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Gender differences in the mediolateral placement of the patella and tibial tuberosity: a geometric analysis

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Abstract

Objectives: The relative positions of the tibial tuberosity and the center of patella are crucially important to determine the Q angle. The aim of this study was to evaluate a geometric method to analyze the positions of the center of patella and the tibial tuberosity, to document and discuss possible sexual differences.

Methods: One hundred paired limbs (50 males and 50 females) of healthy adult Indian volunteers were studied. Trigonometric analysis was used to accurately determine the relative positions of the center of patella and the tibial tuberosity with respect to the medial and lateral joint lines. Two ratios R1 and R2 determined mediolateral placement of the center of patella and tibial tuberosity. Gender differences were documented using appropriate statistics.

Results: The center of the patella was more medially placed with respect to the joint lines in females. The mean values of R1 were not significantly different in males (1.48±1.02) and females (1.51±0.62). The tibial tuberosity was usually more laterally placed with respect to the joint lines. The mean values of the tibial tuberosity were significantly greater in females (2.09±0.90) as compared to males (1.29±0.67).

Conclusion: In supine position, the tibial tuberosity was significantly placed more laterally in females possibly contributing to a greater Q angle in females.

Key words: tibial tuberosity; center of patella; sex differences; geometric analysis; Q angle

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Introduction

The quadriceps angle (Q angle) is an important parameter to assess patellofemoral mechanics and thus it is of great interest for clinicians. The angle defines the alignment of the quadriceps femoris muscle relative to the underlying skeletal structures of the pelvis, femur and tibia.[1] It is formed by the crossing of two lines. The first line extends from the anterior superior iliac spine (ASIS) to the center of the patella (CP). The second line is drawn from the tibial tuberosity (TT) to the CP. The angle formed between these two lines represents the Q angle.[2]

Many studies found the mean Q angle significantly greater in females.[3-5] However the explanation for this finding is still unclear. Any sex differences must 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 gives a more lateral proximal reference point than in men.[6,7] Even if women did have a wider pelvis at the level of ASIS, the effect is minimal because the distance between the ASIS and the patella is large. Trigonometric studies have shown that mediolateral translations of the ASIS have little effect on the Q angle.[8]

Thus gender differences may arise primarily from differences in the mediolateral placement of the CP and TT. A previous study found the TT more lateralized with respect to the CP in females.[4] In another study, the mediolateral placement of the CP with respect to the femoral epicondyles and its relationship to the Q angle was studied in 109 asymptomatic subjects. In the majority the CP was found more laterally in females.[2] The aim of this study was to evaluate a geometric method to analyze the positions of the TT and CP, to document and discuss possible sexual differences.

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 the age of 18 years and above were included in the study. The mean age of the subjects was 23 years (ranged between 18 and 43 years). All measurements were taken once by a single investigator. These measurements were subsequently analyzed. To assess inter-observer variability, twenty measurements (bilaterally in 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.

Measurements

All measurements were performed bilaterally on the subjects in supine position and keeping the pelvis square. The legs were extended at the knee joint with the quadriceps muscle relaxed. The feet were in neutral rotation, such that the second toe was pointing directly upwards and the feet were perpendicular to the resting surface. 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 center of the TT. The points on the medial and lateral joint lines (MJL and LJL) which showed maximum transverse distance were marked too.

Trigonometric analysis

Trigonometric analysis was utilized to accurately determine the relative positions of the CP and center of the TT with respect to the MJL and LJL (**Figure 1**). This was done by constructing a quadrilateral on a graph sheet as follows: The maximum transverse diameter between the LJL and MJL was drawn and labeled AB. Lines were drawn joining the two ends of this line with the CP (labeled P) and center of the TT (labeled T), thus completing the quadrilateral (**Figure 1**). Perpendiculars were drawn from P and T to meet the line AB at E and F respectively. The following ratios were calculated, AE/BE (ratio 1 – R1) and BF/AF (ratio 2 – R2).

