Comparative study of non-obese & obese normal children feet using various external foot measurements and foot print

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ABSTRACT

Objective: To compare the external foot measurements & foot print of non-obese& obese children **.Methods**:15 male and 15 female school children, without other health problems, who could be classified as overweight or obese according to international standard BMI cut-off points and hip-waist ratio on the basis of age and sex, were selected as experimental subjects. An additional 15 male and 15 females non-overweight children, matched for age, height, and sex to the overweight/obese children, were selected as non-overweight controls. To characterize the external structure and arch height of each child's feet, various foot dimensions , including foot length, normalized Instep length, Normalized Fibular Instep length, Normalized foot breadth, normalized navicular height truncated, and Staheli's Plantar Arch Index, were directly measured for the right foot of each child.**Results:** The external foot measurements namely instep length, fibular instep length and foot breadth were normalized using foot length. Student's T-test was used as Statistical test for data analysis and was compared with the age matched normal children. No significant difference was found between the groups. **Conclusion:** We concluded from this study that the external foot appearance of obese and non-obese children is similar and no significant difference is noted when compared using external foot measurements and footprints.

Keywords: Obesity, Plantar Arch, foot dimensions.

INTRODUCTION

Obesity is a medical condition in which excess body fat has accumulated to the extent that it may have an adverse effect on health, leading to reduced life expectancy and/or increased health problems. As with obesity in adults, many different factors contribute to the rising rates of childhood obesity. Changing diet and decreasing physical activity are believed to be the two most important in causing the recent increase in the rates.The healthy BMI range varies with the age and sex of the child. Obesity in children and adolescents is defined as a BMI greater than the 95th percentile. Obesity is a leading preventable cause of death worldwide, with increasing prevalence in adults and children, thus it is one of the most serious public health problems of the 21st century. Before the 20th century, obesity was rare; in 1997 the WHO formally recognized obesity as a global epidemic. There have been recent studies like, 'Obesity affects 12% of under 11s' (14th December, 2006) and 'Levels of obesity in children aged 2 to 10years rose from 9.9% to 13.4% between 1994 and 2004, according to health survey in England' (25th January, 2007).

In India, urbanization and modernization has been associated with obesity. In Northern India obesity was most prevalent in urban populations

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(male = 5.5%, female = 12.6%), followed by the urban slums (male = 1.9%, female = 7.2%).Obesity rates were the lowest in rural populations (male = 1.6%, female = 3.8%). Socioeconomic class also had an effect on the rate of obesity. Women of high socioeconomic class had rates of 10.4% as opposed to 0.9% in women of low socioeconomic class. With people moving into urban centers and wealth increasing, concerns about an obesity epidemic in India are growing.Various authors have suggested that excessive increases in weight bearing forces caused by obesity may negatively affect the lower limbs and feet.[1-3] Feet, as the body's base of support, continually endure often high ground reaction forces generated during activities of daily living. The component primarily responsible for absorbing and dissipating these forces in the feet is the longitudinal arch. Although this arch comprises bony articulations, ligaments and muscles, it is primarily the ligaments that support and stabilize the longitudinal arch, as well as acting as powerful energy-storing mechanisms.[4,5] When learning to walk, exercising walking we learn how to contract the muscles of the foot plant, and thereby generally the arch architecture of the plant itself organizes. The development of arches of foot takes place by the age of 5-8 years. Muscles provide secondary support by maintaining the arch during dynamic tasks. Ligaments rarely incur physiological fatigue and therefore offer a greater resistance to stress compared to muscles.[6] However, repeated excessive loading may stretch ligaments beyond their elastic limit, damaging soft tissues and increasing the risk of foot discomfort and subsequent development of foot pathologies.

