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Variation In Q-Angle And Patellar Position In Relation To Bmi: A Clinical And Geometric Analysis.

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ABSTRACT

The quadriceps angle (Q-angle) is considered clinically an important parameter which displays the biomechanical effect of the quadriceps muscle on underlying skeletal structures of pelvis, femur and tibia. The aim of this study was to evaluate a geometric method to analyze the positions of the center of patella and the tibial tuberosity and discuss possible gender and bilateral differences in normal, overweight and obese individuals. The study was conducted on 150 students 56 males and 94 females of healthy asymptomatic normal adults between 18 to 25 years of age in Anatomy Department of Sharda university, greater Noida. The subjects were divided into 3 groups (Group 1- Normal), (Group 2- Over weight) and (Group 3- Obese) based on BMI. The clinical importance of conducting this study was explained to all participants. Bilateral asymmetry and gender variation was determined using appropriate statistical method. Bilateral asymmetry in Q-angle was higher on left limb compared to right limb in both the genders in group 1 & 2 having significance in overweight males (16.1±1.23 , $p<0.05$) but in group 3 the bilateral asymmetry in Q-angle was higher on right limb compared to left limb having higher significance in females (21.1±1.81, $p<0.05$). The values of Q-angles were significantly more in females in all the three groups ($p<0.05$). A Significant medial shift of patella ($R_P>1$) was also seen with increase in BMI.
Keywords: Q- angle, Body mass index (BMI), Bilateral asymmetry, Ratio of Medial placement of patella (R_P), Anterior superior iliac spine (ASIS).

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INTRODUCTION

The quadriceps angle is an important indicator of biomechanical function in the lower extremity especially for an understanding of the normal anatomical and functional features of the patellofemoral joint [1, 2]. Q- angle is measured by crossing of two imaginary lines, the first line extends from the anterior superior iliac spine (ASIS) to the centre of the patella (CP) and the second line from the tibial tuberosity (TT) to the CP. When assessed correctly, it gives very useful information concerning the alignment of the pelvis, leg and foot [3-6]. Formation of this angle depends upon the quadriceps muscle's pull from the pelvis to the patella, and the patellar tendon's pull on the tibia [7, 8].

The average Q angle for men is 14° and for women is 17°; an excess of 15-20° in Q angle value is typically considered to contribute to knee extensor dysfunction and patellofemoral pain [9, 10]. It is often used as an anatomical risk factor for developing chondromalacia patella and patellar subluxation or dislocation [11, 12]. The Q- angle is significantly greater in females because of their gynaecoid pelvis as compared to men's smaller android pelvis [11]. The gender differences may also arise from differences in the medio lateral placement of CP and TT [13] and because of higher Q-angle in females, they would require a higher valgus orientation of the knee on weight-bearing [14] and more prone to developing patello femoral problems. This clearly states that the quadriceps muscle is one of the most important soft tissue structures that actively contributes to the normal functioning of patellofemoral joint [7, 8].

Besides gender difference the earlier studies have documented bilateral differences in the Q-angle, which can be due to a relative alteration of the three bony point's of quadriceps muscle strength. Since ASIS position is relatively fixed, it is unlikely to be a cause for bilateral variability. This variability can be attributed due to a relative alteration in the positions of the CP and the TT [15, 16] and this bilateral discrepancy has been implicated in etiology of lower extremity injuries. The improper movement of patella on the patello femoral troclear groove and effects of excessive foot pronation on the Q-angle can lead to patello femoral pain syndrome which is commonly encountered in patients who are involved in competitive or recreational sports and as well as in military population [17, 18].

From the above studies it is clear that a normal value of Q- angle depends upon the alignment of patella. The patella can also be pulled off the track because of increase in weight of the individual.

During past two decades, the prevalence of obesity has risen greatly worldwide and this has become a major health issue in both developed and developing countries. Problem of obesity right during childhood as well as in adult age group is a matter of growing concern in India also [19, 20].

Increase in body weight alters the normal integrity and anthropometry of weight bearing joints. In the present study we wanted to see the effect of BMI [21] on the alignment of bones forming the knee joint.

But till date there is dearth of literature relating the effect of BMI on alignment of patella and its affect on the Q-angle.