Statistical analysis

The values of R1 and R2 were grouped into three categories separately for males and females based on whether they were less than, equal to, or more than one. The mean and standard deviation were calculated for ratios R1 and R2. The unpaired t test was performed to determine if there was any significant difference ($p<0.05$) in the ratios mentioned above. Inter-observer as well as intra-observer variability was assessed using the intraclass correlation coefficient. All statistical analysis was performed using SPSS version 10.0 for Windows.

Results

The results of the study are summarized in **Table 1**. When the R1 values were analyzed, it was noted that in both sexes, the value of R1 was greater than one in the majority of subjects. This indicated that the CP was usu-

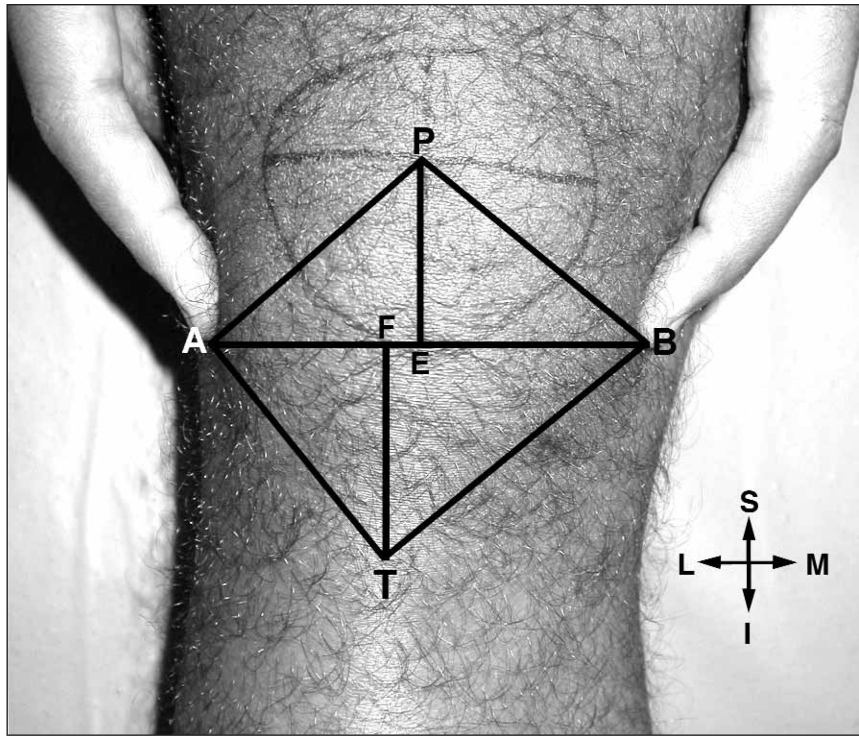

Figure 1. Construction of the quadrilateral for calculation of ratios R1 and R2 shown on a right leg. **A:** lateral point of the joint line; **B:** medial point of the joint line; **P:** center of patella; **T:** tibial tuberosity; **E** and **F:** points of intersection of perpendiculars drawn from P and T to the line AB respectively; **L:** lateral; **M:** medial; **S:** superior; **I:** inferior.

ally more medially placed with respect to the center of the maximum transverse distance between the MJL and LJL. The number of females with a value more than one was greater than that of males (**Table 1**). However, the mean values of R1 were not significantly different in males (1.48±1.02) and females (1.51±0.62). Similarly, the R2 values were greater than one in the majority of subjects, and more commonly in females (**Table 1**). This denoted that the TT was usually more laterally placed with respect to the center of the maximum transverse distance between the MJL and LJL. The mean values of the TT were significantly greater in females (2.09±0.90) as compared to males (1.29±0.67). The inter-observer correlation coefficient for R1 was 0.71 and 0.83 for R2. The intra-observer correlation coefficients for R1 and R2 were 0.81 and 0.88 respectively.