Increased loading of the feet may be classified according to time-frame and described as temporary, short-term or long-term. A temporary loading effect occurs, for example, when carrying a backpack or wearing a weighted belt that temporarily increases body mass. The previous researches have revealed that one factor moderating foot shape and contact in prepubescent children is obesity. The overweight/obese children had significantly larger contact areas between the total foot (TO), heel (M01), midfoot (M02) and forefoot (M03) and the ground when walking, compared to the non-overweight children. Do overweight and obesity affect dynamic plantar pressure distributions in preschool children? [7]In an attempt to better understand some of the musculoskeletal complications associated with childhood obesity, several studies have investigated the effects of obesity on foot structure and function. Although these investigations have repeatedly documented that obese primary school children typically display flatter feet relative to those of their leaner counterparts, the cause of this increased area of contact between the feet of obese children and the ground is unknown. It has been postulated that the flatter feet of obese children may be caused by the existence of a plantar fat pad underneath the midfoot region or hypertrophy of foot intrinsic muscles or can be some other reason also.

Riddiford-Harland et al [8] examined that the foot structure of obese and normal children. They concluded that excess body mass appeared to negatively affect the foot structure of prepubescent children whereby obese children as young as 8 years of age were displaying structural foot characteristics which may develop into problematic symptoms if excessive weight gain continued. It was also postulated that foot discomfort associated with higher plantar pressures caused by these structural changes in the obese foot may have hindered obese children from participating in physical activity and therefore warranted immediate further investigation. [8]Alternatively, it has been suggested that the flatter feet of obese children may be caused by a collapse of the medial longitudinal arch due to excessive loading of the feet as a result of continually bearing additional body mass. Such a structural collapse can develop into a potentially disabling problem in later life, as proper mechanics of the longitudinal arch are critical to normal foot function. This notion of a longitudinal arch collapse is purely speculative.

The previous studies were restricted to examining how obesity affect external characteristics of the plantar surface of the foot obtained from static weight-bearing footprints. It is, therefore, unknown whether obesity affects other parameters characterizing foot shape.This highlights the need to understand whether the appearance of flat foot shown in obese children actually flat foot or is it just an appearance. This study compares obese children feet with their normal non-obese counter parts of same age & gender group using various foot measurements and footprints.The aim of the study was to compare the external foot measurements & foot print of non-obese & obese children at the same age group.

MATERIALS & METHODS

SUBJECTS

60 subjects, 30 non- obese & 30 obese male school children at the same age group were selected randomly on the basis of their BMI from DAV Public School, Vivek Vihar , New Delhi.

Research design: Experimental study

Sample design: Probability sampling

INCLUSION CRITERIA

1) Age Group – 10-12 yrs.
2) BMI (95 percentile)
3) Ready to participate.
4) Understand Hindi and English.

EXCLUSION CRITERIA

1) Symptoms of macro vascular (e.g. angina, stroke, peripheral vascular disease)
2) Neuromuscular disease
3) Any biomechanical abnormalities which affected their ability to walk.
4) Lower limb injuries
5) Frequent falls
6) Inner ear tube implant
7) Use of corrective devices or footwear e.g. Orthosis
8) Leg length discrepancy of one inch or greater.

EQUIPMENT USED

1. A measuring tape with centimeters scale was used for measuring the various external foot parameters
2. White chart paper, Pencil, ruler, Pen marker, Ink was used to take the foot print of the subjects.
3. Weighing scale & Stadiometer were used to find out the BMI of the subjects

PROCEDURE

The written consent was documented from each subject. The subjects were divided into two groups: Group 1 (obese) and Group 2(non-obese). To characterize the external structure and arch height of each child's feet, 5 foot dimensions were directly measured twice (three times if the values were not within 3 mm of each other) for the right foot of each child, while the children stood erect, eyes looking forward. Following were measured to the nearest 0.1 cm. To maximize reliability of the data, all the data from each of the 60 subjects was measured using the same apparatus and procedure.

OUTCOME MEASURES

Foot Length

It is the distance from the end point of foot to the longest to end. The child was made to stand and a point was marked at the heel and another point was marked at the tip of the longest toe. The distance was measured and recorded.

Normalized Instep Length

It is the ratio of a distance from the end point of foot to the inside middle foot point to foot length. To measure the instep length, the child was made to stand and a point was marked at the heel and another point was marked at the first metatarsophalangeal (MTP) joint. The distance was measured and recorded. Then the instep length was divided by foot length to get normalized instep length.

