What Determines the Magnitude of the Q Angle? A Preliminary Study of Selected Skeletal and Muscular Measures

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Context: Q-angle size has been found to correlate poorly with skeletal measures of pelvic breadth and femur length. Because the patella is exposed to the forces of quadriceps contraction, muscular forces might also affect Q-angle magnitude.
Objective: To compare bilateral measurements of the Q angle with selected skeletal and muscular strength measures.
Design: In vivo study of anthropometric and quadriceps peak torque measures.
Setting: Research laboratory.
Participants: Thirty-four healthy men and women, mean age 20.9 ± 2.7 years.
Main Outcome Measures: Q angles, pelvic breadths, femur lengths, and peak torque during dynamic knee-extension exercise, normalized to body weight.
Results: Significant differences in Q-angle magnitude, femur length, and peak $torque_{BW}$ were observed between sexes, but not between limbs. Pelvic breadth did not differ significantly between sexes. Correlational analysis revealed a weak, yet significant, linear relationship between Q angle and peak $torque_{BW}$ in the right lower limb.
Conclusions: These findings lend some support to the notion that Q-angle magnitude is inversely related to quadriceps strength.

Byl T, Cole JA, Livingston LA. What determines the magnitude of the Q angle? A preliminary study of selected skeletal and muscular measures. *J Sport Rehabil.* 2000;9:26-34.

The quadriceps (Q) angle is the angle formed by 2 lines: 1 drawn from the anterior superior iliac spine (ASIS) to the midpoint of the patella and the other from the midpoint of the patella to the tibial tubercle.[1] It is a skeletally based measure that is considered useful in evaluating patellofemoral joint function and lower extremity alignment.[2-5] When the Q angle exceeds 15–20° it is thought to contribute to knee extensor dysfunction and patellofemoral pain by increasing the tendency for lateral patellar malposition[5-9] and, hence, altered patellofemoral stress distribution.[10-13] Although inadequate descriptions of data sets, combined with incomplete statistical treatments and the failure to gather data simultaneously from comparable

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control groups, limit the generalizability of many previous studies, a recently completed investigation[7] has shed new light on the Q-angle magnitude debate. Indeed, these investigators concluded that it might be the magnitude and the extent of bilateral—that is, left versus right—imbalance in Q-angle measures that predispose an individual to anterior knee pain.

The literature clearly illustrates that women, on average, have larger Q angles than men do.[14] The underlying reasons for this gender difference in Q-angle magnitude, however, are not clear. The common assumption that larger Q angles in women are the product of their wider gynaecoid pelves in comparison with the narrower android pelves of men[3,15-18] appears to be erroneous, because absolute pelvic widths expressed as measures of biiliocristal,[19] bitrochanteric,[20] or ASIS-to-ASIS[21] breadths are consistently less on average in women than in men. The notion that shorter femurs lead to a greater valgus orientation of the knee[20] is also often cited as a predisposing factor for increased Q angles, yet empirical investigations[20,21] have failed to demonstrate significant relationships between measures of pelvic breadth or femur length and Q-angle magnitudes in men or women. Horton and Hall[20] found the mean right Q angle for women to be 4.6° greater than that for men, even though men had larger bitrochanteric breadths (32.4 ± 1.7 cm vs 29.4 ± 3.7 cm) and significantly longer femurs (44.3 ± 2.7 cm vs 39.4 ± 2.1 cm). The size of the Q angle, moreover, was found to correlate poorly with hip width ($r = -.31$, $P < .01$) and femur length ($r = -.30$, $P < .01$). Given that the ASIS is used as a landmark in defining the Q angle, it might be more appropriate to express hip width using an ASIS-to-ASIS measurement rather than bitrochanteric breadth. The evidence nonetheless suggests that the size of the Q angle must be the product of more than skeletal dimensions alone.

In 2 recent investigations, researchers[7,22] observed significant differences in Q-angle magnitude between young adult men and women. This finding was expected; their observations of significant bilateral (right vs left) imbalances in Q-angle size, however, were unanticipated. In attempting to explain their findings, the researchers hypothesized that the observed Q-angle differences by gender and between limbs were related to differences and bilateral imbalances in the size and strength of the quadriceps muscle, with large values for these variables tending to reduce the magnitude of the Q angle. Empirical investigations of this hypothesis have not been completed. Given that the patella, which provides the point at which the 2 rays for the Q-angle intersect, is a mobile structure embedded in the tendon of the quadriceps femoris musculature and that it is exposed to the physiologic forces imposed by muscular contraction,[2,5,9,11] further study seems warranted. The purpose of this preliminary study, therefore, was to examine the relationship between bilateral measurements of the Q angle and selected skeletal (pelvic breadth and femur length) and muscular strength (quadriceps peak torque) measures.

