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Original Research Article

A STUDY OF VARIABILITY OF QUADRICEPS ANGLE (Q-ANGLE) IN A GROUP OF ASYMPTOMATIC YOUNG ADULTS

Tuhin Ghulyani[1], Sumit Babuta[2], Virendra Kumar[3], Meenakshi Singhal[4]

1.Assistant Professor, Department of Anatomy, Dr. Sampurnanand Medical College, Jodhpur, Rajasthan, India, 2. Associate Professor, Department of Anatomy, SMS Medical College, Jaipur, Rajasthan, India. 3.Ex-Professor and Registrar, Department of Anatomy, Saraswati Medical College, Unnao, Uttar Pradesh, India.4.Assistant Professor, Department of Anatomy, Mahatma Gandhi University of Medical Sciences & Technology, Jaipur, Rajasthan, India.

*Corresponding author – **Dr. Sumit Babuta**
Email id – Sumitbabuta@gmail.com

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ABSTRACT

Background: The knee is a complex joint posing a challenge to biomechanics and has an immense clinical applied aspect. One of the ways to study force vectors acting on the knee joint is the Quadriceps angle (Q angle). The purpose of this study was to establish the normal values and ranges of Q angle in a cohort of asymptomatic college-going adults of the Rajasthan region.**Methods:** The Q angle was analyzed in one hundred and twenty healthy adult volunteers divided into two equal groups of male students (MS) and female students (FS). The Q angle was measured using a flexible plastic goniometer with the subject in a supine position, knees extended, quadriceps relaxed and feet in a neutral position. **Results:** The mean Q angles were higher in females and it was statistically significant ($p<0.05$). The mean Q angle of both limbs in MS and FS was 12.84° and 14.48°, respectively. The means of right and left Q angle in males was 12.62° & 13.07° and in females was 14.37° & 14.58°. The majority of subjects (n=84, 70 %) showed a bilateral difference and the difference was mostly small (1°) in 50 (41.67%). The mean Q angle was higher on the left side, in both groups, but the difference was not statistically significant ($p>0.05$).**Conclusion:** The results corroborate Q angle disparity in gender and it is higher in females than males. However, the mean Q angle obtained differs from most other foreign population studies. Though the Q angle was found to vary bilaterally in most individuals, the difference was insignificant. A large-scale study of Q angle gender-related difference is recommended, between individuals of similar height & age, of both sexes. This will give more reliable results to treating surgeons.

Keywords: Quadriceps angle, Q angle, gender differences, center of patella, tibial tuberosity

INTRODUCTION

The knee joint has to bear body weight and stress during walking and physical activities. A well-functioning knee is important to perform daily activities. One of the ways to define the force vectors acting on the knee joint is the Quadriceps angle (Q-angle). It is calculated between bisection of two lines at the center of patella (CP), one line connecting the anterior superior iliac spine (ASIS) to the CP, and upwards extended part of the other line connecting the tibial tuberosity (TT) to the CP.**(1)** The anatomical and biomechanical significance of Q angle is that it depicts the influence of lateral pull of quadriceps muscles over the patella and patellofemoral joint mechanics. Conventionally Q angle is assessed with the subject in a supine position; knee at or near full extension with quadriceps relaxed; the foot is placed in a neutral position concerning supination and pronation.**(2)** However, it has also been studied in different static positions. Important features of the Q angle include

different value ranges in genders **(3);** bilateral variations within-individual **(4)**; different values in different static body positions during measurement**(5)**; and it can change with increasing age **(6,7)**. Normal values of the Q angle cited were 10 - 14° for men and 14 -17° for women.**(3,8)** Strenuous physical activity has also been shown to have significant effects on the normal values of Q angle in an individual.**(7)** Many factors influencing Q-angle include anthropometries of pelvis, body stature, femoral anteversion, external tibial torsion, placement of tibial tuberosity, and genu valgum.