Normalized Fibular Instep Length

It is the ratio of a distance from the end point of foot to the outside middle foot point to foot length. To measure the fibular instep length the child was made to stand and a point was marked at the heel and another point was marked at the fifth MTP joint. The distance was measured and recorded. Then the fibular instep length was divided by foot length to get normalized fibular instep length.

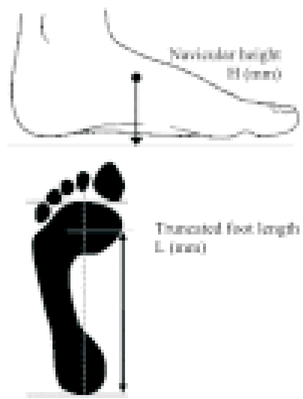
Normalized Foot Breadth

It is the ratio of a distance from the inside middle foot point to the outside middle foot point to foot length. To measure the normalized foot breadth the child was made to stand and a point was marked at the first MTP joint and another point was marked at the fifth MTP joint. The distance was measured and recorded. Then the foot breadth was divided by foot length to get normalized foot breadth.

Normalized navicular height truncated

It is the ratio of navicular height relative to the truncated length of the foot. Navicular height is the distance measured from the most medial prominence of the navicular tuberosity to the supporting surface. Foot length is truncated by measuring the perpendicular distance from the first metatarsophalangeal joint to the most posterior aspect of the heel, with a lower normalized navicular height ratio indicating a flatter foot.

Fig 1 & 2: Measurement of the Truncated length & Navicular height of the foot



Staheli's Plantar Arch Index

Footprints were recorded for each child's right and left foot. Each child slowly lowered one foot (of which the underside is inked) onto the chart paper and then stood motionless in an equal weight-bearing anatomical position for 2 seconds, while looking straight ahead, before quickly removing the foot. Two footprints of both the right and left feet were taken to obtain a permanent image of the plantar surface of the foot in contact with the ground during weight bearing.

The plantar arch index establishes a relationship between central and posterior regions of the footprint, and it is calculated as follows: a line is drawn tangent to the medial forefoot edge and at heel region. The mean point of this line is calculated. From this point, a perpendicular line is drawn crossing the footprint. The same procedure is repeated for heel tangency point. We thereby obtain the measurement of the support

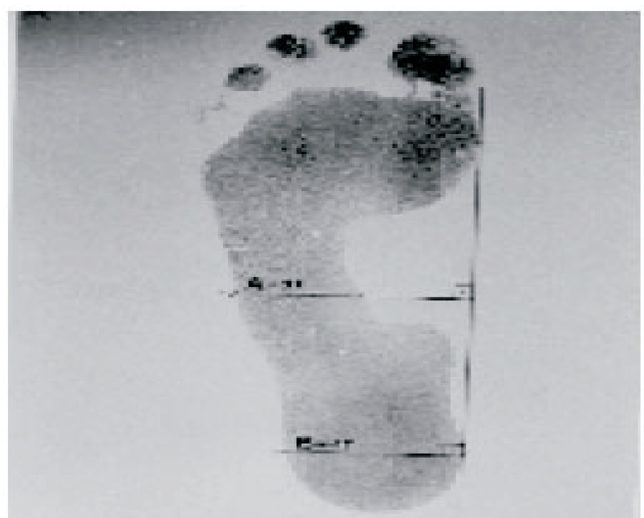


Figure 3- *Measurement of the width of the central region (A) and heel region (B) of the foot, in millimeters, on a footprint. The plantar arch index is obtained by dividing A value by B value.*

width of the central region to the foot (A) and of the heel region (B) in millimeters. The plantar arch index (PI) is obtained by dividing the A value by B value (PI = A/B).

STATISTICAL ANALYSIS

Student's t-test was used to compare the external foot measurements of obese & non-obese control groups. Values were presented as mean± standard deviation. Statistical significance level was set at $p < 0.05$.

RESULTS

The study was aimed at comparing the external foot structure of obese and non-obese children, aged 10-12 years. Two groups (obese and non-obese) were formed each comprising of 30 children. Matching was done on the basis of age (mean age 11yrs) and gender.