Methods

Thirty-four young adult (20.9 ± 2.7 years) men ($n = 16$) and women ($n = 18$) from the general university population volunteered to participate in this study. On entering the lab, each individual completed an informed consent form, a general information questionnaire, and an anterior knee pain screening questionnaire. The latter 2 instruments were used to ensure that participants had no history of lower limb dysfunction or injury. Exclusion criteria included a history, or visual identification, of congenital deformities, traumatic injury, or surgery to the feet or lower limbs.

All experimental procedures were approved, prior to data collection, by the Department of Kinesiology and Physical Education's research ethics committee. Q-angle, pelvic breadth, and femur length measurements were taken bilaterally with the participant in a standing position, with knees extended and the quadriceps muscle group relaxed. The feet were positioned side by side, with the medial borders of the feet touching in the so-called Romberg position.[23] A transparent plastic, full-circle goniometer, with two 0.32-m arms and 1° increments, was used to measure the Q angle, with the ASIS, midpoint of the patella, and midpoint of the tibial tubercle as landmarks.[24] Pelvic breadth—that is, bitrochanteric—and ASIS-to-ASIS and femur length measurements (posterior edge of the greater trochanter to the lateral joint space of the knee) were derived using anthropometric calipers. All measurements for a given variable were made by the same investigator. Intertester reliability and measurement error were established in a preliminary study. An $r = .80$ ($ICC_{2,1}$)[25] for goniometric measurements of the right Q angle indicated that measurement reliability was excellent[26] and measurement error (1.0°) was limited. Intertester reliability for bitrochanteric ($r = .79$, $ICC_{2,1}$) and ASIS-to-ASIS ($r = .55$, $ICC_{2,1}$) measures of pelvic breadth was good to excellent, and the reliability for these measures of femur length ($r = .50$, $ICC_{2,1}$) was fair. The measurement error of the anthropometric calipers was established at approximately 0.3 cm.

Peak torque (Nm) values were gathered using a CYBEX® II+ isokinetic dynamometer in conjunction with an MS-DOS-compatible computer. The participants were seated, with stabilization straps placed around the thigh and waist and with the hip flexed at 95°. The arms were held crossed over the midsection to isolate the quadriceps during torque production. Once the subject was properly positioned and secured and calibration was completed the subject performed 3 submaximal warm-up trials at velocities of 120, 90, and 60°/second. Three maximal-effort test contractions were then performed at a velocity of 60°/second. One-minute rest intervals were allowed between trials and between the warm-up and testing contractions. Peak torque was recorded as the largest value observed during the 3 testing trials. All measurements were completed for 1 limb prior to testing the opposite limb, with the order of limb testing randomized among subjects. Quadriceps peak torque values (Nm) were normalized to body weight (N), yielding the peak $torque_{BW}$ variable that was used for the purposes of analysis.

Two separate multivariate analysis of variance (MANOVA) procedures were used to analyze the data. The first was used to determine whether significant differences by gender or limb, or interaction effects, were observable for the Q-angle, femur length, quadriceps peak torque, or femur length variables. The second MANOVA, in contrast, was used to determine whether a main effect by gender was observable for the pelvic breadth measurements of ASIS-to-ASIS breadth or bitrochanteric breadth. Pearson product–moment correlation coefficients were also generated to examine the relationships between the dependent variables.

Results

Mean values for the Q-angle, quadriceps peak torque, femur length, and pelvic breadth measurements are listed in Table 1. The MANOVA procedure revealed significant differences in Q angle and peak torque$_{BW}$ by gender (Hotelling $T^2 = .69$, $F_{3,62} = 14.25$, $P < .001$) but not by limb (Hotelling $T^2 = .01$, $F_{3,62} = 0.08$, $P < .97$). Interaction effects were not observed. Univariate F tests confirmed that the mean right and left Q angles for women were larger and significantly different ($F_{1,64} = 9.83$, $P < .003$) from those of the men. Both men and women demonstrated slightly larger but not significantly different Q-angle values in the right versus the left lower limb. This finding is of some interest, given that for 11 of the 34 participants studied, the magnitude of the Q angle in the left and right lower limbs differed by more than 4°. Significant differences were also observed between men and women, but not between limbs, for peak torque$_{BW}$ ($F_{1,64} = 90.05$, $P < .001$) and femur length ($F_{1,64} = 8.75$, $P < .001$) measures. No significant differences (Hotelling $T^2 = .06$, $F_{2,31} = 0.91$, $P < .41$) in pelvic breadth measures were observed between men and women.