Clinically Q-angle is used by physicians and physiotherapists during any identification, evaluation, and surgical treatment of knee joint function. Q-angle values greater than 15° in men and 20° in women are considered abnormal. Abnormal Q angle is thought to increase the lateral force on the patella which may increase the compression stress of the lateral patella on the lateral lip of the femoral sulcus. In some individuals, this lateral vector may become large enough to sublux or dislocate patella over the femoral sulcus during the pull of the quadriceps muscle and are considered at potential risk for developing patellar subluxation, chondromalacia patellae, patella alta, anterior cruciate ligament injury, or patellofemoral stress syndrome (PESS). Here the clinicians must note that the subluxated patella may show a smaller Q angle because the center of patella will lie more in line with the ASIS and TT.**(9)** Women are at a greater risk for knee injuries and reasons postulated are wider hips and greater dynamic Q-angle than males during physical exercise. Literature search for studies done to evaluate bilateral variability of Q-angle made us reach an inconclusive opinion, as very few obtained a statistically significant difference. Additionally, whether the magnitude of the Q-angle is greater on the right or left side remains indecisive.

This study is aimed to establish the normal Q-angle values in a cohort of college-going asymptomatic students of the Rajasthan region, its gender-related difference, and bilateral variations within subjects. The data obtained may be useful to treating surgeons and physiotherapists.

MATERIALS AND METHODS:

This study was conducted on one hundred and twenty (120) healthy adult college-going volunteers of the age range 18-30 years. The design of this study included the formation of two groups 1) male students (MS) and 2) female students (FS) with sixty individuals each. Subjects with a history of any fracture in the lower limb, knee pain, dislocation of patella, knee disorder, surgery on the knee, clinical evidence of meniscal injury, patellar tendinitis, and/or any condition which may interfere with data collection were excluded from this study.

The Q-angle was measured bilaterally, with the subject in a supine position & pelvis squared, and by using a transparent plastic universal goniometer with a 1° increment. While measuring in the supine position, the lower limbs were extended and kept together with knees touching each other, the quadriceps kept relaxed, and feet were pointing upwards in a neutral rotation. All subjects were kept barefooted during the assessment. The anatomical landmarks center of patella (CP), point of prominence of tibial tuberosity (TT), and anterior superior iliac spine (ASIS) were marked using a delible marker pen. The CP was marked at the point of intersection of maximum horizontal and vertical lengths of the patella. The pivot of the goniometer was placed over the center of patella (CP) and one arm was aligned was TT and the other arm was aligned with ASIS. The angle formed between the above two lines was defined as Q-angle. All measurements were taken by a single examiner and anatomical landmarks were determined by visual examination and palpation.

The data were analyzed using Microsoft Excel and IBM SPSS Statistics version 20 software for windows. The means with standard deviation and ranges were determined. The relationship of Q angle values, bilaterally within-group & between-groups, was analyzed using a one-way analysis of variance (ANOVA) test. A p-value of <0.05 was set as statistically significant

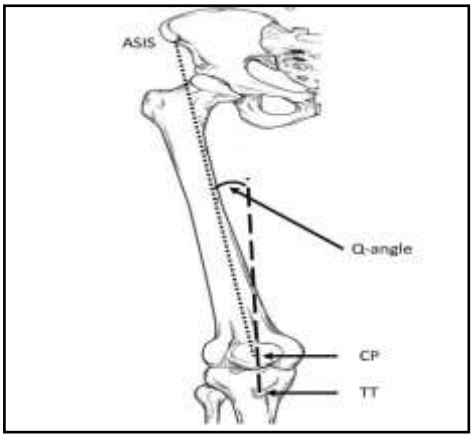

Figure 1: Quadriceps angle formed by the intersection of two lines; one line from the ASIS to the CP with the other line an upward extension from TT to CP.

