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Original Research Paper

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A STUDY OF FOOT MORPHOLOGY IN UNDERWEIGHT AND OVERWEIGHT ADOLESCENTS

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ABSTRACT

Objective: The objective of the present study was to examine the impact that body mass index (BMI) has on adolescent foot morphology between 12-16 years. The purpose of the study was to categorize foot types (flat, average and high arch) and rates of these foot types across underweight, normal weight, and overweight participants. **Method:** A total of 76 adolescents, both male and female, from Satara, Maharashtra, were selected using a simple random sampling technique. Participants who were underweight or overweight according to BMI underwent foot morphology assessments using footprint analysis. Measurements taken included foot length, arch angle, and dorsal arch height. The study design was analytical, and the duration was six months. Statistical analysis was used to evaluate the correlation between BMI and foot morphology. **Result:** The study determined three distinct arch types: flat, slender, and robust. Overweight adolescents showed a higher prevalence of flat feet, correlating with increased pressure on the medial longitudinal arch. In contrast, normal-weight adolescents showed a shift towards robust and slender feet with increasing age. Underweight participants exhibited growth-related foot issues due to malnourishment. **Conclusion:** BMI significantly influences foot morphology in adolescents. Flat feet are more common in overweight adolescents due to excessive weight on the medial arch, whereas underweight adolescents face growth-related complications in foot development. Early identification and intervention may help alleviate potential health problems related to foot structure.

KEYWORDS : Body Mass Index (BMI), Foot Morphology, Flat Feet, Overweight Adolescents, Underweight Adolescents, Arch Angle, Foot Types.

INTRODUCTION

Overweight or obesity and underweight are significant public health concerns, affecting millions of adolescents worldwide.[1] A normal weight is a healthy lifestyle that means your Body Mass Index falls within a weight range that is not associated with an increased risk for weight-related diseases and health issues.[2]

Overweight and obesity are defined as abnormal or excessive fat accumulation that may impair health. An underweight person is a person whose body weight is considered too low to be healthy. A person who is underweight is malnourished. Body mass index (BMI) is a simple index of weight-for-height that is commonly used to classify normal weight, overweight or underweight. It is defined as a person's weight in kilograms divided by the square of his height in meters (kg/m^2). In young adolescents, that is in their developmental stage of life, this main factor-weight-overweight affects the morphology of foot. The unhealthy lifestyle may lead to overweight or obesity, which may cause morphological and physiological developmental changes.[1,3]

Underweight-malnourished refers to deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients, which leads to growth-related issues. The structure of the foot can be acquired or congenital. As the foot is the base of support for the chain of motion and body posture, it is postulated that obese children suffer an increased risk of developing pathologies and injuries due to increased loading, such as a flattening of the medial longitudinal arch.[4] Flat feet can cause difficulty in walking, and can even lead to more serious health issues, and can cause pain in the regions of the feet and waist. Here, we mainly intend to focus on how acquired causes impacts the foot morphology in adolescents and they shall be studied in detail.[5]

The purpose of the present study was to examine foot morphology in its shape. Therefore, the aim was to classify children's feet into different foot types based on foot measures, and further to determine the effect of body mass index (BMI) on the prevalence of these foot types. Assessment of data from a large population of children aims to provide reliable information about these influential factors on the development throughout childhood.

Methodology

Study Design And Data Collection

The approach of this study was cross-sectional with a survey design. The data collection was done over a period of 6 months in Satara, Maharashtra. Total sample size was calculated to be 75 adolescents, using the formula formula $N = 4pq/L^2$. A total of 76 participants (38 underweight and 38 overweight) were chosen through the simple random sampling method. The adolescents, who were 12-16 years old and either underweight or obese according to their Body Mass Index (BMI), comprised the study population.

Participants

The eligibility of the participants was determined based on the inclusion and exclusion criteria. Inclusion criteria was adolescents with either a flat or arched foot falling under overweight or underweight criteria as per th BMI, while adolescents with congenital deformities, bone malformations, or fractures, as well as those with any comorbidities, were excluded from the study. The study was approved by the concerned authorities. The purpose and procedure of how the study would be conducted was explained to all participants. A signed consent form was undertaken by those willing to participate.

