Acta Biomed 2020; Vol. 91, N. 4: e2020121 DOI: 10.23750/abm.v91i4.9077

Original article

The prevalence of genu varum and genu valgum in overweight and obese patients: assessing the relationship between body mass index and knee angular deformities

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Summary. *Background:* Recent studies have shown evidence of a relationship between overweight and obesity with skeletal abnormalities, especially angular knee disorders. We aimed to reveal causal relationship between obesity and skeletal abnormalities. *Methods:* This study was performed on 280 overweight or obese patients (with BMI > 25kg/m^2) who referred to the hospital with which the authors are affiliated in Tehran between 2017 and 2018. Several non-radiographic methods including measuring Q angle, inter-malleoli distance and distance between two knees were used to determine genu varum and genu valgum. BMI was also calculated by dividing the weight by the square of the height. *Results:* The prevalence of genu varumand genu valgum was 8.6% and 10.0%, respectively. There was a significant adverse correlation between the Q angle and BMI. The mean BMI in patients with and without genu varum was 39.07 ± 6.41 kg/m^2 and 42.1 ± 2.26 kg/m^2, respectively, being significantly lower in the genuvarum group (P = 0.008). Also, the mean BMI in patients with and without genu valgum was 43.39 ± 3.33 kg/m^2 and 41.58 ± 4.61 kg/m^2, respectively, being significantly higher in the genuvalgum group (P = 0.044). Also, there was a direct correlation between BMI of patients with inter-malleoli distance and inverse correlation between BMI and two knees distance. *Conclusion:* There is a strong and significant relationship between incidence of obesity and genu valgum; therefore, the prevalence of this deformity in obese individuals is predictable. The lower incidence of genu varum in obese people is predictable in our society. (www.actabiomedica.it)

Keywords: genu valgum; obesity; knee; genu valgum

Introduction

Obesity is one of the most common eating disorders in developed countries (1); it is a global problem, affecting three hundred million people in the world, which has increased the risk of death and reduced life expectancy (2). The prevalence of obesity varied in different regions of the world. Risk factors for this disorder include urbanization, reduced physical activity, and increased calorie intake and modern life (3). Due to its high prevalence and complications, it is important to measure the true body mass index (BMI).

The health of the human skeletal system is threatened by many factors, including the habits of life, occupation, culture, and even the environment. When skeletal abnormalities are raised, attention is paid more to spinal abnormalities, while other parts of the body can also be exposed to multiple abnormalities and complications. In any kind of weakness in the lower limbs, movement, displacement, and daily activities can be difficult. Due to the fact that the lower extremity endures the body weight, the lack of preventing and correcting the abnormalities associated with lower extremity especially knee can cause secondary disorders in other parts of the body disrupting both physical and mental health. The knee joint plays a very important role in supporting the body and transmitting its weight during static and dynamic activities. During the various activities, compressive and tensile forces are introduced into this joint, but its support and stability is further enhanced through the muscles and ligaments around it, and almost no bone agent plays a role in stabilizing it. In this regard, this joint is one of the most vulnerable joints in the body (4). Damage and knee joint disorders are divided into two general categories of traumatic and non-traumatic injuries. Non-traumatic problems include skeletal deformities (such as genu varum and genu valgum), rheumatoid arthritis, and joint degenerative diseases, and its traumatic problems include bursitis, tendon injuries, meniscus damage, and degenerative dislocation (3). Knee skeletal deformities are one of the most common disorders of the knee. These disorders may be congenital or acquired, and the most common ones are genu varum and genu valgum. The genuvalgum is a form of knee deformation in the frontal plate, which, if present, is in contact with the knee joints in the case of weight bearing on the knees led to getting knees away from each other. Genu varum is characterized by is a varus deformity marked by bowing at the knee, which means that the lower leg is angled medially in relation to the thigh's axis, giving the limb overall the appearance of an archer's bow (4,5). These deformations have a relatively high prevalence in Iran, especially among women (6, 7). The presence of these deformations places exposed people at high risk for increased complications such as increased risk of patellofemoral joint damage and tibiofemoral joint osteoarthritis, as well as compensatory changes in ankle and foot joints and an increased risk of tibia fractures (8-10).