Therefore, the present study was undertaken to evaluate by geometric method to analyze the effect of BMI on position of patella and how this affects the quadriceps angle in young adults.

MATERIAL AND METHODS

To carry out this study, we randomly selected 150 subjects 56 males and 94 females of healthy asymptomatic normal adults between 18 to 25years of age in the Anatomy Department from School of Medical Sciences and Research, Sharda University, Greater Noida and who were not having history of spinal, neurological or lower limb injury/ surgery within the 6 months before data collection. This study was performed after approval of the ethical clearance from the Institutional Ethical Review Board (IERB) and participants were informed about the objectives of the study and were free to choose to participate or not for the same. The students who agreed to participate in the study signed an Informed Consent and underwent a general assessment which was done by the same person.

Weight of the subject was measured in light clothes and without shoes using standard apparatus. The weighing scale used would read to the nearest 0.1 kg. The height of the subject was measured without shoes to the nearest 0.5 cm, using a measuring tape. BMI of all the subjects was calculated by using the formula BMI =Weight in kgs/ Height in meter^2. (WHO and National Institute of Health) [21].

Based on the BMI individuals were divided into:

Control group

Normal weight Subjects (Group 1) BMI 19-24.9 kg/m2

Study group

Overweight Subjects (Group 2) BMI 25-29.9 kg/m2
Obese Subjects (Group 3) BMI > 30 kg/m2

All measurements were performed bilaterally on the subjects in standing position with quadriceps relaxed and all measurements were taken once by single investigator. These measurements were subsequently analyzed. To assess inter-observer variability, ten subjects were performed independently by another observer after one week. Finally, the measurements on the same subjects were repeated by the first observer to assess intra-observer variability.

Q-angle measurement

Q -angle was measured in each subject in standing position following the suggestion of Livingston; Spaulding [22], in which the feet are placed together touching medially (with feet parallel), on the floor. All measurements were taken in subjects with their shoes and socks off.

The anatomical landmarks- ASIS, the center point of the patella (CP) and tibial tubercle was palpated and then marked with a water-soluble marker. The pivot of the Universal goniometer was placed on the midpoint of patella. A string was stretched between the ASIS and midpoint of patella to ensure accurate alignment of stationary arm of goniometer. The movable arm was aligned along the line joining the tibial tubercle to midpoint of patella. The angle thus formed between the two arms of the goniometer was measured and recorded as Q- angle.

Mediolateral placement of patella[13]

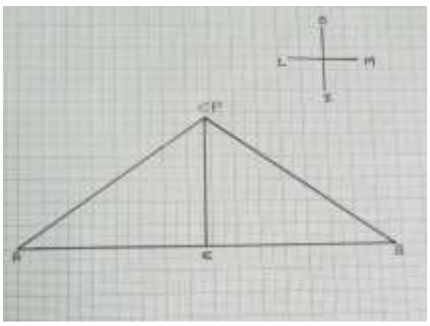
- The outline of the patella was drawn and the (center of patella) CP was marked at the point of intersection of maximum vertical and transverse diameter of patella.
- The maximum transverse diameter between tibial condyles (MC,LC) was noted as A and B
- Center of tibial tuberosity (TT) was marked. (Fig 1)

Figure 1

Trigonometric analysis

A triangle was drawn on the graph by taking the maximum transverse diameter between the tibial condyles and labelling them as AB. Lines was drawn joining the two ends of the line with center of CP. Perpendicular line was drawn from center of patella to the line AB and the point of intersection was labeled as E. Ratio Rp was calculated (AE/BE). (Fig 2)

Figure No–2 Construction of the triangle on a graph paper for calculation of ratio Rp



Statistical Analysis

The mean and standard deviation were determined for the age, BMI, Q -angle and medial placement of the patella in all the three groups. Gender difference in above mentioned parameters and also bilateral differences in Q-angle and medial placement of patella (R_P) was tabulated and was calculated by unpaired student t-test. Pearson correlation coefficients were used to examine the relationship of BMI with Q-angle and R_P .

All statistical analysis was performed using SPSS version 21.0 for windows.

RESULTS

Table 1: The descriptive statistics for age and BMI in each group .