The baseline assessment was taken including the footprints of the adolescents, and measurements were documented using four outcome measures: Body Mass Index (BMI), foot length, arch angle, and dorsal arch height. These measurements were utilized for further evaluation, and statistical analysis was done to determine the relationship between foot morphology and BMI. The results were then utilized for drawing conclusions.

Outcome Measures [7]

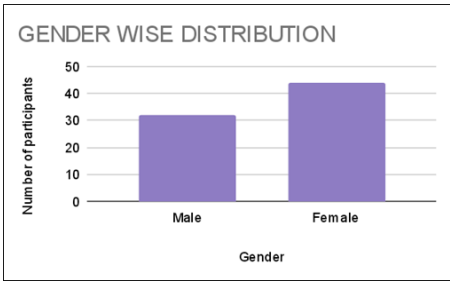
- **Body Mass Index:-** Body mass index (BMI) is a simple index of weight-for-height that is commonly used to

classify normal weight, overweight or underweight. It is defined as a person's weight in kilograms divided by the square of his height in meters (kg/m^2).

- **Foot length** :- Distance between foot end (heel) and foot tip (anterior point of the most protruding toe) along the medial tangent of the foot. (foot measuring line)
- **Arch angle :-** Angle between line connecting the first MTP joint and the medial heel with a second line drawn to the apex of the medial longitudinal arch concavity.
- **Dorsal arch height :-** Height of medial dorsal junction of the foot and leg to the floor.

RESULTS

The study consisted of a total of 76 adolescents, with 57% females (44) and 42% males (32). The gender wise participation leaned slightly higher on the female side.

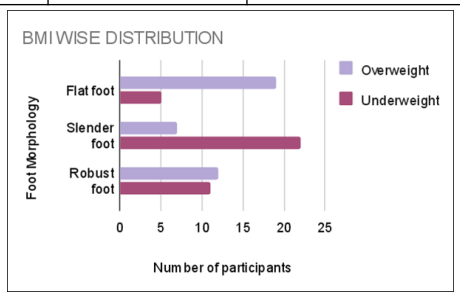


Graph no. 1 - Gender wise distribution of participants

The different foot types noted were, flat feet, slender feet and robus feet. Flat feet mainly characterized by the flattened medial longitudinal arch, medium volume and length. Slender feet having narrow widths of ball and heel along with a low dorsal arch height displaying long toes and relatively high arch. The robust type of feet showed large volume and shorter toes with an average arch.

Table No: 1 Number Of Participants According To Type Of Foot

	Overweight (n=38)	Underweight (n=38)
Flat Foot	19	5
Slender Foot	7	22
Robust Foot	12	11



Graph No.: 2 BMI Wise distribution participants and foot morphology

The prevalence of flat foot was the highest in overweight adolescents, whereas underweight adolescents most likely demonstrated slender foot types. The robust foot morphology was demonstrated almost similar in both the groups.

DISCUSSION

This study aimed to understand and correlate the relationship between Body Mass Index (BMI) and foot morphology in adolescents, especially on the underweight and overweight categories of adolescents. The main aim was to determine how different body weights influence the development and structure of the foot, particularly the medial longitudinal arch, which is critical in providing support and maintaining proper posture. By examining a population of 76 school children aged 12 to 16, this research sought to identify and categorize different foot types—namely flat, slender, and robust—while considering BMI as a significant external variable affecting foot morphology.

Results of this study are consistent with previous research indicating that BMI should be considered an important factor in defining foot type during adolescence. Children and adolescents, unlike adults, did not show obesity as a risk factor for being flat-footed but rather higher plantar pressure in this age group; overweight adolescents had a greater medial longitudinal arch decrease so an elevated occurrence of flat feet. This is consistent with results from Mauch et al. (2008) Because of higher body weight, the loading on the foot raises which results in flattening of the arch and can lead to flatfoot deformities based on Kumar's findings. Accordingly, our results support those of Jiménez-Ormeño et al. meanwhile, this was testified by Gill et al. [2013] stressing that adolescents who are overweight and obese will put the foot arch under high pressure when flattening it out, thereby prompting a range of foot deformities such as flat feet [2].