RESULTS:

The Q-angle was obtained in a group of 120 adult healthy volunteers and divided equally into two groups based on gender. The mean age was 21.18±2.61 and 20.12±3.09 years in MS and FS, respectively. The average Q-angle of all the 240 limbs studied was 13.66±2.45°. The average Q angle of both the limbs was 12.84±2.62° and 14.48 ±1.98° in MS and FS, respectively. The Q angle values obtained are shown in Figures 2 & 3. The mean right Q-angle (RQA) and left Q-angle (LQA) with range is shown in table 1.

The Data analysis showed that the FS group had higher mean Q angles than MS on both sides. Also, this difference was found to be statistically significant (p value<0.05). (Table 2) While comparing the extremes of Q-angles there wasn't any noticeable difference in males (9-19°) and females (10-20°).

In the analysis, it was noted that the majority of individuals (n=84, 70 %) showed a bilateral difference in the Q angle. Among these individuals' majority (n=53, 44.17%) had a higher Q-angle on the left and the remaining (n=31, 25.84%) on the right side, respectively. Although the mean Q angle was greater on the left side in both groups, this difference was not statistically significant (p value>0.05). (Table 3) In most of the subjects, the magnitude of the bilateral difference was only 1° (n=50, 41.67%). Among the 84 subjects exhibiting bilateral difference, the majority (n=81, 96.4%) had a difference of within 3°(Table 4).