Parameters	Group 1 (mean±SD)		Group2 (mean±SD)		Group3 (mean±SD)	
	Males n=27	females n=23	Males n=17	females n=33	Males n=12	females n=38
Age	19±1.5	18±1.24	18.2±1.32	19.1±1.25	18.5±1.8	19±2
BMI (kg/m^2)	22.5±1.52	22.04±1.93	26.3±1.23	26.5±1.28	32±1.5	31.9±1.99
p-value	0.3507		0.5984		0.8737	

There was no statistical significant gender difference was observed in the 3 groups, but overall statistically significant ($p<0.05$) increase in BMI from Group 1 to Group 3was observed using ANOVA.

Q-ANGLE MEASUREMENTS

Table 2: Comparision of bilateral Q-angle asymmetry among male and female in Group 1

Q-angle (in degrees)	Male	p- value	Female	p-value
Rightside (mean±SD)	13.03±2.39	0.4814	17.3±4.52	0.8745
Left side (mean±SD)	13.5±2.48		17.5±4.0	

The values of Q angle were more on left limb compared to the right in both the sexes but no significant bilateral asymmetry was noted ($p>0.05$).

Table 3. Comparison of Bilateral Q-angle asymmetry among male and female in Group 2

Q-angle(in degrees)	Male	p-value	Female	p-value
Right side(mean±SD)	15.58±1	0.0084(sig)	17.8±3.1	0.1895
Left side (mean±SD)	16.1±1.23		18.78±2.9	

The values of Q angle were more on left limb compared to the right in both the sexes but there is significant bilateral asymmetry in males ($p<0.05$) and not in females ($p>0.05$).

Table 4: Comparison of Bilateral Q-angle asymmetry among male and female in Group 3

Q-angle(in degrees)	Male	p- value	Female	p-value
Right side(mean±SD)	19.66±2.18	1.000	21.1±1.81	0.0008(sig)
Left side (mean±SD)	19.66±1.81		19.34±2.51	

The values of Q angle were more on right limb compared to left in both the sexes but there is significant bilateral asymmetry in females ($p<0.05$) and not in males($p>0.05$).

The comparison of the bilateral Q-angle values for symmetry for the asymptomatic subjects (group 1,2,) using independent t-test is shown in table 2 ,3. The results showed there was a significant difference in the Q-angle values obtained with the left limb having higher values compared with the right limb except in group 3 where right limb values were higher.

Table 5: To show gender difference in Q-angle values in all the three Groups

Q-angle(in degrees)	Group1 Males females (mean±SD)	Group2 Males females (mean±SD)	Group3 Males females (mean±SD)
Right side	13.03±2.39 17.3±4.52 p=.0001	15.58±1 17.8±3.1 p=.0062	19.66±2.18 21.1±1.81 p=.0266
Left side	13.5±2.48 17.5±4.0 p=0.0001	16.1±1.23 18.78±2.9 p=0.0007	19.66±1.81 19.34±2.51 P=0.6850

The values of Q-angles were significantly more in females in all the three groups ($p<0.05$). A significant gender difference was seen only in group 1 and 2.

Table 6: To show gender difference in R_P values in all three Groups

parameters	Group1 Male female	Group2 Male female	Group3 Male female
R_P-right side (mean±SD)	1.03±0.04 1.05±0.08 p=0.3028	1.21±0.32 1.30±0.29 p=0.3205	2.35 ±0.31 2.28±0.25 p=0.5599
R_P -left side (mean±SD)	1.03±0.04 1.05±0.09 p=0.5330	1.23 ±0.25 1.33±0.29 p=0.2330	2.26± 0.28 2.21±0.25 p=0.4289

The values of RP were more in females in group 1 and 2 but no significant gender difference was noted. However, in group 3 the values of RP in males were more but this was insignificant($p>0.05$)

Table 7: Pearson Correlation between BMI and Q-angle in all three Groups

Groups	right lower limb r-	 p-	left lower limb r-	 p-
Group1	0.20	0.07	.12	0.11
Group2	0.20	0.31	.3	.043 *
Group3	.4	.012	.8	.000**

* Indicates significance $p<0.05$ ** Highly significant $p=0.001$

A weekly positive correlation was seen in all the three groups, it was not significant in group 1 whereas in group 2, 3 a significant strength of association was seen in left limb.