For the entire sample, there was a weak yet significant relationship between Q-angle magnitude and peak torque$_{BW}$ in the right ($r = -.41$, $P < .01$) but not the left ($r = -.31$) lower limb (Figure 1). Correlations between Q-angle magnitude and femur length and ASIS-to-ASIS or bitrochanteric breadths, in contrast, were extremely weak (Table 2) and not significant.

Comments

The descriptive Q-angle data gathered in this investigation are in agreement with the literature, and they support the common observation that women, on average, have larger Q angles than men do. The female participants had right and left Q angles 3.8° greater than those of the male participants, differences that fall within the range of 3.4–4.9° for the same value observed in prior investigations using the same methodology.[7,20,21,27] Bilateral imbalances in Q-angle measures were also observed, with Q angles in the right lower limb tending to be greater on average than those in the left lower limb. This agrees with the findings of others,[7,22] although it must be

Table 1 Observed Mean (±*SD*) Q-Angle, Peak Torque, Femur Length, and Pelvic Breadth Values by Gender and Limb*

	Female (*n* = 18)		Male (*n* = 16)		Entire Sample (*N* = 34)	
	Left	Right	Left	Right	Left	Right
Q Angle (°)	9.7 (4.5)	10.1 (6.2)	5.9 (4.1)	6.3 (4.6)	7.9 (4.7)	8.3 (5.7)
Peak torque	113.2 (25.1)	109.4 (28.9)	184.6 (34.7)	189.5 (41.8)	146.8 (46.7)	147.1 (53.6)
Peak torque$_{BW}$†	0.19 (0.04)	0.18 (0.04)	0.24 (0.04)	0.25 (0.05)	0.21 (0.05)	0.21 (0.06)
Femur length (cm)	43.2 (2.3)	42.8 (2.2)	45.0 (3.1)	45.0 (3.4)	44.1 (2.8)	43.8 (3.0)
ASIS breadth (cm)	23.3 (2.1)		23.6 (1.5)		23.5 (1.9)	
Greater trochanteric breadth (cm)	31.2 (2.0)		32.0 (1.3)		31.6 (1.7)	

*Values given are for bilateral lower limb measures only.

†Peak torque$_{BW}$ = peak torque (Nm)/body weight (N).

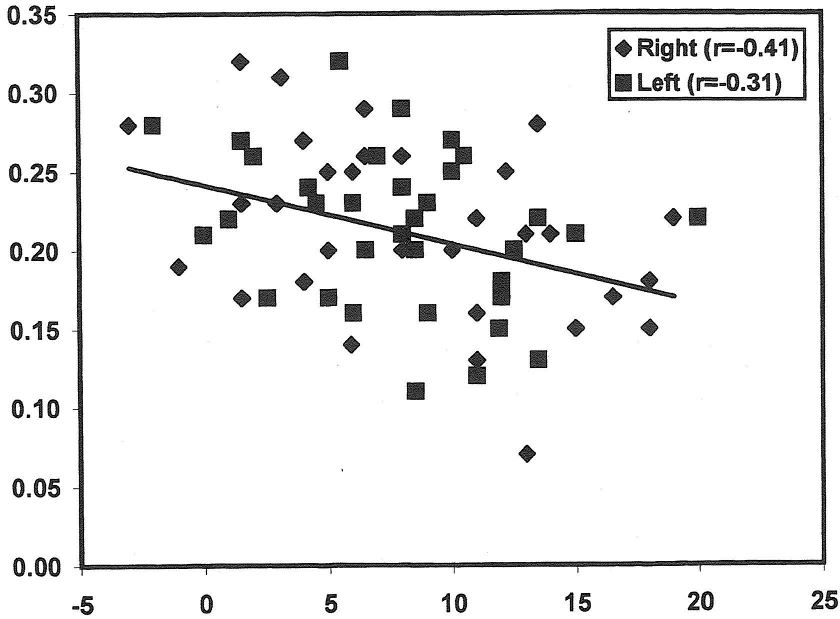

Figure 1 Scatterplot of Q-angle vs peak torque values for the right and left limbs of each participant.

