pressures were related to a higher arch index (low arch).

Contrary to this, no positive correlation was found between increment in body weight and flatter foot by Evans.[18] Oladipo et al from their study in Nigerian subjects reported that length and breadth of right foot was significantly more than the left foot under similar weight bearing conditions in right hand dominant person, thereby advocating that the size of the shoe for right foot should be 2-3 mm more in length and breath for more comfort which also has a forensic significance.[19]

In our study on normal weight, overweight and obese groups the values of foot arch index were statistically significant ($p<0.05$) on right and left side both in Indian and Nigerian.

Such studies in future will create awareness in population for obesity and its consequences on foot arch index affecting the quality of life and activities of daily living.

CONCLUSION

In the present study, all the three groups (normal, overweight and obese) have shown statically significant difference in plantar arch index in both Indian and Nigerian subjects. The plantar arch index depicted a progressive increase with increase in body mass index signifying a flatter foot.

In the same age group the Nigerian subjects were found to be taller than Indian subject which reflected as lower BMI. This can be attributed to racial and climatic conditions. The result of our study shows that increase in body mass index leads to rise in weight bearing force, which in turn may result in reduction of physical activity.

Efficiency of movement may be improved with aerobic exercises , resistance training and modifications in gait posture and balance. Additionally, future research should categorize the overweight individuals on the basis of age, sex and lifestyle factors and to do specific modifications in style of living to reduce body mass index and thereby the morbidity and improvement in the quality of life.

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