Recent studies have shown evidence of a relationship between overweight and obesity with skeletal abnormalities, especially angular knee disorders. What we did in this study was to determine the relationship between genu varum and genu valgum abnormalities with overweight and obesity indices in order to reveal the causal relationship between obesity and skeletal abnormalities.

Materials and Methods

This study was performed on 280 overweight or obese patients (with BMI > 25kg/m2) who referred to the hospital in Tehran between 2017 and 2018. The exclusion criteria were unwillingness to collaborate in measuring and completing the checklist, incomplete measurements, inability of the patient to stand, and also BMI greater than 47 or less than 25 kg/m2. The study was in accordance with the ethical standards of the responsible committee on human experimentation (institutional or regional) and with the Helsinki Declaration of 1975, as revised in 1983.

After obtaining satisfaction from patients, height, weight, BMI, presence or absence of knee deformity and its degree were measured. To measure the height correctly, the person was completely flat behinds the stadiometer where the thoracic throat, buttocks, and heels were in contact with the vertical axis of the gauge. Several non-radiographic methods were used to determine genu varum and genu valgum: 1) measuring Q angle (Figure 1): First, the patient was taken three

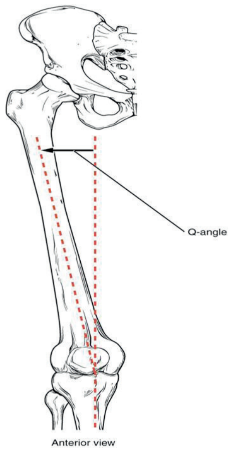

Figure1. Measurement of the Q-angle

steps forward, then stood and the lower limbs were as close as possible. Three indications were made to determine the femoral and tibial axes on the patient's body including proximal marker on the navel, middle marker at the center of the knee joint and the distal marker on the posterior midline of the medial and lateral malleolus of the lower limb. The femoral axis consists of a line connecting the navel to the middle of the knee joint and the tibial axis consists of a line connecting the knee to the ankle. These two axes produce angles that are measured by an angle gauge. The Q angle ranged 1 to 21 degrees is considered as the normal, while an angle of more than 21 degree is diagnosed as genu varum and less than 1 degree as genu valgum; 2) determining the distance between the two knees: first, the patient stood and closed the lower limbs as much as possible and then distance between the two knees of the patient was measured by a calibrator. A distance of more than 3 was considered as genu varum; 3) determining the distance between the two medial malleoli: the patient stood and closed the lower limbs and then distance between the two medial malleoli was measured by a calibrator that a gap of more than 8 in women and more than 4 in men was considered as genu valgum. To calculate the actual length of the lower limb (total length of the femur and tibia), the patient's height and length of the seat base were measured. In measuring the patient's sitting height, the patient was first seated in the chair and leaned completely flat and then height was measured by meter. To calculate the actual length of the lower limb, we obtained the difference between the sitting heights from the base length of the seat. The difference between the patient's height and the pointed measurement showed actual length of the lower limb. In measuring the apparent length of the lower limb, the length of the tibia was measured by the meter and the angles were measured by the goniometer. Then the lower limb length was determined based on the mathematical formula related to the triangle's sides and cosinus rule. The BMI of the patients was also calculated by dividing the weight by the square of the height. All participants were visited by endocrinologist and parathyroid disease, vitamin D metabolism disorder, hereditary hypophosphatemic rickets and other genetic disorder which associated with skeletal deformity were ruled out.

Descriptive analysis was used to describe the data, including mean ± standard deviation (SD) for quantitative variables and frequency (percentage) for categorical variables. Chi square test, t test, or Mann-Whitney U test were used for comparison of variables. The association between the quantitative variables was assessed using the Pearson's or Spearman's correlation coefficient tests. For the statistical analysis, the statistical software IBM SPSS Statistics for Windows version 22.0 (IBM Corp. Released 2013, Armonk, New York) was used. Data were summarized using means and ranges. Results were given as mean + SD. Statistical significance was set at the 0.05 level. Comparison of the groups was performed using student's t-test in parametric values and the chi-squared test in non-parametric values. Further Correlation analysis was performed using linear regression methods to access the relation between BMI and measured orthopedic parameters.