Table 2 Pearson Product–Moment Correlation Coefficients (*r*) Between Right and Left Q Angles and Selected Muscular and Skeletal Variables*

	Left Q angle	Right Q angle
Peak torque$_{BW}$	–0.31†	–0.41†‡
Femur length	–0.13†	–0.18†
ASIS breadth	–0.13	–0.25
Greater trochanteric breadth	–0.23	–0.22

*For entire sample ($N = 34$).
†Left and right peak torque and femur length values are correlated with left and right Q-angle values, respectively.
‡$P < .01$.

noted that the difference between mean right and left Q-angle values in this study was small and not statistically significant. Our findings for other skeletal measures, including femur length and pelvic breadth, were also consistent with the literature,[19,20,21] with mean femur length for men being greater and significantly different from that of the women studied, and no significant differences in pelvic breadth measures observed between the genders.

Although there is much evidence to suggest that women have larger Q angles than men do, there appears to be little support for the often-cited assumption that this is because they have wider pelves and shorter femurs than men do. The data in this study, and others,[20,21] clearly do not support the notion that women have wider hips than men do. Atwater[19] has attributed the gross misconception of greater hip width in women versus men to 2 factors, including an apparent disregard of existing pelvic breadth data and a failure by many to distinguish between measures of absolute pelvic breadth and relative values of the same, expressed as a percentage of height or other breadth measurements. The shorter femur explanation is perhaps more appealing because women do indeed, on average, have shorter femurs than men do. However, correlational analyses in this study and by others[20] have been unable to demonstrate a significant relationship between hip breadth or femur length and Q-angle magnitude. It appears, then, that differences in the aforementioned skeletal dimensions alone do not account for the observed differences in Q-angle magnitude between men and women.

The results of this study support Hahn and Foldspang's[22] hypothesis that Q-angle magnitude is related to the strength of the quadriceps muscle group. Although the relationship between Q-angle magnitude and quadriceps peak torque was weak, it was directionally correct; that is, as quadriceps peak torque increased, the magnitude of the Q angle decreased. Quadriceps contraction is thought to reduce the Q angle by pulling the patella superiorly and laterally,[6,22] although empirical investigation of this phenomenon has been limited.[21,28]

In a similar vein, it is postulated that hypertrophy of the quadriceps musculature can contribute to a reduction in the corresponding Q angle. Biedert and Gruhl's[28] recent observation of lower Q-angle values in the stronger, dominant lower limb lends support to the increased quadriceps strength–lowered Q-angle hypothesis. This finding could have important implications for rehabilitation programs, in particular those aimed at treating patellofemoral pain. In a recent article, Powers[12] reported that although quadriceps strengthening produces successful clinical results in the treatment of patellofemoral pain, the mechanism by which symptoms are reduced and functional ability is improved has not been established. He hypothesized that gross quadriceps strengthening might produce subtle alterations in contact locations and pressure distributions within the patellofemoral joint. Could it be that small reductions in lower limb alignment, brought about via quadriceps training programs and hence altered patellar positions, in combination with the results of other treatment interventions, might help alleviate patellofemoral pain symptoms? This question has yet to be answered through empirical investigation. Hence, further research via a multifactorial longitudinal prospective study on the effect of quadriceps-strengthening programs on the Q angle and other measures of patellar alignment is warranted. Such a study must be multifactorial, however, because patellofemoral pain is a complex problem, one that is associated with more than excessive Q angles alone.

To the best of our knowledge, this represents the first time that the Q-angle–quadriceps strength relationship has been empirically examined and reported in the scientific literature. It must be recognized, however, that our findings have limited generalizability because of the small number of participants studied and their homogeneous nature, that is, asymptomatic. More specifically, the data gathered from these asymptomatic individuals might not accurately represent the same data collected from symptomatic patients. Studies incorporating larger samples of populations with differing characteristics—for example, asymptomatic versus symptomatic, trained versus untrained—will validate or invalidate the conclusions of this preliminary investigation. More important, however, they might allow clinicians to regain some confidence in the Q angle as a reliable clinical measure.

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