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The Quadriceps angle (Q angle) in Indian men and women

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SUMMARY

The quadriceps angle (Q angle) is a clinical measure of the alignment of the quadriceps femoris musculature relative to the underlying skeletal structures of the pelvis, femur and tibia. The aims of this study were to calculate the Q angle in a young, healthy adult Indian population in order to document any significant differences in the Q angle between males and females and to analyze these differences. Two hundred limbs (100 from males and 100 from females) from healthy adult Indian volunteers were studied. The Q angle was measured using a goniometric method with the subjects supine, the quadriceps relaxed and the lower limbs in neutral rotation. Lateral placement of the tibial tuberosity with respect to the centre of the patella was measured. Inter-observer variations in the above mentioned parameters were studied in twenty limbs. The average Q angle value of all 200 limbs was 12.73° ± 2.58. The mean value in females was 14.48° ± 2.02 and 10.98° ± 1.75 in males. The lateral placement of the tibial tuberosity was 0.9 ± 0.59 cm and 1.8 ± 0.65 cm in males and females respectively. Both the Q angle and the lateral placement of the tibial tuberosity were significantly greater in females. The intra-class correlation coefficient was 0.66 for the Q angle and 0.8 for the lateral placement of the tibial tuberosity. Females had a significantly greater Q angle as compared to males as a result of a more laterally placed tibial tuberosity.

Key words: Q angle – Sex differences – Tibial tuberosity

INTRODUCTION

The knee joint is a complex synovial joint of the condylar variety that is stabilized by ligaments and muscles. It is involved in around 50% of musculoskeletal injuries (Baker and Juhn, 2000). The quadriceps angle (Q angle) is an important parameter to assess patellofemoral mechanics and is thus of great interest to clinicians. It is a clinical measure of the alignment of the quadriceps femoris musculature relative to the alignment of the underlying skeletal structures of the pelvis, femur and tibia (Livingston, 1998). It was first defined by Brattstrom (1964) as an angle formed between the ligamentum patellae and the extension of the line formed by the quadriceps femoris muscle resultant force with its apex at the patella. Later, Insall (1976) described the technique of measuring the Q angle using the anterior superior iliac spine (ASIS) as the proximal landmark. The line joining the ASIS and the centre of the patella (CP) was used to approximate the angle of the quadriceps femoris resultant force (Insall et al., 1976). Thus, the value of the Q angle is dependent on the relative positions of the ASIS, CP and the tibial tuberosity (TT), which are the three bony points used to measure it.

The Q angle has come to be accepted as an important factor in assessing knee joint func-

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tion (Emami et al., 2007). An increase in the Q angle beyond the normal range is considered indicative of extensor mechanism misalignment, and has been associated with patellofemoral pain syndrome, knee joint hypermobility, and patellar instability (Sendur et al., 2006; Smith et al., 2008; Waryasz and McDermott, 2008). Moreover, its role in assessing lower-extremity injuries in sports and military populations has been documented (Rauh et al., 2007).

There is a paucity of literature about the Q angle in Indian populations (Jha and Raza, 2000). Also, much controversy exists regarding the reason for larger Q angles in females (Grelsamer, 2005). The aims of this study were to calculate the Q-angle in a young, healthy adult Indian population in order to document any significant differences in the Q-angle between males and females, and to analyze these differences. The relative positions of the TT and CP are crucially important to determine the Q angle. The present study describes a method used to analyze the above positions and explain their influence on the Q angle.

Materials and methods

The subjects for the study were normal healthy adult volunteers and college students from India without any history of lower limb, spinal or neurological injury. The procedure was explained to the subjects who then signed an informed consent form. Ethical clearance for the study was obtained from the Institutional Ethical Review Board (IERB). A total of 200 lower limbs (100 subjects consisting of 50 males and 50 females) were studied. Males and females of 18 years of age and above were included in the study. The mean age of the subjects was 23 years (range 18-43 years). All measurements were taken by a single investigator. Twenty measurements (bilaterally in ten subjects) were performed independently by another observer after one week to assess inter-observer variability.