Results

In this study, 280 patients with overweight (8 cases 2.9%) or obese (272 cases, 97.1%) were enrolled in the study. In terms of baseline characteristics of the patients, the mean age of patients was 41.07 ± 11.21 years in the range of 19 to 75 years and in terms of gender distribution, 57 cases (20.4%) were men and 223 cases (79.6%) were women. The mean weight of the patients was 113.75 ± 15.47 kg and the mean

BMI of the patients was 41.66 ± 4.14 kg/m^2.In terms of educational level, 5 cases (1.8%) were illiterate, 48 (17.1%) primary school, 6 cases (2.1%), high school, 136 cases (48.6%) had diploma and 85 cases (30.4%) had academic degree. Previous history of arthritis was reported in 80 patients (28.6%) and history of trauma to the lower limbs was reported in 41 (14.6%) cases. In terms of the indexes measured in the lower limb, the mean Q angle was 13.10 ± 10.37 degrees in the range of -20.6 to 36 degrees. Accordingly, the frequency of genu varum was 8.6% and the frequency of the genu-valgum (Q angle less than 1 degree) was evaluated as 10.0%. Also, the mean distance between two malleoli was 2.84 ± 3.32cm and between the two knees was 0.03 ± 1.51cm. The mean apparent length of the lower limb was 73.13 ± 5.31cm, the mean total length of the tibia and femur was 73.33 ± 5.30cm, and the difference between the actual and apparent length was 0.26 ± 0.45cm.In terms of differences in orthopedic measurements between men and women (Table 1), there was no difference across the two genders in mean BMI, Q angle, as well as the prevalence rate of genu varum and genu valgum. There was no significant correlation between age and Q angle (r = 0.046, P = 0.432). The mean age in patients with and without genu varum was 45.38 ± 10.71 years and 40.66 ± 11.20 years, respectively, which was slightly higher in the genuvarum group (P = 0.048). Also, the mean age in patients with and without genu valgum was 41.11 ± 10. 13 years and 41.66 ± 11.39 years, respectively, which did not differ between the two groups (P = 0.984).

In terms of the relationship between the BMI of the patients and the indices related to of genu varum and genu valgum (Table 2), there was a significant, but adverse correlation between the Q angle and BMI (Figure 2). The mean BMI in patients with and without genu varum was 39.07 ± 6.41 kg/m^2 and 42.1 ± 2.26 kg/m^2, respectively, which was significantly lower in the genuvarum group (P = 0.008). Also, the mean BMI in patients with and without genu valgum was 43.39 ± 3.33 kg/m^2 and 41.58 ± 4.61 kg/m^2, respectively, which was significantly higher in the genu valgum group (P = 0.044). Also, there was a direct correlation between BMI of patients with inter-malleoli distance (r= 0.166, P = 0.055) and inverse correlation between BMI and two knees distance (r= -0.155, P = 0.009) (Figures 3 and 4). An inverse correlation was found between the BMI of the patients with the apparent and actual differences in the lower extremity (r= -0.227, P = 0.001). There was no significant correlation between the BMI of the patients with the length of the lower limb and the total length of the femur and tibia.

The frequency of history of arthritis in patients with and without genu varum was 45.8% and 27.2%, respectively, which was significantly higher in the genuvarum group (P = 0.05).Also, the history of arthritis in patients with and without genu valgum was 42.9% and 27.0%, which was slightly higher in patients