The external foot measurements namely instep length, fibular instep length and foot breadth were normalized using foot length. Student's t-test was used as statistical test for data analysis and was compared with the age matched normal non-obese children.

Age

In each group, 30 children were included with mean age of 11 years and standard deviation of 0.830.

Body Mass Index (BMI)

The obese children comparatively had a mean BMI :32 ± 0.894 kg/m2 and non-obese counter children had 19.76 ± 2.794 kg/m2 . The calculated t value was more than the critical value therefore it was significant.

Waist to hip ratio

The mean WHR for Group 1 (obese children) was 0.955± 0.034 and that for Group 2 (non-obese) was 0.826 ± 0.067 respectively. The p value was less than 0.05 and therefore it was significant.

Foot Length

The mean± SD for Group 1 was 8.777 ± 0.418 and for that of Group 2 was 8.67 ± 0.594. The calculated t value for foot length was lesser than the critical value($p > 0.05$) and therefore it was insignificant. Thus there is no significant difference in foot length of obese and non-obese children.

Normalized Instep length

The NIL for Group 1 was 0.738 ± 0.022 and for Group 2, it was 0.735 ± 0.028. The calculated t-value was 0.073 which was less than the critical value ($p>0.05$)and hence was insignificant and no difference was found in normalized instep length of obese children and their non-obese counter parts.

Normalized Fibular Instep length

The mean for Group 1 was 0.639 ±0.022 and that for Group 2 was 0.631±0.036. The calculated t value was 0.182. Hence the p value was greater than 0.05 and therefore it was insignificant. Hence there was no significant difference in NFIL between Group 1 and 2.

Normalized Foot Breadth

The values of NFB for Group 1 and Group 2 were 0.432 ± 0.027 and 0.440 ± 0.027 respectively. Since the calculated t-value was less than the critical value therefore the p-value was greater than 0.05 and hence there was no significant difference in NFB of obese and non-obese children aged 10-12 years.

Normalized Navicular Height

The mean±SD for Group 1 and Group 2 were 0.256± 0.041 and 0.274±0.047 respectively. The calculated t-value was 0.333 & p-value was greater than 0.05. This indicated that no significant difference was between normalized navicular height of obese and non-obese children at the mean age of 11 years.

Plantar Arch Index

The plantar arch index for group 1 and 2 with mean ±SD were 1.356 ± 0.087 and 1.408 ± 0.099

Table 1: Comparison of Age, BMI, Waist-Hip ratio & Foot measurements between obese & non-obese children

	Age	BMI	WHR	FL	NIL	NFIL	NFB	NNH	PAI
Group 1(Obese)	11 ± 0.83	32 ± 0.89	0.96±0.03	8.78±0.42	0.74±0.02	0.64±0.02	0.43±0.03	0.26±0.04	1.36±0.09
Group 2(non-obese)	11 ± 0.83	19.76±2.79	0.83±0.07	8.67 ± 0.59	0.74±0.03	0.63±0.04	0.44±0.03	0.27±0.05	1.41±0.10
t- Test	NS	34.87	2.22	0.58	0.07	0.18	0.19	0.33	0.66
p value	> 0.05	< 0.05	< 0.05	> 0.05	> 0.05	> 0.05	> 0.05	> 0.05	> 0.05

Fig.1: Shows comparison of NIL, NFIL, NFB & NNH between obese & non-obese children