Measurement of the Q angle

A goniometric method as described by Jha and Raza (2000) was adopted. The measurement of the Q angle was performed with the subject supine and keeping the pelvis square. The legs were extended at the knee joint with the quadriceps muscle relaxed. The feet were placed in a position of neutral rotation, such that the toes were pointing directly upwards and the feet were perpendicular to the resting surface. The following bony landmarks were marked with a marker pen: ASIS, CP and centre of the TT. The outline of the patella was drawn with a marker pen, after palpating the borders and making sure that the skin was not stretched in doing so. The CP was defined as the point of intersection of the maximum vertical and transverse diameters of the patella. The point of maximum prominence was defined as the centre of the TT. A line was drawn from the CP towards the ASIS using the straight edge of a measuring tape. Another line joined the centre of the TT and the CP. The second line was extended upwards. The angle formed between the above two lines was defined as the Q angle and was measured with a goniometer (Fig. 1).

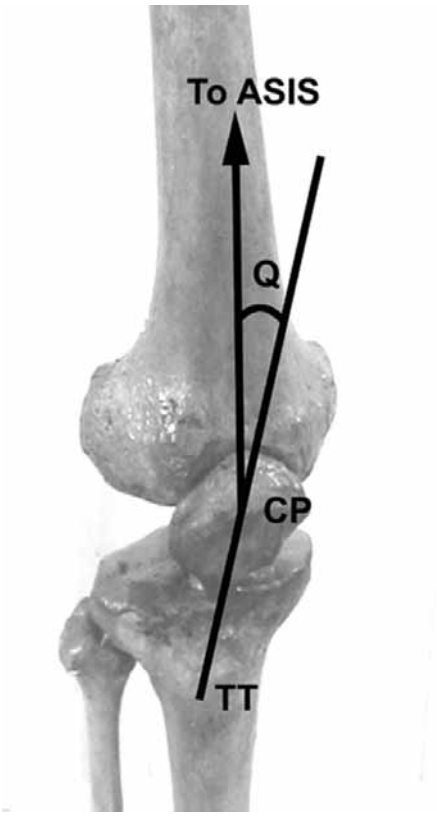

Figure 1. Measurement of the Q angle. ASIS: anterior superior iliac spine; CP: centre of patella; TT: tibial tuberosity; Q: quadriceps angle.

Measurement of relative position of CP and TT

A frontal-view digital photograph of the knee with the markings mentioned above was taken with a scale and the lateral placement of the TT was calculated as follows using Adobe Photoshop software. A vertical line was drawn inferiorly from the CP. A horizontal line was drawn from the TT to meet the above line at A (Fig. 2). The distance from TT to A (d in

Fig. 2) was measured in centimeters (to the nearest millimeter) and represented the lateral placement of the TT with respect to the CP.

