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A COMPARISON OF THE BILATERAL, DYNAMIC Q-ANGLE IN FEMALES

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The purpose of this study was to investigate the Q-angle during the stance phase of walking and jogging. Twenty-one females were recruited to participate in the study. Subjects were filmed walking and jogging on the treadmill and the bilateral, Q-angle measurements were calculated for heel-strike (HS), mid-stance (MS), and toe-off (TO) at each speed. Significant differences ($p < 0.05$) in the Q-angle were found between HS and TO and between MS and TO for both legs during walking. There were no significant differences found during jogging for the left leg; however, there were significant differences in the right leg from MS to TO. A comparison of the Q-angle values showed that HS, MS, and TO were significantly different between the right and left legs for walking, and only MS and TO were significantly different for jogging.

KEY WORDS: Q-angle, gait, measurement.

INTRODUCTION: The quadriceps angle, Q-angle, is a measurement that represents the angle between the quadriceps femoris force vector and the patellar ligament force vector. The quadriceps femoris force vector is represented by a line connecting the anterior superior iliac spine (ASIS) to the center of the patella, and the patellar ligament force vector is represented by a line connecting the tibial tuberosity to the center of the patella (Figure 1). The relative angle that is formed between these two lines defines the Q-angle. There is much debate as to what quantifies a 'normal' Q-angle and what constitutes an 'excessive' Q-angle. Collado, Besier, Beaupré, Gold, Draper, Delp, and Fredericson (2010) reported a positive correlation between greater lateral tilt and displacement of the patella with a Q-angle of 15° and greater. While there is continued debate over the cause of patellofemoral pathologies (Heiderscheit, Hamill & Caldwell, 2000; Horton & Hall, 1989; Schulthies, Francis, Fisher & van de Graaff, 1995), some clinical evidence indicates that an increased Q-angle results in greater surface contact between the lateral aspect of the patella and the lateral condyle of the femur during functional weight-bearing activities (Chen & Powers, 2010).

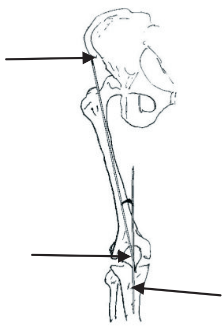

Figure 1

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A significant limitation in the Q-angle literature is the lack of standardization during the measurement procedure. The anatomical landmarks are easily identified, but the procedure for measuring the Q-angle has not been standardized. For example, should the measurement be taken with the quadriceps relaxed or contracted isometrically; should the feet be positioned shoulder width apart or positioned with the medial sides touching; and, should the subject be standing or supine? France and Nestor (2001) demonstrated that 1mm of measurement error in the location of one landmark can result in a 2.8° difference in the overall measurement of the Q-angle. Woodland & Francis (1992) measured the Q-angles in 269 males and 257 females and found that the Q-angle increased an average of 0.9° from supine to standing in the male subjects and 1.2° in the female subjects. Guerra, Arnold and Gajdosik (1994) compared supine and standing measurements taken with the quadriceps relaxed versus isometrically contracted. The male subjects demonstrated a 0.2° increase in Q-angle whereas the female subjects had a 0.7° decrease from the supine to standing positions. Furthermore, the Q-angle decreased in both standing and supine positions when the quadriceps was contracted isometrically. These slight changes in Q-angle indicate that it is not static but rather a dynamic consequence to muscle contraction, leg loading, and foot and leg position. Therefore, the purpose of this study was to compare the standing Q-angle with measurements taken during the stance phase of walking and jogging.