Overweight adolescents, due to increased pressure on the medial longitudinal arch, exhibited a higher prevalence of flat feet compared to their normal-weight or underweight peers. This finding is supported by Mickle et al. (2006), who demonstrated that overweight and obese children were more likely to have flat feet due to the excess fat accumulation, which alters the arch's structure. Additionally, Sadeghi-Demneh et al. (2016) confirmed a strong correlation between flatfoot and obesity in school-aged children, suggesting that excessive body weight puts undue strain on the arch, contributing to the flattening of the foot[8],[9]

In contrast, the underweight adolescents (who should have less pressure on the medial longitudinal arch) were more likely to be having slender feet. These correspond with Wo niacka et al. (2013) that a lesser body mass may put less stress on the arch and therefore enhance a higher or less broad profile of the arch. The presence of robust feet was found throughout the BMI distribution, and its prominence increased with older age, suggesting that as children grow, the morphology of their feet adapts with not only to changes in body mass but also to natural developmental forces. [3]

Interestingly, the study revealed a progressive shift in foot types as children age, particularly in normal-weight individuals, where both robust and slender feet became more prevalent. This finding emphasizes the complex interaction between BMI, growth, and foot structure, reinforcing the notion that foot morphology is not static but develops in response to both internal factors, such as growth, and external variables, such as weight .

This is further corroborated by Dowling et al. (2004), who observed that overweight children have altered plantar pressure distributions, which significantly affect the foot's shape and functionality. Moreover, Wo niacka et al. (2015) noted that increased obesity levels in children result in progressive flattening of the longitudinal arch, a finding that parallels the current study's results on overweight adolescents. Similarly, Brzezi ski et al. (2019) found a direct relationship between increased body mass and lower-extremity defects, including flat feet, further supporting the role of excess weight in the development of foot abnormalities [6,10,11]

An interesting finding of this study is the shift towards robust and slender feet in normal-weight adolescents as they age. This shift aligns with studies like Wo niacka et al. (2013), which highlighted the dynamic nature of foot morphology, showing that foot type can change as children grow and their

bodies adapt to changes in weight and physical development.[11]

Conversely, underweight adolescents, with less pressure on the medial longitudinal arch, were more likely to have slender feet. This is consistent with the findings of Stavlas et al. (2005), who documented that normal or lower body mass resulted in more pronounced arches and slender foot structures in a Mediterranean population. The study's results suggest that lower body weight, with reduced mechanical loading, allows for a more natural development of the foot's arch, unlike the over-stressed arches seen in overweight individual[7]

This is important because early detection of foot abnormalities in children — particularly if a child is overweight or underweight — can provide better outcomes later, the researchers noted. These measures are important as early intervention and timely management can prevent long-term postural, gait, and musculoskeletal issues in kids. Although the study was limited to BMI and achieved a strong correlation between BMI and foot morphology, other potential covariates including activity level, nutrition, and genetic predispositions may have also affected foot development.

In conclusion, this study revealed the influence of BMI on foot morphology in adolescents. Because extra weight of overweight children, they are more likely to have flat feet due to the increase in the pressure on the medial longitudinal arch, while children who are relatively thin (underweight) with little foot weight show a tendency towards slender feet. Frequent review of the development of the feet in children, especially if increased BMI is very important to prevent musculoskeletal problems in the future. Further research could expand on this study by considering additional variables, such as activity levels and genetic factors, to develop a more comprehensive understanding of foot morphology and its determinants.

CONCLUSION

Body Mass Index plays a very critical role in shaping foot morphology during adolescence. Flat feet were more common in obese individuals due to the increased pressure exerted on the medial arch of the foot. This collapse of the arch was due to increased pressure on the medial aspect of the foot, which may affect posture or gait and can cause discomfort. On the other hand, underweight adolescents often encounter growth-related challenges. Lower body mass in underweight people may contribute to a slender foot structure during development, potentially leading to insufficient support and instability in the foot during thier growth.

For both the groups identifying these foot-related issues early on will play a major role. By catching these problems in their early stages, healthcare professionals can implement interventions, such as custom orthotics or exercises targeted to specific foot type, to help improve foot function and prevent further complications. Early intervention not only lowers the chance of long-term issues like joint discomfort or limited mobility that could result from abnormal foot anatomy, but it can also improve the health of the feet.

Limitations

- The limitation was faced because of the shorter duration for study.
- Limited to one geographical location
- 3D View scanner was not available

Further Scope

- The study can be performed on a larger population.
- More technologies and outcome measures can be used for the further and in detail study.

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