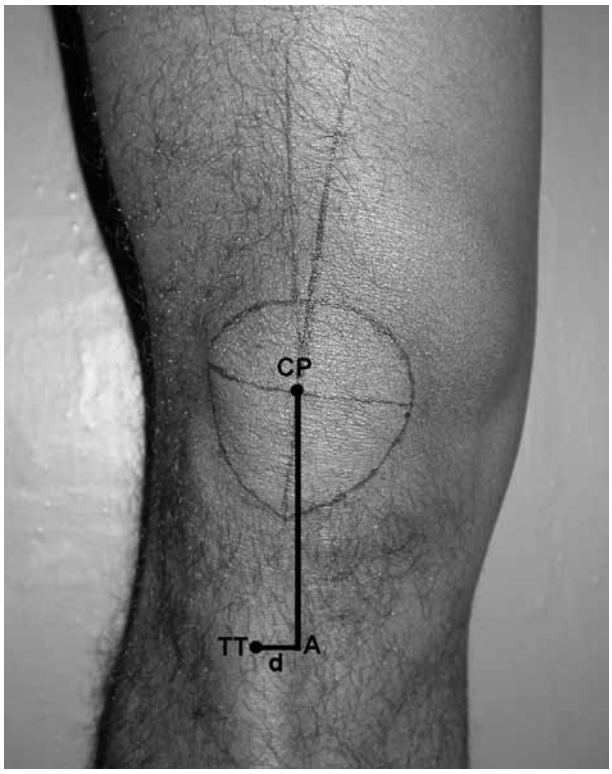

Figure 2. Determination of the relative lateral placement of the tibial tuberosity with respect to the centre of patella. CP: centre of patella; TT: tibial tuberosity; A: point of intersection of vertical line drawn from CP and horizontal line drawn from TT; d: lateral placement of TT.

Statistical Analysis

The mean and standard deviation were determined for the Q angle values and the lateral placement of the TT for males and females separately. Sex differences in the Q angle values and the lateral placement of the TT were tabulated. The unpaired t-test was performed to determine if there was any significant difference ($p<0.05$) between males and females. Spearman's rank order correlation coefficient between the Q-angle and the lateral placement of the TT was calculated. Inter-observer variability was assessed using the intra-class correlation coefficient. All statistical analysis was performed using SPSS version 10.0 for Windows.

Results

The average Q angle value of all 200 limbs was 12.73° ± 2.58. The mean values were found to be higher in females (14.48°) as compared to males (10.98°) (Table 1). The Q angle values as well as the lateral placement of the TT were compared between male and female subjects (Table 1). The higher Q angle value in females was found to be highly significant. The lateral placement of the TT was also significantly greater in females as compared to males. When the lateral placement of the TT was tabulated (Table 2), it was observed that the greatest frequency was in the range of 0.5-1 cm in males and 1.5-2 cm in females. In most of the male limbs (86%), it was seen that the lateral placement of the TT was less than 1.5 cm. In females however, 68% of the limbs showed a value of more than 1.5 cm. In three male limbs the TT was medially placed with respect to the CP. This was not seen in females. In males, lateral placement of the TT of more than 2 cm was not noted, while in females 34 limbs (34%) showed a value of more than 2 cm (Table 2). The Q angle showed a significant positive correlation ($r = 0.49$, $p < 0.001$) with the lateral placement of the TT. The inter-observer correlation coefficients for the Q angle and lateral placement of the TT were 0.66 and 0.80 respectively.

Table 1. The mean Q angle values and lateral placement of the tibial tuberosity in males and females.

Parameter	Sex	Mean ± SD (range)	Significance
Q angle	Male (n=100)	10.98° ± 1.75 (5 - 16)	$p < 0.0001^*$
	Female (n=100)	14.48° ± 2.02 (11 - 22)	
d	Male (n=100)	0.9 ± 0.59 (-2.1 - 2)	$p < 0.0001^*$
	Female (n=100)	1.8 ± 0.65 (0.3 - 3.7)	

d: lateral placement of tibial tuberosity in cm; **n**: refers to the number of limbs in which the Q angle was measured; **SD**: standard deviation; *: unpaired t-test.

Table 2. Differences in the lateral placement of the tibial tuberosity in males and females.

Parameter	Sex	Range of values of d in cm							
		<0	0 - 0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	2.5 - 3	>3
d	Male† (n=100)	3	18	40	25	14	0	0	0
	Female† (n=100)	0	2	11	19	34	21	10	3

d: lateral placement of tibial tuberosity; **n**: refers to the number of limbs; †: number of limbs in each range.

Discussion

The mean Q angle reported in the literature varies from 8° to 22.8° in different populations (Jha and Raza, 2000; Omololu et al., 2009; Woodland and Francis, 1992). This could be due to several factors such as racial variations as well as differences in age, sex, and the height of the subjects in these studies. In addition, the methods of measurement of the Q angle vary from study to study. The positions of the body and foot as well as the degree of contraction of the quadriceps muscle play a crucial role in determining the Q angle. It is thus imperative to take into account the above factors when comparing the values of the Q angle from different studies. In the present study, the subjects were placed in the supine position, with the feet in neutral rotation and the quadriceps muscle relaxed. The values of the Q angle in previous studies in which the subjects were in the supine position are shown in Table 3. In the present study the mean Q angle in the subjects was comparable to the results from a study conducted in India (Jha and Raza, 2000).