Table 1. Measured orthopedic parameters in men and women

Parameter	Men (n=57)	Women (n=223)	Test	P value
BMI	41.92 ± 5.29	41.71 ± 4.30	Independent t-test	0.456
Q angle	13.55 ± 8.95	12.98 ± 10.72	Independent t-test	0.710
genu varum	8.8%	8.5%	Chi square	0.998
genu valgum	10.5%	9.9%	Chi square	0.882
Inter-malleoli distance	1.98 ± 2.89	2.06 ± 3.39	Independent t-test	0.128
Inter-knees distance	0.79 ± 1.73	0.59 ± 1.45	Independent t-test	0.358
The apparent length of the lower limb	75.75 ± 5.81	72.45 ± 4.97	Independent t-test	0.001*
The total length of tibia and femur	76.03 ± 5.74	72.63 ± 4.95	Independent t-test	0.001*
The difference between actual and apparent lengths	0.28 ± 0.74	0.26 ± 0.45	Independent t-test	0.780

** Statistically significant difference*

Table 2. Correlation between measured orthopedic parameters and BMI

Parameter	R coefficient	P value
Q angle	-0.376	< 0.001*
Inter-malleoli distance	0.166	0.005*
Inter-knees distance	-0.155	0.009*
The difference between actual and apparent lengths	-0.227	0.001*
The actual length of lower limb	0.037	0.538
The total length of tibia and femur	0.016	0.790

