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Original Article

Physiotherapy Section

Correlation between BMI and Static Biomechanical Lower Extremity Kinetic Chain Variables in Overweight Young Adults: A Cross-sectional Study

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ABSTRACT

Introduction: Lower Extremity Alignment (LEA) is a main influencing cause in the active motion of the human body. Changes in the lower limb kinetic chain can be pushed by Body Mass Index (BMI). The gait may be impacted, which may result in more energy usage. However, little is known about how BMI and other static alignment parameters such as Quadriceps (Q)-angle, tibial torsion and plantar arch index are related.

Aim: To determine the correlation between BMI and lower extremity kinetic chain variables such as pronated feet, femoral anteversion, Q-angle, tibial torsion, plantar arch index, angle of toe and pelvic inclination.

Materials and Methods: The present cross-sectional study was conducted in the Department of Physiotherapy, Santosh Hospital Ghaziabad, Uttar Pradesh, India, from January 2021 to December 2021. A total of 160 participants age ranged between 18 years and 30 years with a BMI between 25 kg/m^2 and 29 kg/m^2 were included in the study. The following parameters were measured: pronated foot, angle of toe, plantar arch index, pelvic inclination, femoral anteversion, Q-angle and tibial torsion. Correlation between BMI with the seven static alignment parameters mentioned above was statistically analysed by using Pearson's correlation coefficient and Spearman's correlation test.

Results: The mean age of the subjects was 23.82±2.021 years and mean BMI of the participants was 26.37±1.501 kg/m^2. There was significant correlation between BMI and pronated foot of both sides (r-value=0.256, 0.199, p-value=0.001, 0.012), BMI and plantar arch index of both sides (r-value=0.198, 0.161, p-value=0.013, 0.043). However, no significant correlation was found between BMI and Q-angle (r-value=0.137,0.144, p-value=0.087, 0.72), BMI and tibial torsion (r-value=0.024, 0.066, p-value=0.766, 0.413), BMI and anteversion (r-value=0.111, 0.134, p-value=0.164, 0.92), BMI and angle of toe (r-value=0.127, 0.139, p-value=0.111, 0.081) and, BMI and pelvic inclination (r-value=0.012, 0.013, p-value=0.885, 0.870).

Conclusion: BMI was positively correlated with the pronated feet and plantar arch index, and this relationship was statistically significant. However, no statistically significant relationship between BMI and pelvic tilt, femoral anteversion, Q-angle, tibial torsion and angle of toe.

Keywords: Body mass index, Flat foot, Plantar arch index, Pronated foot, Tibial torsion

INTRODUCTION

It is seen that males and females in prepubescent period under the age of 12 years, do not significantly differ from each other in terms of height, body mass, girth, muscle strength, bone breadth, or skin fold thickness. No difference is found in knee laxity, hip anteversion, or tibiofemoral angle before this age, indicating that lower extremity's anatomical and postural characteristics are likewise similar [1]. The architecture of the hips and knees differ by sex in the adult population, with females having more anterior pelvic tilt, femoral anteversion, tibiofemoral angle, quadriceps angle and genu recurvatum. On the other hand, there are no gender differences in the measurements of tibial torsion and foot pronation as evidenced by navicular drop and rear foot angle [1].

The prevalence of flat feet was significantly increased by an increase in temporary body mass, which typically happens during the pubertal age group (12-15 years) [1]. Another study found that young adults between the ages of 18 years and 24 years, with higher Body Mass Index (BMI), have a propensity to develop low arch feet suggest that weight may be a significant factor in the development of low arch feet, this because when body mass grows, both static and dynamic plantar pressures increase, significantly altering the structure of the foot [2]. However, as evidenced by a larger area of foot contact with the ground, obesity appeared to flatten the patients' Medial Longitudinal Arch (MLA) [3].