In the present study it was found that the mean Q angle was significantly greater in females as compared to males. This is in concurrence with other studies conducted so far (Jha and Raza, 2000; Omololu et al., 2009; Woodland and Francis, 1992). However, the explanation for this finding is far from clear. Any sex differences in the value of the Q angle must necessarily be due to a difference in the relative placement of one or more of the bony landmarks used to determine the Q angle. In the past, it was hypothesized that the reason for a higher Q angle in females was their wider pelvis, which resulted in a more lateral proximal reference point than in men (Grelsamer et al., 2005). Although women have a wider pelvis in a traditional sense, the ASIS in women is no more lateralized than in men. Even if women did have a wider pelvis at the level of ASIS, the effect on the Q angle would be minimal. This could be because the ASIS is so far from the patella. Trigonometric studies have shown that seemingly important mediolateral translations of the ASIS have little effect on the Q angle (Grelsamer et al., 2005). Thus it follows that sex differences in the Q angle must necessarily be due to differences in the placement of the distal two bony points (CP and TT). In this study, the relative lateral placement of the TT with respect to the CP was measured. The TT was found to be significantly more laterally placed in females as compared to males. This is in concordance with the study done in India, in which it was found that the TT is more lateralized with respect to the CP in females as compared to males (Jha and Raza, 2000). The Q angle showed a significant positive correlation with the relative lateral placement of the TT. This provides direct evidence for alteration of the relative placement of the distal two bony landmarks as a cause for gender variability in the Q angle. A more laterally placed TT in females could be due to an increase in the valgus angle or tibial torsion (Herrington and Nester, 2004).

The reliability of the Q angle measurement has been questioned by some authors (Greene et al., 2001; Smith et al., 2008). Greene et al. (2001) found a poor intra-observer and inter-

Table 3. Q angle values in the supine position in different studies.

Authors	Year	Number of normal limbs studied	Mean value of Q angle in males	Mean value of Q angle in females	Method of measurement	Details
Woodland and Francis	1992	M = 538 F = 514	12.70°	15.80°	Universal goniometer	Quadriceps relaxed, patella in sagittal plane and regardless of foot position
Jha and Raza	2000	M = 280 F = 220	12.36°	13.96°	Universal goniometer	Quadriceps relaxed and foot in neutral rotation
Grelsamer et al.	2005	M = 90 F = 48	13.30°	15.70°	Protractor	Quadriceps relaxed and foot in neutral rotation, knee flexed 10°
Belchior et al.	2006	M = 0 F = 40	-	17.15°	Radiological with pen and protractor	Quadriceps relaxed and foot placed in U podalic stabilizer
				14.50°	Radiological with pen and protractor	Quadriceps contracted and foot placed in U podalic stabilizer
Omololu et al.	2009	M = 708 F = 246	10.6°	21°	Universal goniometer	Quadriceps relaxed
Present study	2009	M = 100 F = 100	10.98°	14.48°	Universal goniometer	Quadriceps relaxed and foot in neutral rotation

M: males; F: females.

observer correlation in the measurement of the Q angle, with values 0.14-0.37 and 0.17-0.29 respectively. In addition there was a poor correlation (0.13-0.32) between clinically and radiographically derived Q angles (Greene et al., 2001). In a systematic review of the literature, Smith et al. (2008) found that there was a lack of standardization in the measurement procedure of the Q angle. This could be the reason for the poor intra and inter-observer correlation coefficients that were noted. The inter-observer correlation in the present study was higher, probably due to proper standardization of the procedure. France and Nester (2001) found that even small differences in the placement of the CP and the TT could alter the Q angle greatly. Thus, the findings in the present study need to be validated using more accurate radiological methods.

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