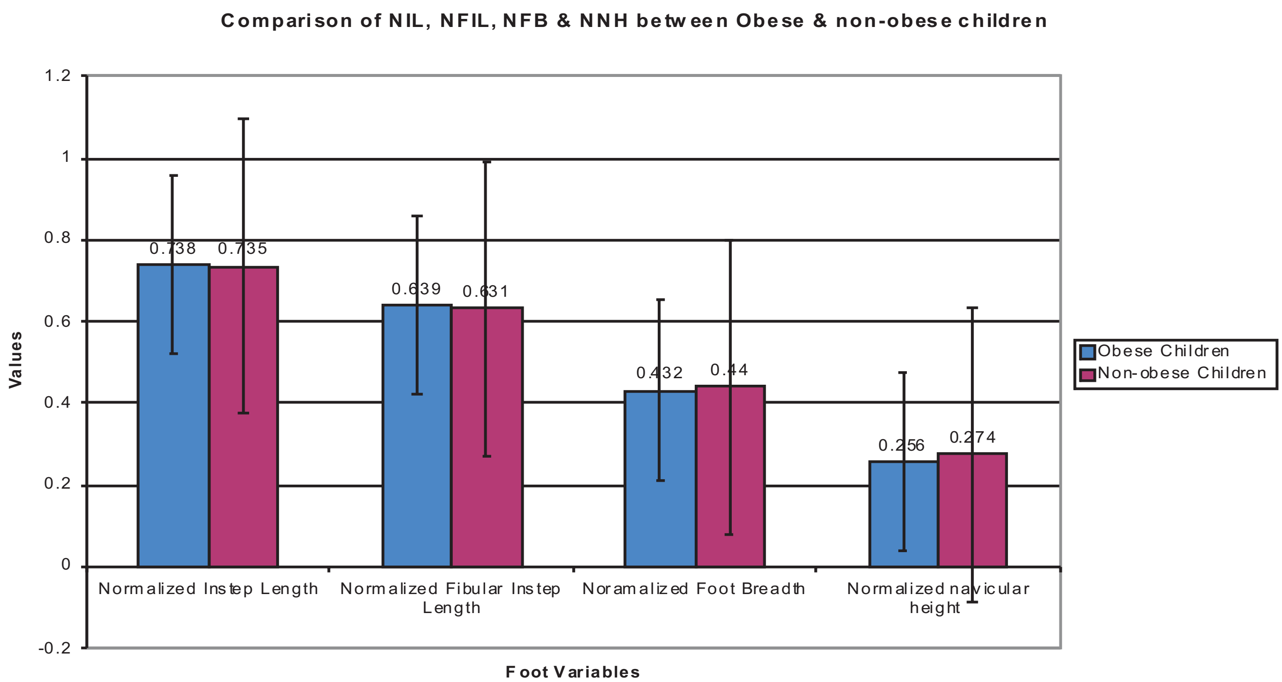
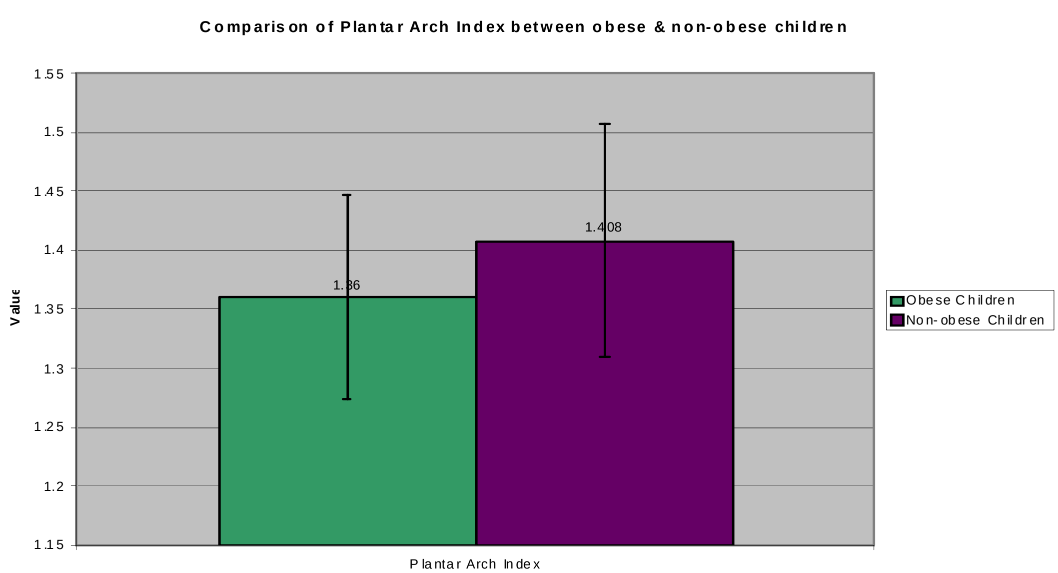


Fig.2: Shows comparison of Plantar Arch Index between obese & non-obese children



respectively, p was > 0.05 and hence it was insignificant.