Flatfoot or pes planus refers to a Medial Longitudinal Arch (MLA) that is abnormally low. The talus bone's head is medially and distally displaced from the navicular in pes planus. As a result, the tibialis posterior muscle's tendon and spring ligament are stretched to the point where the MLA no longer functions in a person with pes planus [4]. The person has rigid flatfoot if the MLA is absent or non functional in both the seated and standing positions. A person has a flexible flatfoot if the MLA is present while they are sitting or standing on their toes but disappears when they take a footflat stance. Infants often have flat feet which are typical and natural because of baby fat, which hides the growing arch, and also the arch has not yet fully matured [4].

Lower Extremity Alignment (LEA) is a main influencing cause in the active motion of the human body. Minor variation in the standard positions may establish to be a propagating cause for injuries due to distorted joint biomechanics, changed neuromuscular control and discrepancy among ligament and muscle forces. It has been observed that changes in any one lower limb joint's alignment result in changes in the positions of the proximal and distal joints, linking all the joints together into a chain known as the kinetic chain [5]. The appendicular skeleton should be viewed as "stiff, overlapping segments in series," according to Dr. Arthur Steindler's 1995 proposal. He also defined the kinetic chain as a combination of multiple successively placed joints constituting a complicated motor unit [5]. The incidence of knee injuries in women has been linked to a variety of risk variables, including gender differences in LEA [6]. Regardless of gender, increased navicular drop and anterior pelvic tilt were substantially linked to a history of Anterior Cruciate Ligament (ACL) rupture [5].

Since body mass is a significant factor in the development of low arch feet as seen in studies, but in these studies only one factor was considered [2,7,8]. There are very few studies taken into account in which the effects of BMI on lower extremity kinetic chain is seen [5,9]. Hence, attributing to paucity of literature, the present study aimed to find out if any correlation exists between BMI and lower extremity kinetic chain variables such as pronated feet, femoral anteversion, Quadriceps (Q)-angle, tibial torsion, plantar arch index and angle of toe and pelvic inclination in young over weight population.

MATERIALS AND METHODS

The present cross-sectional study was conducted in the Department of Physiotherapy, Santosh Hospital Ghaziabad, Uttar Pradesh, India, from January 2021 to December 2021. The Institutional Research Committee grants permission for the research (IEC no F.No.SU/2021/092). Written informed consent was taken from all the study participants.

Inclusion criteria: Healthy, asymptomatic adults, aged between 18 years and 30 years and with a BMI ranged between 25 and 30 were included in the study.

Exclusion criteria: Individuals with a history of any pathological condition at the spine or any lower limb joints, as well as those with a history of trauma to the spine, hip, or knee (including fractures, surgery, and/or ligament injuries), were excluded from the study. Subjects with a history of grade 3 or grade 1, 2 ankle sprains that occurred within three months were excluded from the study [5].

Sample size calculation: sample size calculated was 160, by the statistician using formula:

$$c = 0.5 \times n\left(\frac{1+r}{1-r}\right) n = \left[\frac{z_\alpha + z_\beta}{c}\right]^2 + 3$$

r=correlation between target variables

n=required sample size

z_α=1.96 at α=5% z_β=0.84 at 80% power [8]

A total of 160 students were enrolled from the Department of Physiotherapy of the study institution.

Study Procedure

Demographic data such as age, gender and BMI were collected from all the study subjects.

BMI calculation: BMI was calculated as: weight (in kilograms) divided by the square height (in meters) or BMI=Kg/m^2.

Staheli's Plantar Arch Index (SPAI) [10]: To measure the width of the centre region (A) and the heel region (B) in millimeters a tangent is drawn touching medial aspect of forefoot and heel then perpendicular is dropped at mean point of the tangent and at the greatest width of the heel region. The A value and B value were divided to produce Staheli's Plantar Arch Index (SPAI). A/B=SPAI. Normal arch index ranges between 0.210 and 0.260 [Table/Fig-1].