Table 8: Pearson Correlation between BMI and R_P in all Sthree Groups

Groups	right lower limb r-	p-	left lower limb r-	p-
Group1	0.54	0.001	0.59	0.001
Group2	0.30	0.017	0.34	0.007
Group3	0.40	0.002	0.49	0.001

A significant positive correlation was seen in all the three groups.

DISCUSSION

The purpose of our study was to investigate possible alterations in the position Sof patella in a sample of young asymptomatic individuals with high Q-Angle and raised BMI.

In our study the Q-angle is measured in standing position with quadriceps relaxed. The Q-angle was measured in standing so that the normal weight bearing stresses are included.

Gender difference

The Q angle was significantly more in females in all the three groups (Table-5). As for the difference between men and women, Skalley et al [23] noted little difference between the Q angles of men and women. In studies which did find a difference, such as those of Woodlands and Francis [24], Aglietti, Insall and Cerulli [25] and Hsu et al [27] the differences ranged from 3° to 4.6°.

There are many reasons being documented for higher Q-angles in females. Pantano et al [27] has shown that sex differences in anatomical characteristics contribute to greater Q angle in females. When assessed at its widest point, the pelvis of a woman is accepted as being wider than that of a man and it is logical to assume that their anterior superior iliac spine is also more lateralized. In addition, women have been shown to exhibit a greater interacetabular distance and increased hip width when normalized to femoral length than seen in men [3]. If a woman's anterior superior iliac spine were more lateralized, the pull of the quadriceps would also be more lateral, and women would have a higher incidence of patellar instability. Most recently, an excessive Q angle has been implicated as a potential risk factor for noncontact anterior cruciate ligament injuries in female athletes [28].

When compared with men, women exhibit greater amounts of static external knee rotation alignment and active hip internal rotation [29]. Greater pelvic width and increased knee external rotation have been suggested to contribute to greater amounts of standing genu valgum alignment in women than in men.[30] The structural combination of increased hip adduction, femoral anteversion, and genu valgum may explain, in part, the well-documented larger Q angle in women than in men [31, 32].

Bilateral Q-angle asymmetry

There was no significant bilateral asymmetry seen in group 1 (Table 2) this is in consistent with the findings of previous authors [33, 34] however in group 2 (Table 3) the Q-angles in males (n=17) was significantly more on left side (16.1±1.23) than right side (15.58±1) In group 3 (Table 4) the Q-angle in females was significantly more on right side (21.1±1.81) than left (19.34±2.51).

Hahn and Foldspang were among the first investigators to see bilateral asymmetry while doing a detailed study on athletes (n=339) [35]. Following this, other studies have documented similar bilateral variations. In some of these studies it was found that the mean Q angle on the right side was greater than that on the left [35, 36]. In other studies, the mean Q angle was more on the left as compared to the right,[37] but this difference was insignificant. In only two of the studies were these differences significant [38, 22].

One of the explanations put forth for this is the bilateral difference in the quadriceps strength. It was found that the Q angle varied inversely with the peak torque angle during active knee extension [36]. However, in the studies which showed significant bilateral differences in the Q angle, the quadriceps muscle was relaxed [38, 22].

In present study the difference in right-left Q-angle in both the sexes was $\leq 1^{\circ}$. The bilateral differences more than 4° predisposes the individual to knee joint pathologies or injuries [39, 40].

Correlation between Q-angle and BMI

There is significant increase in values of Q-angle with BMI using one-way analyses of variance (ANOVAs) ($p < 0.001$) . In group 2 and 3 (Tab 6) positive correlation of Q-angle with BMI was seen ($p<0.05$). As mentioned above the alignment of lower extremity is associated with the magnitude of the Q angle. Q-angle mainly depends on three bony landmarks that is anterior superior iliac spine, center of patella and tibial tuberosity. In our study we have seen only the displacement in position of patella with BMI by calculating the ratio R_P. The values of R_P more than 1 indicates medial placement of patella and we have obtained positive correlation with BMI in all the three groups (Table 11) Increased body weight and mass modify how the limbs and whole body create and react to forces. Excess adiposity also interferes with the interaction of joints and muscles that are crucial to functional capacity and postural balance [41]. Obesity may also compromise the ability to resist muscular fatigue. Muscular fatigue impairs balance control and requires a greater level of cognitive resources for balance coordination. Park et al [42]. discovered that excessive fat mass significantly increased the rate of perceived exertion of postural stresses. Maffiuletti et al [43] determined that resistance to muscle fatigue in the quadriceps, hip abductors and external rotators is reduced in obese individuals, potentially interfering with the normal integrity of the knee joint complex.