** Statistically significant difference*

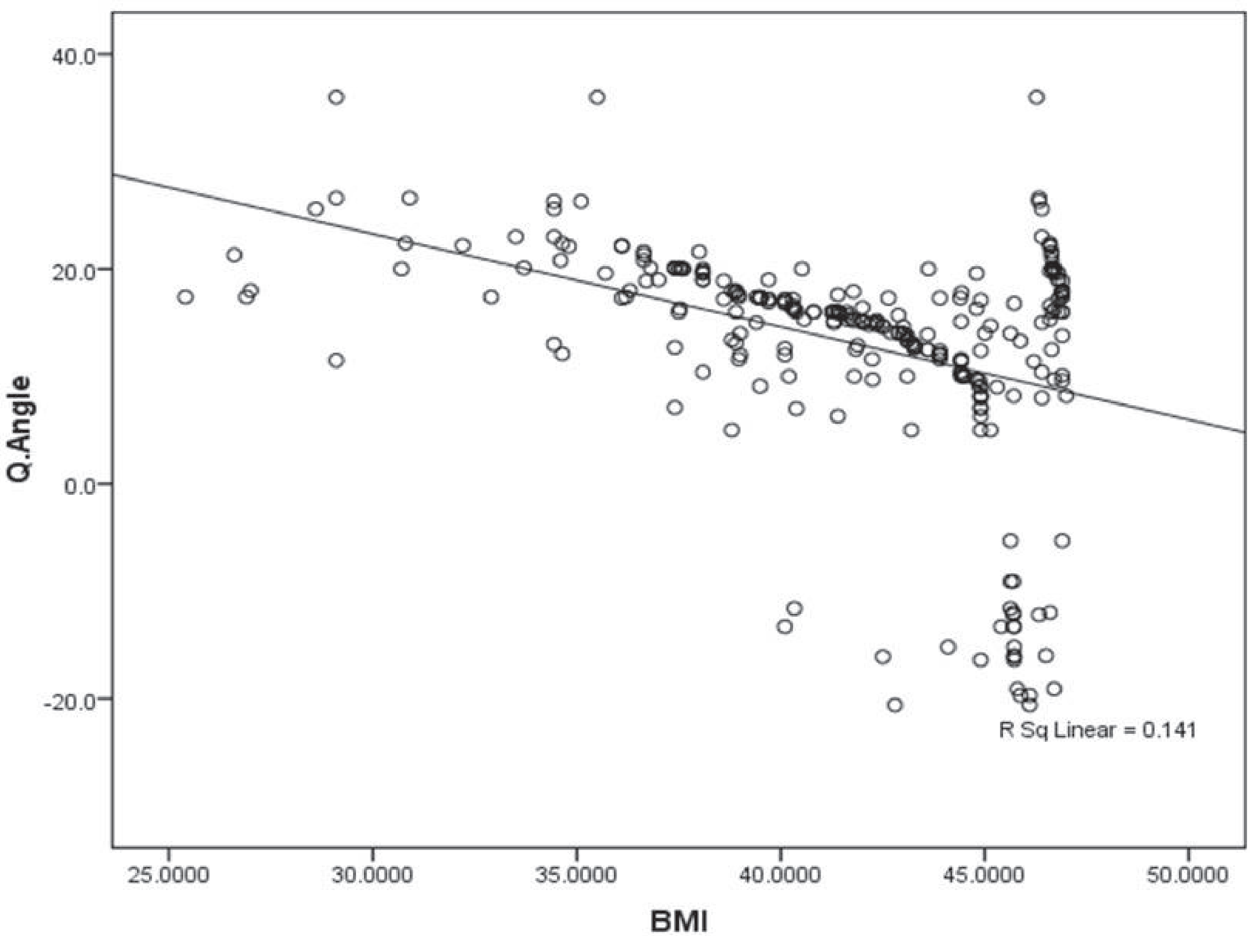

Figure 2. Correlation between BMI and Q angle

with genu valgum (P = 0.072). History of trauma in patients with and without genu varum was expressed in 16.7% and 14.5%, respectively, which did not differ between the two groups (p = 0.763). These rates on those with and without genu valgum was 17.9% and 14.3% respectively with no difference (p = 0.578).