[Table/Fig-1]: Measurement of Staheli's Plantar arch index.

Femoral anterversion [11]: The amount that the femoral neck projects forward from the frontal plane of the shaft is known as femoral anteversion.The femoral neck's angle with the femoral condyle, often known as the Craig's test, is used to measure the hip's anteversion. The client was made to lie on his or her stomach with the knees bent 90 degrees toward the edge of the plinth. The greater trochanter of the femur was palpated on the back, and the hip was passively rotated laterally and medially until it was parallel to the examination table or reached its maximum lateral position. The degree of anteversion was then determined using goniometry, which involved drawing a line through the tibia's shaft and dividing it into the medial and lateral condyles. Adult mean angle anteversion typically ranges from 8-15° [Table/Fig-2].

[Table/Fig-2]: Measurement of femoral anteversion.

Quadriceps angle [12]: The quadriceps angle (Q-angle) is referred to as the angle of quadriceps muscle force and is defined as the angle between the quadriceps muscles (mainly the rectus femoris) and the patellar tendon. The client was in lying supine position maintaining his quadriceps muscle relaxed. The anterior superior iliac spine the midpoint of the patella, and the tibial tuberosity, which was then extended above the knee, were connected by a line, and the midpoint of the patella was connected by another line. The angle that was created between these two lines was measured using goniometry. Normal range of quadriceps angle is 12-20° [Table/Fig-3].

[Table/Fig-3]: Measurement of quadriceps angle.

Pronated foot or navicular drop [13]: The individual was in a bilateral posture, with body weight equally distributed over both feet, and the navicular tubercle was palpated and noted. As patients steadily everted and inverted their foot and ankle, subtalar joint neutral, which is defined as the position where the medial and lateral portions of the talar head are equally felt, was achieved. The individuals were told to hold the subtalar joint neutral position while the height of the navicular tubercle from the floor was measured. After that, the subjects were told to relax their stance, and the difference in navicular height between the neutral and relaxed stances of the subtalar joint was measured in millimetres. Growing positive numbers suggest growing pronation of the feet. Beyond 10 mm, a measurement is abnormal [Table/Fig-4].

[Table/Fig-4]: Measurement of navicular drop.

Tibial torsion [14]: Subjects lie supine with femoral condyles in frontal plane. Apex of both malleoli was palpated, a line was drawn joining the two apices. A second line was drawn on heel parallel to floor. Tibial torsion was calculated by angle formed intersection of two lines. Tibial torsion in adult is 13-18°, if >18° than referred as toe-out position [Table/Fig-5].

[Table/Fig-5]: Measurement of tibial torsion.

Pelvic inclination [15,16]: An inclinometer was used to measure the pelvic angle, which is the angle created by a line connecting the anterior and posterior superior iliac spines with respect to the horizontal plane. The average pelvic tilt is between 10.9-17.1°. The normal range of the pelvic inclination, was 10.91-21.74° [Table/Fig-6].

[Table/Fig-6]: Measurement of pelvic inclination.

Angle of toe in and out [17]: A six meter walkway is created using regular crepe paper. A chair was placed at the end of walkway to provide ambulation trial. Water soluble ink is applied to the sole of both the feet. Subjects were instructed walk down the walk way as naturally as you walk down the street. A third foot print and consecutive foot print were then evaluated for Foot Progression Angle (FPA). A line parallel to edge of paper is represented by line of progression. Longitudinal axis of foot was determined as line from the bisection of the widest part of heel through the centre of second toe. The angle between line of progression and longitudinal foot axis represented FPA. Average right and left foot was calculated. FPA value describes external rotation of lower extremity (out-toeing). Negative value represent internal rotation of lower extremity during gait (in-toeing) [Table/Fig-7].

[Table/Fig-7]: Measurement of angle of toe in and out.