Discussion

The ASIS, CP and center of TT are taken as landmarks for the measurement of the Q angle. Any variations of the Q angle are consequently due to changes in the relative placement of the three bony points. Thus, an accurate method to determine the positions of the bony

Table 1
Differences between R1 and R2 in males and females

Ratio	Sex	Value			Mean ± SD	Significance
		<1	1	>1		
R1	Male (n=100)	31	4	65	1.48 ± 1.02	P≤0.82
	Female (n=100)	8	3	89	1.51 ± 0.62	
R2	Male (n=100)	34	3	63	1.29 ± 0.67	**P<0.0001***
	Female (n=100)	7	0	93	2.09 ± 0.90	

n: number of measurements made; **SD:** standard deviation; *****: unpaired t test.

landmarks is essential for understanding these variations. The position of the ASIS remains fairly constant. However the patella is a highly mobile sesamoid bone whose position varies considerably. The position of the TT is also variable. It was found that even small differences in the placement of the CP and the TT could alter the Q angle greatly.[2,9] There have been few studies to precisely determine the relative positions of the TT and the CP.[2,8,10]

The MJL and LJL are easily palpated in most subjects and can be used to define the positions of the CP and TT. As the PC moves medially and the TT moves laterally the values of R1 and R2 increase, respectively. An increase in R1 or R2 would result in an increase in Q-angle if the positions of the TT and the CP, respectively, and the ASIS remain unchanged (**Figure 2**). Thus, R1 and R2 are indicators of the mediolateral position of the CP and TT respectively. The advantage of using ratios is that comparisons can be made more accurately between different populations instead of absolute measurements. It must be noted that all measurements were made on the subjects in supine position, the feet in neutral rotation and the quadriceps relaxed. It is imperative that the position of the subject and the lower limb, and the degree of contraction of the quadriceps are taken into account when comparisons are made. It is recommended to measure the Q angle in the standing position, as it depicts the functional position of the lower limb.[11] The present study was done with the subjects in a supine position to enable accurate comparison with the previous similar study.[4] The degree of contraction of the quadriceps is especially important in determining the location of the CP, which in turn could influence the value of the Q angle. Contraction of the quadriceps causes a decrease in the Q angle in the supine or standing position by causing an upward and lateral movement of the patella.[11] A disadvantage of measuring the Q angle with the quadriceps contracted is that the varying strength of the quadriceps in the subjects would cause variable positioning of the CP. Thus, it would be difficult to make precise comparisons between the subjects.[12]

The line joining the two points of maximum transverse distance of the two lines is roughly midway between the two points of interest in the present study, namely the