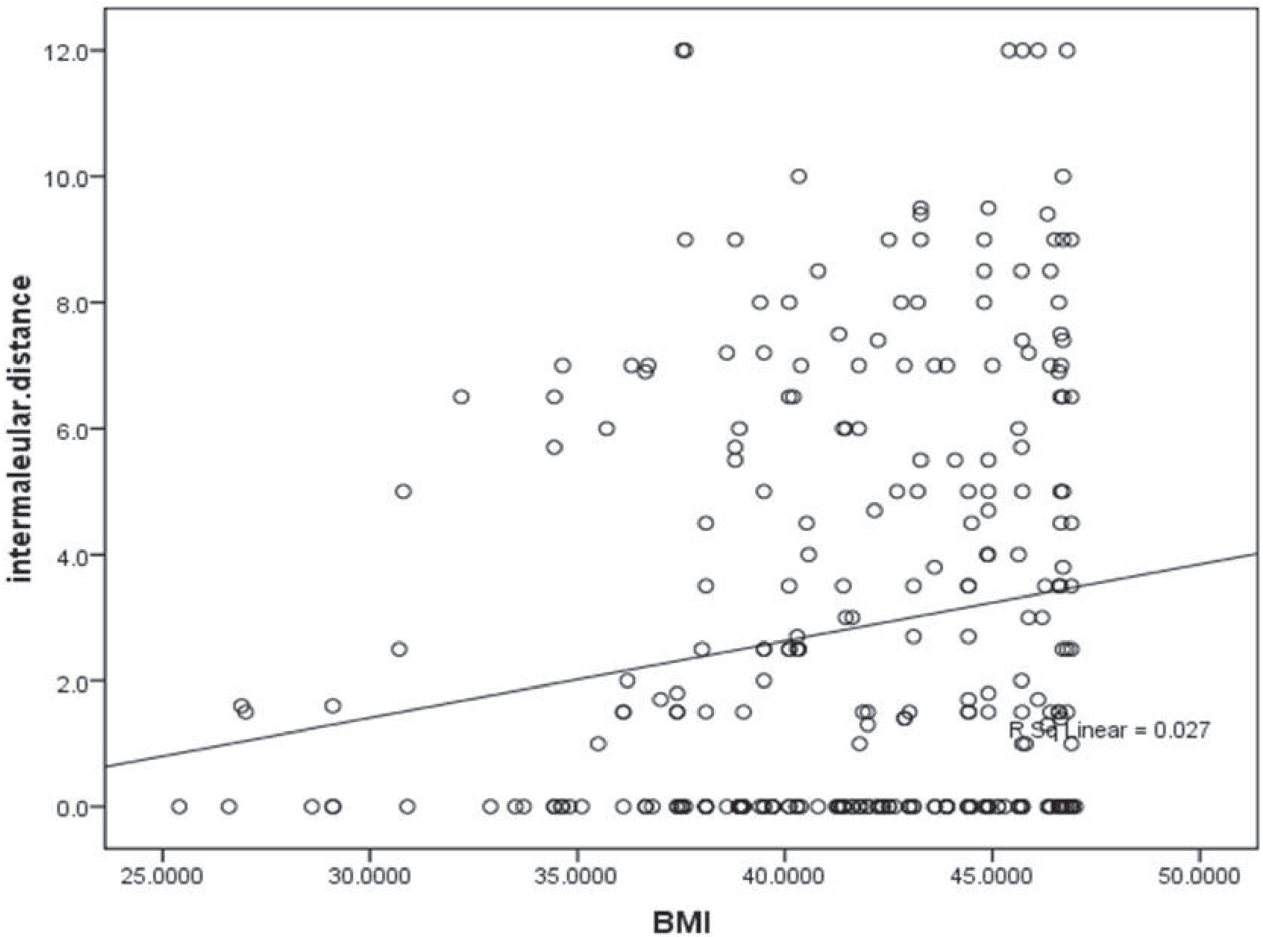

Figure 3. Correlation between BMI and Inter-malleoli distance

Discussion

What was the main purpose of this study was to assess the relationship between BMI of patients with obesity and the occurrence of genu varum and genu valgum in the form of structural and angular abnormalities on the knee. In fact, our goal was to evaluate whether increased knee deformity in patients could have a significant correlation with BMI. Considering that these changes and deformities are more pronounced in growth ages, most of the existing studies have performed on children and this issue has been less addressed among adults. Also, considering the importance of a close relationship between obesity and metabolic diseases, and in particular cardiovascular disorders, addressing this issue can even more reveal the relationship between knee deformities and other disorders and underlying diseases.

What we found clearly in this study was a significant and strong correlation between the characteristics of knee deformities, especially the presence of genu varum and genu valgum with BMI, so that we found a significant, but inverse correlation between the Q angle and BMI of the patients. In this regard, BMI was lower in genu varum group but was higher in genu valgum group. In other words, people with obesity have a higher prevalence of the genuvalgum and a lower incidence of genu varum. More interestingly, the relationship between knee deformities with BMI is completely independent of other underlying features such as gender and age of the patients. The results of our study with other studies in this regard are also