DISCUSSION

The results of this study showed that no difference existed between the obese and non-obese children external foot measurements at the age group of 10-12 years. Thus alternative hypothesis was rejected & null hypothesis was accepted. In this study, mean values were calculated for 7 chosen external foot measures which are used to characterize the foot structure. Some of the mean values were found to be in agreement with values reported previously [9,10] whereas some did not. Non-obese children displayed a similar mean arch index value (1.356 ± 0.087) to those reported by Cavanagh and Rodgers [11] (1.348 ± 0.077) for 107 subjects (mean age, 11.5 years). Interestingly, this study found a higher mean arch index value (1.356 ± 0.087) compared to previous study [12] (1.021 ± 0.067), from which our normative reference values were derived. This difference may be because medial longitudinal arch development happens primarily through age, thus, higher plantar arch indexes are expected in younger children, while these indexes are lower in older children. Other authors admit that major variations on plantar arch happen until the age of 7. The suggestion of this index having a decreasing incidence up to approximately 5 years old, remaining stable after that, was responsible for our decision to study a group of children above that age, working with lower age groups we could reduce the usefulness of our indexes to the intended end.

The normalized navicular height did not show any difference between obese children group and non-obese children group. Previous researches have shown differences between the two with lower NNH in case of obese children. This variation can come as palpation of the navicular head is more difficult in full or 90% of weight bearing than in 10% of weight bearing. This finding may have occurred because the soft tissue on the medial border of the arch becomes taut in 90% of weight bearing. Although the measuring procedure was consistent within it, but in each turn the palpation might have been on a slightly different landmark in the 90% of weight bearing condition. The consistently higher values for navicular height suggested that perhaps the posterior portion of the navicular was being measured rather than the anterior portion.

Considering footprint a poor evaluation approach [13], still there is almost an uncountable number of authors who advocated its use [14-18]. The correlation between X-ray studies and footprint showed that the footprint is effective for individual studies and population-based investigations. Some cannot find a correlation between footprint and clinical measurement of the plantar arch, regarding it is invalid to determine plantar arch height, others also consider that footprints present several approach failures. The plantar arch index and the navicular vertical height are correlated, but the second is better, because it directly measures navicular, which is the key to medial arch, in addition to be easy to achieve.

Some researchers have incorporated the use of radiographs [19, 20] or photographs [21] to classify the medial longitudinal arches of their subjects. Hawes et al [22] measured the highest point of the soft tissue along the medial longitudinal arch in full weight bearing. Although this measurement, as well as footprint measurements, [23, 24] can be easily obtained, we do not believe that these measurements necessarily represent the state of the bony architecture of the foot. The soft tissue on the plantar surface of the foot is thick and variable and can mask the true bony architecture of the foot.

Saltzman et al[25] correlated measurements taken at 50% of weight bearing with measurements obtained from radiographs to determine their validity. The authors concluded that the measurements correlated well with the measurements obtained from radiographs. Measurements obtained from radiographs of talar height/ foot length, calcaneus to first metatarsal angle, and calcaneal inclination were compared with measurements of navicular height/footprint length, arch height/ footprint length, and talar height/footprint length. The measurements obtained from radiographs were different from the clinical measurements. Therefore, we do not believe that these measurements had concurrent validity. Dividing navicular height by foot length is important because the height of the navicular may not give an accurate representation of the arch.

Plantar Arch Index & Navicular height are considered important to determine the presence of a flat foot. No statistically significant difference was found between obese & non-obese children feet, indicating that obesity does not affect the external characteristics of the plantar surface of children feet.

CONCLUSION

We concluded from this study that the external foot appearance of obese and non-obese children was similar and no difference was noted when compared using external foot measurements and footprints. Thus obesity doesn't have significant role on foot measurements at the age group of 10-12 years of children.

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