STATISTICAL ANALYSIS

Data were collected and statistically analysed using Statistical Package for the Social Sciences (SPSS) software version 28.0. Values of pronated foot, pelvic inclination, femoral anteversion, Q-angle and tibial torsion, plantar arch index, angle of toe were checked for normality using the Kolmogorov-Smirnov and Shapiro-Wilk normality test. Correlation between BMI and kinetic chain variables was assessed using the parametric Pearson's correlation coefficient for the data that passed normality and using the non parametric Spearman's correlation coefficient for data that did not pass normality. The level of significance of this study was set to p-value <0.05.

RESULTS

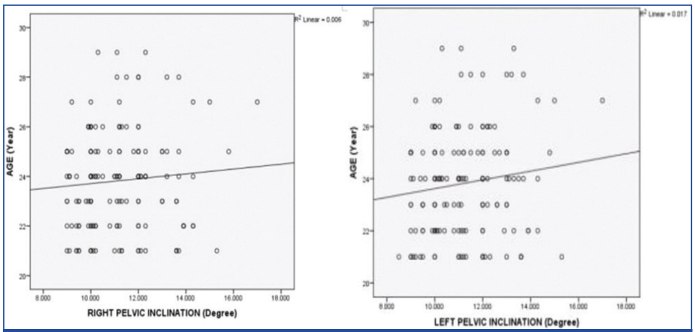
Out of total 160 subjects, 57 were females and 103 males, having a BMI <30 kg/m^2. The mean age of the subjects was 23.82±2.021 years, mean BMI of the participants was 26.37±1.501 kg/m^2.

BMI was positively correlated with the pronated foot and plantar arch index, and this relationship was statistically significant. However, no significant relationship was found between BMI and other variables such as pelvic inclination, femoral anteversion, tibial torsion, angle of toe and quadriceps angle [Table/Fig-8,9a-g].

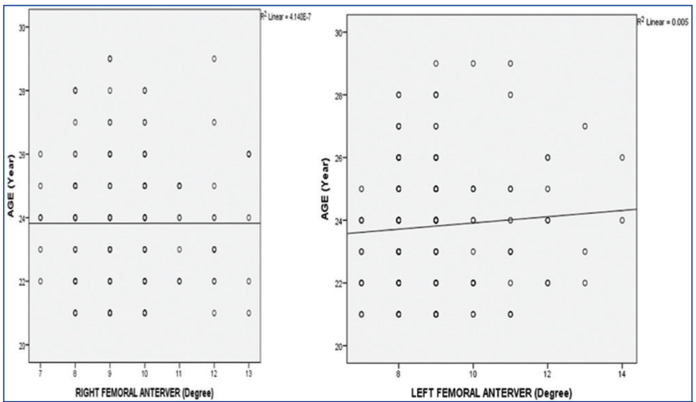
Parameter	Mean±SD (degrees)	BMI: 26.379±1.501	
		r-value (Pearson's correlation coefficient)	p-value
Pelvic inclination			
Right	11.156±1.6266	0.012	0.885
Left	11.212±1.5800	0.013	0.870
Femoral anteversion			
Right	9.47±1.426	0.111	0.164
Left	9.08±1.412	0.134	0.92
Quadricepsangle			
Right	18.45±1.333	0.137	0.087
Left	18.22±1.411	0.144	0.72
Tibial torsion			
Right	14.06±1.959	0.024	0.766
Left	13.85±13.85	0.066	0.413
Angle of toe			
Right	11.18±2.438	0.127	0.111
Left	11.07±2.275	0.139	0.081
Pronated foot			
Right	6.888±0.6841	0.256	**0.001**

left	6.793±0.6920	0.199	**0.012**
Plantar arch index			
Right	0.5450±0.1860	0.198	**0.013**
left	0.5591±0.1827	0.161	**0.043**