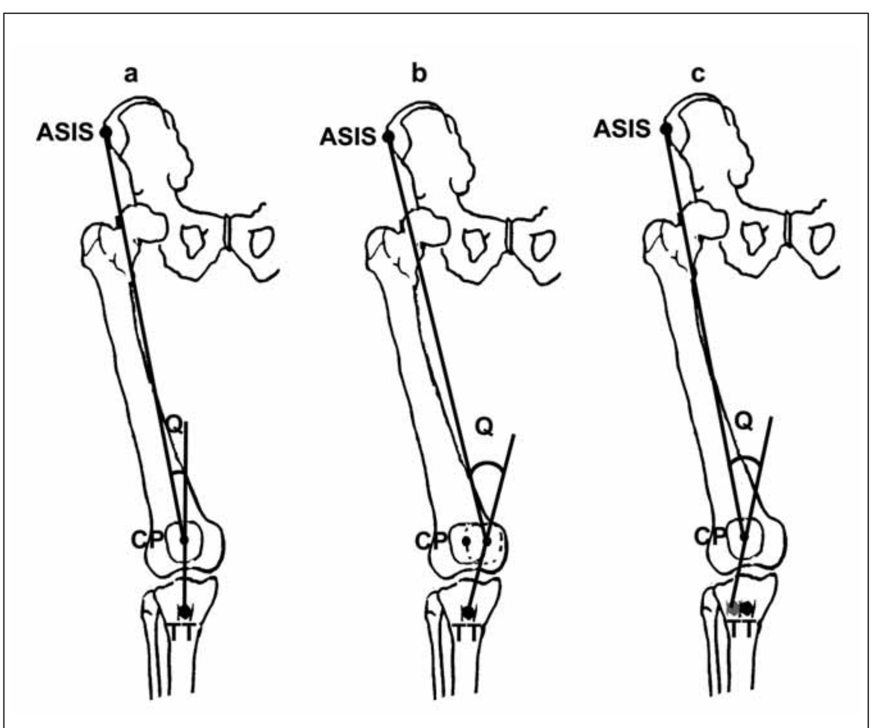

Figure 2. Variations in the Q angle produced by alterations of the relevant bony landmarks. **a:** measurement of Q angle without alteration of the bony landmarks; **b:** increase in the Q angle due to a medial shift of the patella; **c:** increase in the Q angle due to a lateral shift of the tibial tuberosity. **ASIS:** anterior superior iliac spine; **CP:** center of patella; **TT:** tibial tuberosity; **Q:** quadriceps angle.

CP and TT. This makes it convenient as a line of reference. However, more importantly, the reference line mentioned in the present study would remain more or less constant regardless of the position of the tibia or femur. This would make it suitable to define the positions of the CP and TT. A disadvantage of using the MJL and LJL is the difficulty of precisely locating these lines in obese individuals. In such individuals other radiological imaging modalities should be used to locate of the MJL and LJL.

The position of the CP was more often medially placed, which differs from another study which showed that CP was more often laterally placed.[2] This could be due to the different reference points used in the two studies to define the mediolateral placement of the patella. The previous study utilized the medial and lateral epicondyles of the femur as reference points. In addition, the measurements were taken with the subjects in the standing position.[2] A more recent study however found a correlation between the Q angle and medial, not lateral, patellar displacement.[13] Racial factors may also play a role in the variability of the location of the CP. In the present study, there was no significant gender difference in the placement of the CP. Thus, a more medially placed CP is unlikely to be a cause for the increase in the Q angle in females.

The TT on the other hand was significantly more lateralized in females in the present study. This is in concordance with the study done in India which found that the TT is more lateralized with respect to the CP in females.[4] However, in this previous study, the positioning of the TT was in relation to the CP and not with respect to independent reference points as in the present study. It has been proposed that a more laterally placed TT in females could be due to an increase in the valgus angle or tibial torsion.[2] More recent studies have shown that females have a significantly greater valgus angle, though no significant gender difference was noted in the value of tibial torsion.[14] A greater degree of lateralization of the TT has also been noted in patients with anterior knee pain as well as patella-femoral arthritis.[15-17] Other tests, such as the tibial tuberosity-trochlear groove (TT-TG) distance, are now used to evaluate anterior knee pain and patellar instability. The TT-TG distance can be precisely measured in CT scans in the pre-operative assessment of an abnormal lateral position of the TT.[18,19]

Although the Q angle has been used to evaluate and treat patello-femoral joint pathology, some authors have questioned its reliability and validity.[20-22] Though measurement of the Q angle may not be an optimal test to evaluate patella-femoral joint pathology it does have a role in the prediction of risk of knee injuries in runners.[23] The inter-tester reliability of the Q angle could be improved by proper standardization of the method, and adequate training of the testers.[24] Though controversies exist on the utility of the Q angle, the authors feel that the present study could have some value in explaining the gender differences that exist in the Q angle.

In the present study both the inter-observer as well as the intra-observer variability was greater for R1 as compared to R2. This could be due to the greater number of factors required to determine the CP, thus increasing the likelihood of errors occurring. Errors can occur in the determination of R2 as well because the center of the TT cannot be precisely identified in some subjects. In these subjects, the center of the TT is a plateau like area atop the TT. Thus, the findings in the present study need to be validated using more accurate radiological methods, by which the bony landmarks used to determine the Q angle can be more precisely identified.

Conclusion

Any sex differences of the Q angle derive from different relative placement of one or more of the bony landmarks used. In this study, ratios have been used to determine the placement of the CP and the TT. In the supine position, the TT was found to be significantly more laterally placed in females as evidenced by the higher R2 values in them. Thus, it seems that the greater Q angle in females is due to a more laterally placed TT.

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