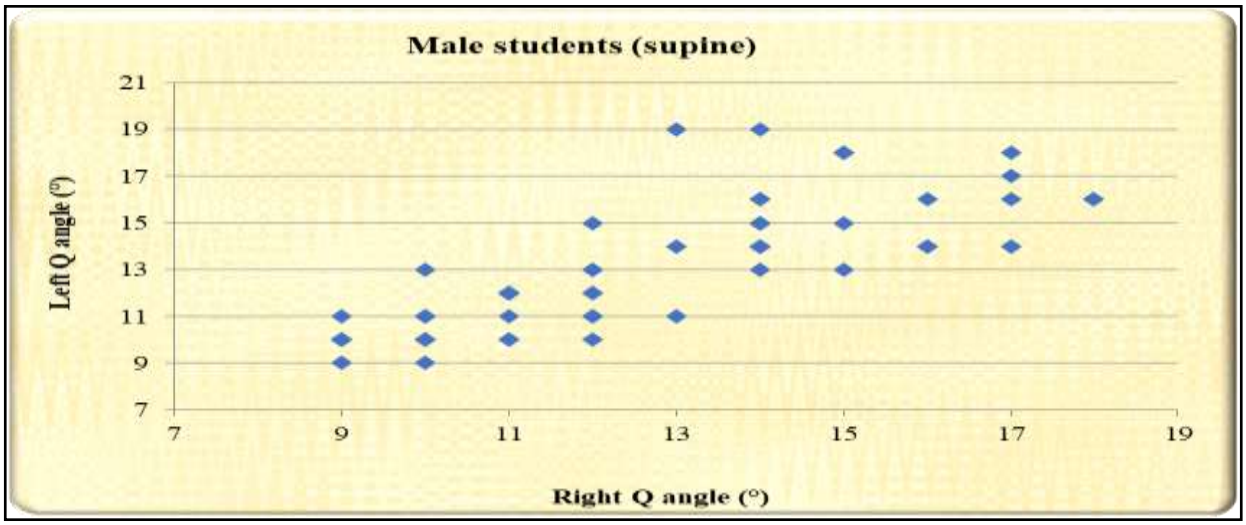

Figure 2: Scatter plot of right Q angle and left Q angle of male students

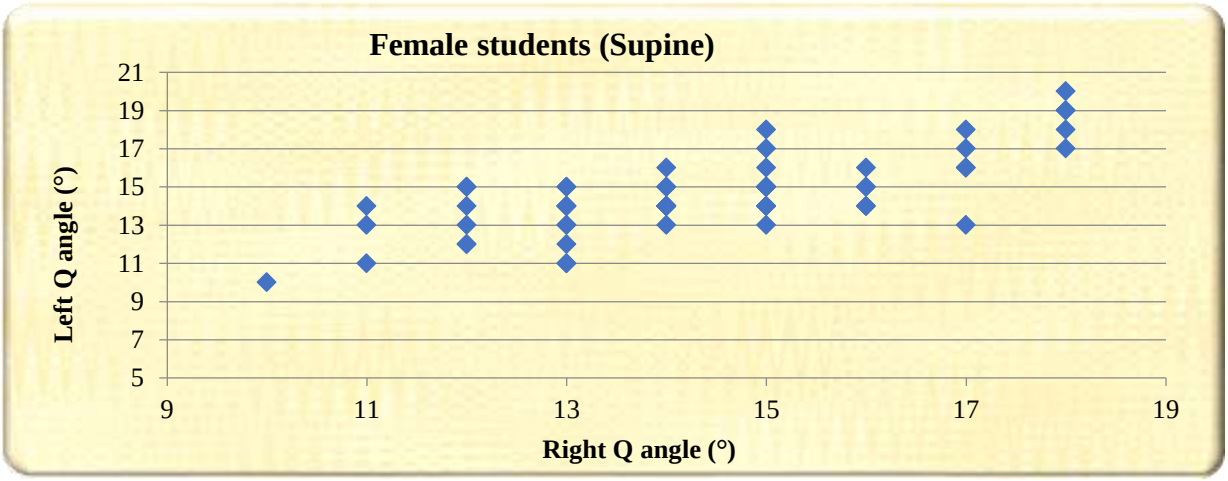

Figure 3: Scatter plot of right Q angle and left Q angle of female students

Table 1: Values of Q angle (in degrees)

Group	RQA		LQA		AQA in both limbs	
	Mean±SD	**Range**	**Mean±SD**	**Range**	**Mean±SD**	**Range**
MS	12.62±2.56°	9-18°	13.07±2.67°	9-19°	12.84±2.62	9-19°
FS	14.37±1.97°	10-18°	14.58±2.00°	10-20°	14.48±1.98	10-20°

MS-male student, FS-female student, RQA-right Q angle, LQA-left Q angle, AQA-average Q angle

Table 2: Comparison of Q-angle within different groups. (one-way ANOVA test)

S.no	Group-1	Group-2	Side	p-value	Result
1	FS	MS	Right	5.31E-05	Significant
2	FS	MS	Left	0.000609	Significant

Table 3: Comparison of right and left Q-angle within-group. (one-way ANOVA test)

S.no	Group	Side-1	Group	Side-2	p-value	Result
1	MS	Right	MS	Left	0.348139	Not significant
2	FS	Right	FS	Left	0.550902	Not significant

Table 4: Shows the bilateral differences of Q-angle (n=120)

Difference between right and left Q-angle (in degrees)	RQA=LQA		RQA>LQA		RQA<LQA	
	MS	**FS**	**MS**	**FS**	**MS**	**FS**
0°	14	22	-	-	-	-
1°	-	-	7	10	22	11
2°	-	-	7	5	3	7
3°	-	-	1	0	4	4
>3°	-	-	-	1	2	-
TOTAL	14	22	15	16	31	22

DISCUSSION:

The present study was aimed to assess the Q angle in a cohort of 120 healthy college-going students. This similar status, as students of the Rajasthan region, helped this study to decrease the effect of lifestyle, nutritional status, and racial difference among randomly chosen volunteers. The advantage of using a goniometer is that of no radiation exposure & is inexpensive in comparison to a radiological study. Additionally, goniometric evaluation has been shown to correlate well with their radiographic counterpart values.**(10)** The measurement of the Q-angle is influenced by static body position, foot position. Olerud and Berg **(11)**, in their study of two-dimensional photographic analysis of Q-angle with different positions of the foot, reported that it can vary by 5° to 15° in internal or external rotation of the foot, respectively. In another study, Guerra et al **(12)** assessed Q-angle values in a controlled foot position by keeping long axes of feet perpendicular to the coronal plane. Livingston and Spaulding **(13)** used the three-dimensional OPTOTRAK method of analyzing the Q-angle magnitude in different foot positions and observed a statistically significant change with position. Thus, they emphasized that a practitioner must recognize the influence of foot positioning during measuring the magnitude of Q-angle and ensure that standardized foot positions should be used. Here it is noteworthy to mention that the contractile state of the quadriceps femoris muscle should also be considered. Studies have shown that a difference in Q angle magnitude can be caused by isometric quadriceps contraction.**(12,14,15)** Thus, the subjects must also be informed to relax the quadriceps muscle during measurement. It is for these reasons the present study was carried out opting a standardized method, with the feet in neutral rotation and the quadriceps muscle relaxed, to increase reliability.