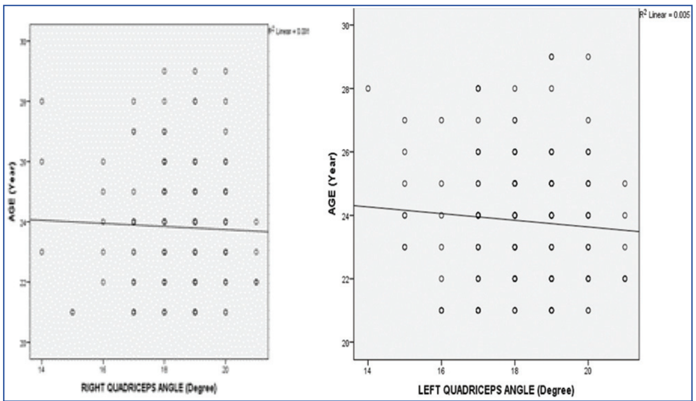
[Table/Fig-8]: Correlation of BMI with kinetic chain variables of right and left feet.
Correlation is significant at 0.05 level (2-tailed). Using student t-test.
The p-value in bold font indicates statistically significant values.



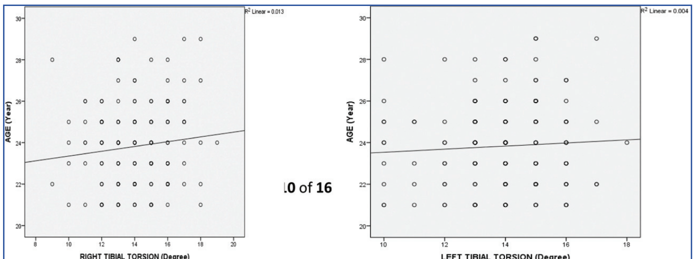
[Table/Fig-9a]: Correlation between BMI and pelvic inclination.



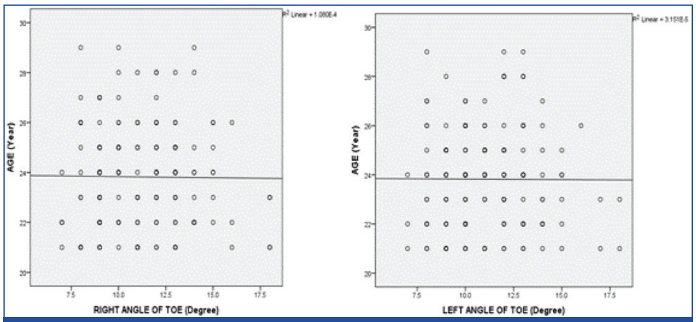
[Table/Fig-9b]: Correlation between BMI and femoral anteversion.



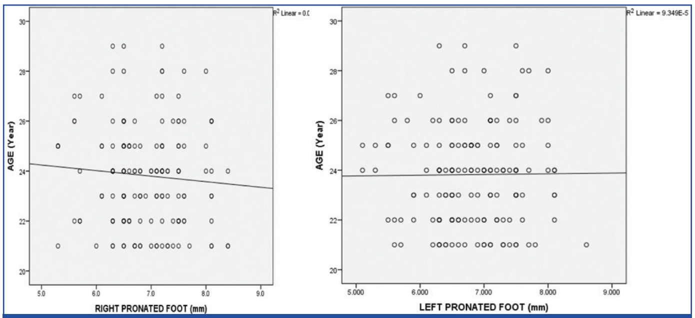
[Table/Fig-9c]: Correlation between BMI and quadriceps angle.



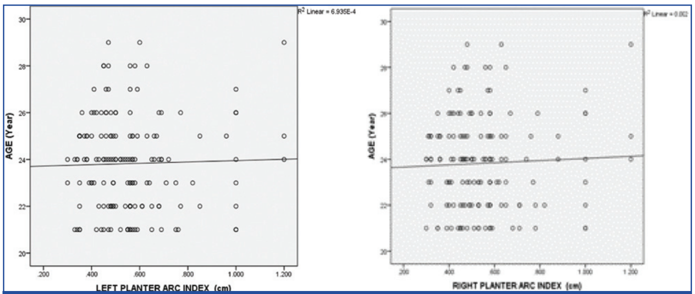
[Table/Fig-9d]: Correlation between BMI and tibial torsion.