Weakness in the above-mentioned muscles can lead to displacement of patella from its normal anatomical position.

Medial/Lateral placement of patella

In overweight and obese subject, the centre of patella was placed more medially with respect to tibial condyles ($R_P>1.15$). In Group 1 the range of ratio R_P was 0.9-1.14. The Q- angle in this group was within normal range. The value of R_P >1.15 had higher Q-angle as in overweight and obese subjects (Table-7). One-way analyses of variance (ANOVAs) showed significant effects of BMI on position of patella ($p < 0.001$) (Table-8).

Medial displacement of patella is due to increased tibiofemoral angle which represents the valgus angle formed by anatomical axis of femur and tibia [24, 44, 45]. Hip internal rotation would effectively displace the anatomical axes of the femur into adduction and the tibia into abduction move the patella medially relative to the anterior superior iliac spine and tibial tuberosity laterally (Poweres et al., 2003) [44], thereby increasing the tibiofemoral angle, thus increasing Q angle Further , abnormal gait patterns resulting from increased hip internal rotation can also indirectly lead to compensations in other parts of the lower extremity, such as a compensatory external rotation of the tibia on the femur (Magee, 1992) [46] in turn would position the tibial tuberosity more laterally, resulting in an increased Q angle.

Apart from abnormal motions in the transverse plane, excessive frontal-plane motions can influence the patellofemoral joint (Powers et al.,1995) [47]. Most notably, valgus at the knee which is a common presentation in obese may increase the Q angle, as the patella would be displaced medially with respect to the ASIS. In comparison, a varus position of the knee could decrease the Q angle, as the patella would be brought more in line with the ASIS.

Femoral anteversion on the other hand represents a medial torsion of femur, as femoral neck is projected forward relative to femoral condyles. Excessive femoral anteversion would essentially place femur into more medially rotated position, potentially resulting in a medial displacement of the patella and also associated with intoning gait which is compensated by an external rotation of tibia on femur

[48]. Earlier studies have documented that Weak hips lead to a collapse inward of the knee and thus the foot, called "induced pronation [49]. As the joints of lower extremity work in closed kinematic chain during the stance the effect of foot position plays an important role in determining the Q-angle. The excessively pronated foot causes an external tibial torsion deviating the tibial tuberosity laterally and an anteversion at femur increasing the Q- angle [49, 50]. However, the present study was limited to the effect of BMI on knee joint complex. With advanced imaging techniques like MRI which is highly specific diagnostic tool to evaluate knee joint pathology, the role of measuring Q- angle has its own importance since it is a noninvasive and simple screening method which can be performed in the outpatient department. It does have a role in the prediction of risk of knee joint injury especially in obese individuals.

In the present study both inter-observer and intra-observer variability for Q-angle and R_P was less as proper standardization of measuring method was done, before proceeding with the study.

Hence, it can be stated from our results that there is significant medial displacement of patella with raised BMI. This change in position of patella in overweight and obese subjects lead to raised Q-angle.

CONCLUSION

The quadriceps angle is an important indicator of biomechanical function and normal alignment of the lower leg, providing useful information on the functional ability of the lower extremity.

- A significant increase ($p<0.05$) was seen in the mean values of Q-angle with BMI in all the three groups.
- The values of Q-angle were higher in females than males in all the three groups.
- A significant bilateral difference in Q-angle was observed in overweight males and obese females.
- Significant medial shift of patella ($R_P>1$) was seen with increase in BMI.
- No significant bilateral and gender differences of ` R_P' was seen in all the three groups.
- A positive correlation of BMI with Q-angle and with` $R_P$' was observed, however there was weak correlation of increased values of Q-angle with` R_P' .

This finding supports our hypothesis that lower extremity alignment can be disturbed with BMI which might affect the position of the anatomical landmarks used to measure the Q angle, thus impacting its magnitude.

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