The range of Q angle (9-20°), observed in our study, is comparable to other studies where it has varied from 8 to 24° in different populations **(16,17,18,19).** It is worthy to mention here that while comparing the results of different populations, several factors can influence Q-angle magnitudes such as age, gender, the height of the subjects, and method of measurement. In this study, mean RQA- 12.62° & LQA-13.07° and RQA-14.37° & LQA-14.58° was obtained in males (n=60) and females (n=60), respectively. These values are higher than the results of Livingston and Mandigo **(16)** RQA-9.5° & LQA-10.4° and RQA-10.5° & LQA-12.2° in males (n=26) and females (n=24), respectively. Whereas a Jordanian study **(20)** obtained much higher values of RQA-14.6° & LQA-14.3° and RQA-18.6° & LQA-18.3° in males (n=219) and females (n=200), respectively. Literature showed varied Q angle magnitudes in Nigerian studies by B. Omololu et al **(17)** RQA-10.7° & LQA-10.5° and RQA-21° & LQA-20.9° in males (n=354) and females (n=123) in supine position, respectively; Jaiyesimi and Jegede **(22)** observed RQA-12.30° & LQA-10.38° and RQA-17.06° & LQA-14.84° in males (n = 200) and females (n=200), respectively; Ebeye et al **(28)** results were RQA-12.92° & LQA-12.27° and RQA-16.93° & LQA-16.3° males (n=90) and females (n=100), respectively; Sra et al **(11)** reported RQA-12.88° & LQA-15.70° in males (n=70). This discrepancy could be due to racial differences and also could be influenced by different static positions used in measuring the Q-angles. Our results were close to a Nepalese study by Maharjan R. et al **(21)** of RQA-13.81° & LQA-14.07° and RQA-13.80° & LQA-14.08° in males (n=614) and females (n=586), respectively. A wider range was reported by another Indian author Nandi M. et al **(22)** of RQA-11.81° & LQA-11.79° and RQA-17.44° & LQA-17.13° in males (n=43) and females (n=52) in the supine position, respectively.

In this study, the average Q angle (mean of Q angles in both limbs) AQA-14.48° obtained in females was strikingly similar to 14.48° obtained in the supine position by other Indian studies Veeramani et al (23) and Bhat M.A. et al (24). Though the reason for this similarity could be racial, a study at a larger scale will give a more reliable result. Also, the AQA in males (12.84°) in our study is slightly higher than in these studies (10.98°).

Some foreign authors reported higher average values of Q angle among females in the supine position. (Table 5) The AQA of all 240 limbs observed in this study was 13.66° and it is comparable to that of another Indian Study (13.07°) by Jha and Raza **(18)**.

In the present study higher mean Q angles were recorded in females bilaterally as compared to males and it was statistically significant. Though a noticeable difference was not observed in ranges. This gender-related difference is in concurrence with most other studies.**(8,17,23)** Various explanations have been given for a higher Q angle in females, namely their wider pelvis, which results in a more lateral proximal reference point than in men.**(7)**

Table 5: Q-angle values in the supine position in different studies.