[Table/Fig-9e]: Correlation between BMI and angle of toe.



[Table/Fig-9f]: Correlation between BMI and pronated foot.



[Table/Fig-9g]: Correlation between BMI and plantar arch index.

DISCUSSION

A study was accomplished to correlate the BMI with the pelvic inclination, femoral anteversion, Q-angle, pronated foot, angle of toe, plantar arch index, Q-angle, tibial torsion in 160 normal, asymptomatic individuals having no complaints of pain/stiffness at knee/ankle or any history of knee injury. These included 55 females and 103 males, in the age group of 18-30 years, having a BMI of not more than 30 kg/m^2. Mean age was 23.82±2.02 years; Mean BMI of subject was 26.37±1.50 kg/m^2; Mean pelvic inclination right-side 11.1569±1.626°, left-side 11.212±1.580°. Mean femoral anteversion right-side 9.47±1.426°, left-side 9.08±1.412°, Mean Q-angle right-side 18.45±1.333, left-side 18.22±1.411, pronated foot right 6.888±0.6841, left 6.793±0.692, angle of toe right 11.18±2.438, left-side 11.07±2.275, plantar arch index right-side 0.5450±0.1860, left-side 0.559±0.1827, tibial torsion right-side 14.06±1.959, left-side 13.85±1.654. However, none of variable passed normality. The level of significance of this study was set to p-value <0.05.

From the above data analysis result show no significant correlation was found between BMI and femoral anteversion, pelvic inclination, Q-Angle, angle of toe, tibial torsion. Significant correlation was found between BMI and plantar arch index (p-value=0.013, 0.043) right-side and left-side, pronated foot (p-value=0.001, 0.012) right-side and left-side.

The endocrinology of males and females diverges with the onset of puberty, with males secreting more testosterone and females more oestrogen. Males have larger stature and muscle mass, and girls have more body fat as a result of these hormone variances [1]. Deshmandi H et al., conducted a footprint-based analysis on 1180 students discovered that the prevalence of flat feet was significantly increased by an increase in temporary body mass, which typically happens during the pubertal age group (12-15 years) [2]. Similarly study on young adults between the ages of 18 years and 24 years with higher BMI, have a propensity to develop low arch feet suggest that weight may be a significant factor in the development of low arch feet [9]. Another study by Jaiswal K et al., found that when body mass grows between the ages of 20 years and 25 years, both static and dynamic plantar pressures increase, significantly altering the structure of the foot. However, as evidenced by a larger area of foot contact with the ground, long-term mass gains related to obesity appeared to flatten the patients' MLA [3].

According to Keevil VL et al., a high Waist Circumference (WC) is a clinical sign of central obesity and is connected with a lower grip strength, but a high BMI is linked to a higher overall body mass and stronger grip strength. The most metabolically active adipose tissue is abdominal fat, which focuses on probable mechanisms governing the interactions between fat and skeletal muscle. Additionally, it supports the advice that waist measurement be done in clinical practice, particularly when BMI is below obese ranges [18]. Since majority of the patients in the present study were in the age group of 18-30 years and had a BMI between 25 kg/m^2 and 29 kg/m^2 having overall lean body mass then excessively big WC. Furthermore, Penha PJ et al., reported a decrease in the frequency of excessive pelvic tilt in children aged 7-10 years; they attributed this to effective abdominal control [19].