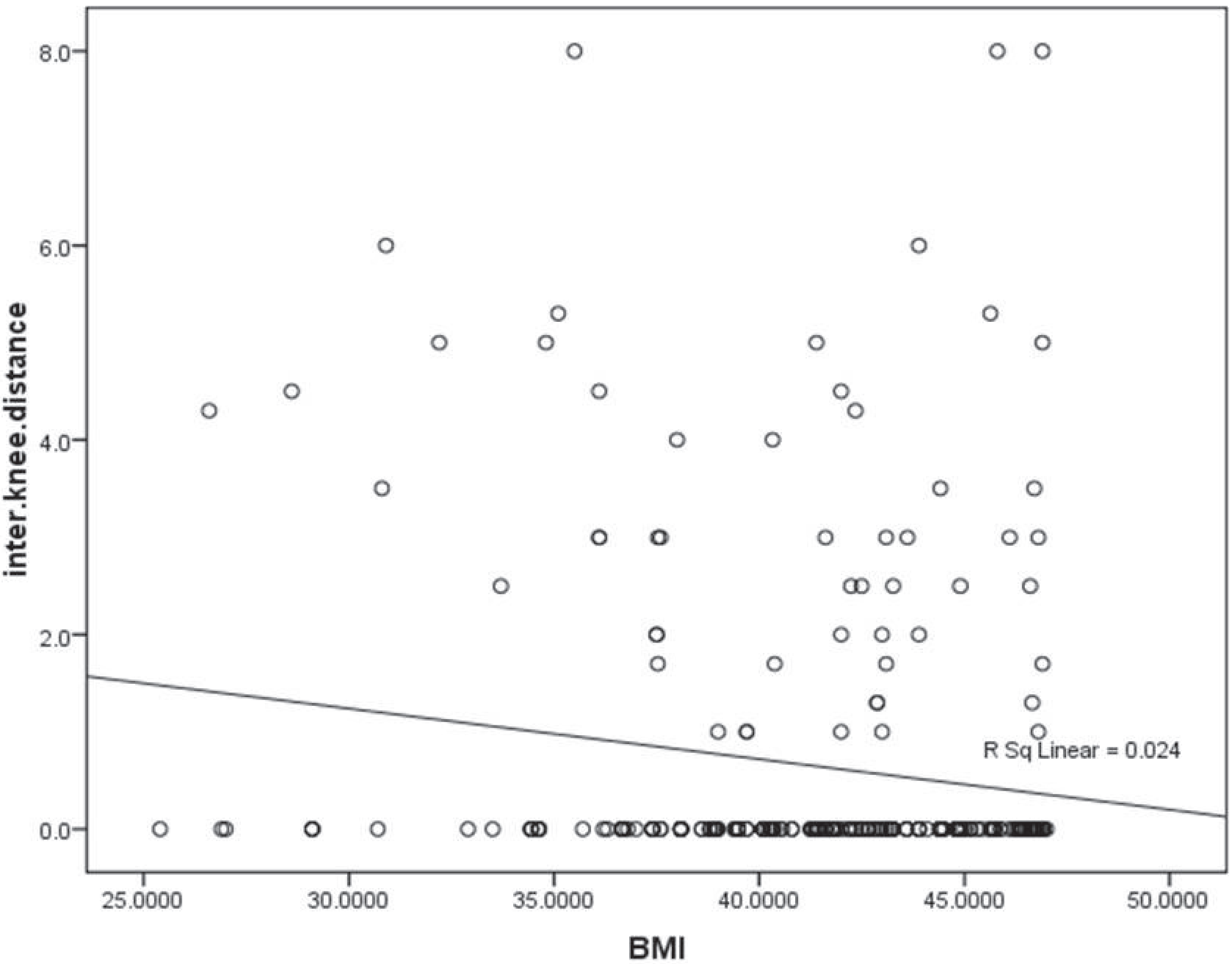

Figure 4. Correlation between BMI and Inter-knees distance

quite consistent. In the study by Ciaccia et al in 2017 (11) and Shapouri in 2019 (12), the prevalence of genu valgum was higher in obese subjects, which was quite in line with our study. But the difference in their study with our study was the difference in the prevalence of these deformities in men and women, which was similar in our study in both genders. Also, in a study by Landauer et al in 2013 (13), the high incidence of genu valgum was confirmed in obese patients. In a study by Taylor et al (14), musculoskeletal status was evaluated in obese children aged 11 to 12 years, and a higher prevalence of genu valgum in obese children was revealed. Also, Bout-Tabaku et al (15) showed that the prevalence of knee deformity was higher in obese women, although this was not confirmed in obese men. An interesting point in our study was that the relationship between knee deformity and obesity can be predicted even in adulthood and even among the elder, so this relationship is completely independent of the age and gender of the patients. Of course, it should be borne in mind that metabolic disorders, especially obesity, are strongly influenced by the growth process, the base metabolism of individuals as well as the hormonal changes of individuals. Therefore, the correlation between knee deformities and BMI in patients should be evaluated in different age groups (especially in women with or without fertility and even sexual maturity) as well as with other confounding factors such as hormonal medication, underlying disorders related to obesity. The limitation of this study is we did not take steps to make sure these patients did not have any hormonal problems or skeletal dysplasia which may cause pathological genu varum / valgum. So, this factor make it difficult to attribute the BMI directly to the development of lower limb deformity.

Conclusion

As the final conclusion, according to the results of our study, there is a strong and significant relationship between the incidence of obesity and the genuvalgum, and therefore the prevalence of this deformity in obese individuals is predictable. Also, the lower incidence of genu varum in obese people is predictable in our society. In addition, the prevalence of knee deformities in obese individuals can be quite independent of the sex and age of the patients.

Conflict of Interest

Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

Acknowledgement

The authors would like to thank the Rasoul Akram Hospital Clinical Research Development Center (RCRDC) for its technical and editorial assists.

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Received: 05 December 2019
Accepted: 19 January 2020
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