Authors	Year	Number of subjects	Population	AQA in males	AQA in females
Woodland and francis(8)	1992	M-269, F-257	American	12.70°	15.80°
Jha and Raza(18)	2000	M-140, F-110	Indian	12.36°	13.96°
R.P. Grelsamer et al (25)	2005	M-45, F-24	American	13.30°	15.70°
Belchior et al (15)	2006	F-20	Brazilian	-	17.15°
Veeramani et al (23)	2009	M-50, F-50	Indian	10.98°	14.48°
Kakarparthi et al (26)	2015	M=100	Saudi Arabia	13 °	-
Bhat M.A. et al (24)	2020	M-100, F-100	Indian	10.98°	14.48°
Present study	2011	M-60, F-60	Indian	12.84º	14.48º

AQA- average Q-angle, M-male, F-female

This explanation was argued by Grelsamer et al **(25)** as they did not observe lateralized anterior superior iliac spine despite the wider pelvis in females and/or higher clinically incidence of patellar instability in females. Using trigonometric analysis, they observed that large changes in the position of the anterior superior iliac spine are required to have a significant effect on Q-angle. They concluded that the gender difference of Q-angle could be due to the taller stature of men than women. However, observations by some studies suggest that gender disparity in the Q angle could be due to differences in the placement of the tibial tuberosity (TT).**(18,27)** They opined that TT is more laterally placed in females than males based on their observation of a statistically significant difference between gender. This view can be supported by the finding of France and nester **(28)** that a small difference in the placement of TT can alter the magnitude of Q angle greatly. Another study by Anh-Dung Nguyen et al **(29)** suggests that a larger femoral anteversion and tibiofemoral angle in females could be the reason for gender variation of Q-angle. The limitation of our study is the small sample size. Oladapo M.O. et al **(6)** observed an increasing trend of Q angle values with increasing age group. Thus, we suggest a larger population-based study in both genders, by first adjusting the same height and age, to obtain a more accurate and reliable gender comparison of Q angle.

Table 6: Comparison of bilateral variability of Q-angle with other studies.

Author	Year	Number of subjects	Result
Hahn and Foldspang(30)	1997	339	R>L
Livingston and Mandigo(31)	1997	50	L>R
Byl T. et al(32)	2000	34	R>L
Livingston and Spaulding(13)	2002	20	R>L*
Sra A. et al(33)	2008	70	L>R*
Veeramani et al (23)	2009	100	R>L
Islam tarawneh et al (20)	2016	419	R>L
Mudasir et al (24)	2020	200	R>L
Present study	2011	120	L>R

R and L – right and left sides respectively; * significant difference observed

Hahn and Foldspang **(30)** were among the pioneers to study bilateral variability in the Q angle. In the present study, the mean Q angle was greater on the left side as compared to the right, in both males and females, but the difference was not statistically significant. A similar finding was seen in the results of Livingston and Mandigo **(16)** in their asymptomatic control group (M-26, and F-24). Another Indian study to observe bilateral variation by Veeramani R. et al **(4)**, Shiva Prakash SS et al **(34)**, and Bhat M.A. et al **(24)** also did not observe a significant bilateral difference. Other workers also reported bilateral variability, but only a few reported a statistically significant difference. (Table 6) Hence the question of whether limb dominance affects the development of muscular and skeletal components of the lower limb leading to significant bilateral variation in magnitude of Q-angle remains challenging due to the discrepancy in results observed in different studies.

CONLUSION:

The present study provides insight into normal Q-angle values of healthy adults in the Rajasthan region. Our findings corroborate that there is a gender-related difference in Q angle, and also most individuals exhibit bilateral variations. Though our study substantiates most other findings of a higher Q angle in females, we strongly suggest that a further reliable result can be achieved by first adjusting the same height and age between subjects. Bilateral variation is to be kept in mind by researchers documenting normal Q angle values for a population, clinicians treating a knee disorder, and physiotherapists evaluating sports athletes. In literature, we also observed differences in mean Q Angle among races and suggest that an abnormal Q angle magnitude is to be defined differently among races. The results of this study may be beneficial to surgeons and sports coaches to identify the individuals at risk of a knee injury.

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