Quadriceps angle did not significantly associate with weight according to a previous study by Khasawneh RR et al., that measured the Q-angle with regard to several body parameters in young Arab population [20]. Additionally, no discernible shift in the Q-angle with weight was reported by Sra A et al., but according to Jaiyesimi AO and Jegede OO research, taller people have slightly smaller Q-angles than do men and women of the same height thus they summarised because men tend to be taller, the minor variation in Q-angles between men and women can be explained by this [21,22]. Another study by Bayraktar B et al., discovered a negative link between quadriceps angle values age and activity. They predicated this outcome on the observation that increased physical activity tends to straighten the quadriceps angle [23]. In the current study, however, the subjects' height varies significantly, and authors did not do inquiry whether they participated in any sports or other forms of physical activity.

There was no link between femoral anteversion and other LEA characteristic in a study by Nguyen AD and Shultz SJ [4]. Their findings showed that there was no link between femoral anteversion and quadriceps angle. Poor measurement reliability that resulted in conflicting measurements was given as the explanation by them. Because poor validity and reliability of (interrater ICC=0.25) the Craig's test, which was used to measure femoral anteversion in the prone lying position, was not a reasonable option [11,24].

The same is true for measuring tibial torsion in the non weight-bearing position, which makes it an inadequate indicator of the alignment of the lower limbs in the functional weight-bearing position [11].

The present study demonstrates a considerable impact of BMI on pronated feet while having no impact on toe angle. Lack of transition to outward torsion has been linked to subtalar joint pronation, which is in line with the findings of the present investigation. In addition, it is believed that a lack of outward tibial torsion results in a "in-toeing" gait, which the person corrects by abducting the foot at the subtalar joint (pronated position) to attain a more typical, straight-ahead stance according to Nguyen AD and Shultz SJ [4].

Each person's body has a unique way of adjusting to changes that take place in every given body segment. Therefore, as demonstrated in their study, not everyone who has increased foot pronation necessarily has changes in the other limb alignment characteristics. The body may often use compensatory measures to handle changes at any one lower extremity joint [4].

The results of the present study are different from those of the other study, because BMI, a measurement that takes into account both fat and fat free mass in its formulation, is the most often used indicator of obesity [8]. Increases in BMI therefore reflect increases in both lean and fat mass, which are also highly associated measurements [25]. Study use different co-variables to account for lean mass in analyses, which could explain why the results are inconsistent [19]. Second, BMI does not reveal how fat is distributed. Considering that the adipose tissue are not uniformly distributed throughout the body and that varied connections between fat and health outcomes have been found depending on the region of fat accumulation, it is crucial to take fat distribution into account. The metabolic effects of obesity are most strongly linked to centrally deposited adipose tissue, and a larger WC is a crucial indicator of the metabolic syndrome [19].

Finally, the present investigation found no connection between BMI and pelvic inclination, femoral anteversion, Q-angle, tibial torsion, and angle of toe because all of the variables that influence the lower limb joints' static alignment in weight-bearing positions were not taken into account in the study. For a more in-depth understanding of how the lower limb kinetic chain functions, it is necessary to take into account variables such the tibiofemoral angle, patellar position, ligamentous laxity, and neck shaft angle of the femur [26]. The existence of a kinetic chain has already been demonstrated in numerous publications, therefore the association between these static alignment components cannot be entirely ruled out [27-30].

Limitation(s)

Additionally, a lot of other interrelated element (patellar position, ligamentous laxity, and neck shaft angle of the femur) that determine how different joints are positioned along the kinetic chain were not taken into account in this study. In order to prove that there is a correlation, more in-depth research and evaluation of the subject are needed

CONCLUSION(S)

In the present study, a positive correlation was found between BMI and pronated feet and plantar arch index, and this relationship was statistically significant, suggesting that weight alone may be an important factor in the development of low arc, which may eventually result in flat feet due to changes in the MLA in young adults who are heavier. However, there is no statistically significant correlation between BMI and the angle of the toe, pelvic tilt, femoral anteversion, Q-angle, and tibial torsion. More studies should be conducted with large sample size and including other elements such patellar position, ligamentous laxity and neck shaft angle of the femur.

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