METHODS: A pilot study was undertaken to demonstrate the ability of the researcher to obtain a reliable, bilateral Q-angle measurement with subjects in both supine and standing positions. Five male and five female subjects volunteered to participate in the pilot study and gave written consent in compliance with the Institutional Human Subjects Guidelines. Subjects stood on a raised platform with feet together so that the medial malleoli and heads of the first metatarsals of the left and right feet were touching. Subjects were asked to maximally contract the quadriceps isometrically when the measurements were taken. A Gollenhon goniometer with retractable arms was used to take the manual measurement. One end of the retractable arm was held over the ASIS, with the axis of the goniometer placed over the mid-patella, and the end of the other retractable arm was held over the midpoint of the tibial tuberosity. The angle between the two segments was measured and recorded. An intraclass correlation coefficient (ICC) was obtained using the Q-angle values of three measurements taken on each leg for both supine and standing positions. The intraclass reliability coefficient for the left side was $r = .89$ and for the right side was $r = .86$.
Twenty-one female subjects having no history of knee injury or pathology were recruited to participate in the study. Subjects were asked to wear a bathing suit or compression shorts to assist with locating the bony landmarks for data collection. Three Q-angle measurements were taken manually on each leg with the subject standing in the position described in the pilot study. In addition, subjects held this position while being filmed for approximately 30 seconds. Following the manual measurements, 5mm reflective markers were glued bilaterally to the ASIS, mid-patella, and mid-tibial tuberosity. Subjects were given a 5 minute period to warm up while walking and jogging on the treadmill. Subjects were then asked to walk barefoot at 4.0 km/h and jog barefoot at 7.3 km/h. A digital video camera was positioned 3.1 m in front of the subject, along the sagittal axis. A 1.2 m by 2.4 m glassless mirror was positioned to the rear, right side of the treadmill at an angle less than 90° for the purpose of allowing the investigator to see when heel strike (HS), mid-stance (MS), and toe-off (TO) were achieved.
Two-dimensional video data were collected during the last minute of the walking and jogging trials with three consecutive gait cycles selected for analysis. Data were transferred from the digital video camera to the Ariel Performance Analysis System (APAS) computer, digitized, and filtered using a cubic spline digital filter. The Q-angle was calculated during the stance phase at heel strike, mid-stance, and toe-off for three consecutive footfalls for both left and right feet. Data were statistically analyzed using the SPSS statistical software package. Correlation coefficients were calculated to compare the standing, manual Q-angle measurement with the standing, digitized Q-angle measurement. An ANOVA was utilized to

compare differences in Q-angle values throughout the stance phases of walking and jogging. A significance level of $\alpha = 0.05$ was chosen a priori. A Scheffé post hoc analysis was used to identify differences at a significance level of $\alpha = 0.05$.

RESULTS: There were significant correlations between the manual and digitized standing Q-angle measurements for both left ($r = 0.92$, $p < .01$) and right legs ($r = 0.88$, $p < .01$). During the stance phase of walking, there were no significant differences in Q-angle from heel strike to mid-stance for either left of right leg. Significant differences were found between heel strike and toe-off and between mid-stance and toe-off for both legs during walking. During the stance phase of jogging, there were no significant differences in the Q-angle for the left leg; however, there were significant differences in the right leg from mid-stance to toe-off.
A comparison between left and right legs for each part of the stance phase during walking showed that there were significant differences between legs for heel strike, mid-stance, and toe-off. Likewise, the jogging condition showed a significant difference between legs for mid-stance and toe-off.

Table 1
Q-angle values

Mode	Leg	Heel-Strike		Mid-Stance		Toe-Off	
		Mean	SD	Mean	SD	Mean	SD
Standing	Left			13.5	± 5.3		
	Right			14.9	± 6.2		
Walking	Left	12.6†	± 6.3	11.7∗†	± 6.6	4.7∗†	± 9.6
	Right	16.4†	± 5.7	15.7∗†	± 5.9	10.5∗†	± 10.7
Jogging	Left	12.4	± 4.9	11.1†	± 5.5	13.7†	± 9.4
	Right	15.0	± 5.7	14.5†	± 5.6	17.9∗†	± 8.2

∗ Significant difference between the stance phases of walking and jogging.
† Significant difference between the left and right legs for the stance phases.

DISCUSSION: While there was a positive correlation between manual and digitized standing Q-angle values, there were some variations. The pilot study showed that the manual measurements taken on the left side had a higher ICC than on the right. Likewise, in the present study, the correlations between the manual and digitized standing Q-angles were greater on the left side than on the right side. Chew et al. (2010) noted that there were significant effects of measurement bias from both goniometer type, short versus long arm, and patient side. The same could be true in the pilot and present study, with the standing, manual measurements taken from the left side having less bias than those taken on the right side.
In the present study, bilateral differences were found between the left and right Q-angle values demonstrating that clinical assessment of Q-angle needs to be performed on both legs. Likewise, a dynamic Q-angle measurement should be taken since static measurements may not provide an accurate predictor of the force vectors between the quadriceps femoris and the patellar ligament during weight-bearing activities.

CONCLUSION: These preliminary findings support the use of a digital measurement system to determine a dynamic Q-angle for walking and jogging conditions. These findings also raise questions for further research regarding the dynamic function of the patellofemoral joint and the relationship between pathomechanics and various knee pathologies. Future work should examine the relationship of the dynamic Q-angle to various knee pathologies such as chrondomalacia, patellofemoral pain, and patellar tendonitis. Subjects with patellofemoral pain may provide a better picture of how the Q-angle relates to these knee pathologies.

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