THE RELATIONSHIP BETWEEN ABDOMINAL MUSCULAR STRENGTH AND QUADRICEPS ANGLE IN SUBJECTS WITH PATELLOFEMORAL PAIN

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The purpose of this study was to investigate the correlation between abdominal flexor muscle strength and Q-angle. A total of 45 subjects participated; Q-angle and abdominal flexor strength utilizing a double-leg lowering test (DLLT) were measured. The relationship between abdominal flexor strength and Q-angle was investigated using a Pearson *r* correlation test. A t-test was used to compare patellofemeral pain syndrome (PFPS) to non-PFPS groups, and to evaluate gender differences. A significant correlation was found between Q-angle and abdominal flexor strength in both genders (male r =.62, p<.001; female r =.52, p=0.019). No significant differences were found in Q-angle between PFPS and Non-PFPS groups (t =.512, p =.61). There was a significant difference in abdominal flexor strength between genders (t=-4.29, p<.0001).

KEY WORDS: patellofemoral pain syndrome, Q-angle, double leg lowering test, hip flexors.

INTRODUCTION: Patellofemoral pain syndrome (PFPS) is one of the most frequently occurring musculoskeletal problems among active adults (Taunton et al., 2002). Increased quadriceps angle (Q-angle) and subsequent abnormal lateral tracking of the patella is believed to be one of the main causes of PFPS (Schulthies, Francis, Fisher, & Van De Graaff, 1995; Emami, Ghahramani, Abdinejad, & Namazi, 2007). Knee injury may also be caused by core instability with regard to lower extremity stability and alignment (Ireland, 2002). PFPS subjects have shown weakness of hip abductor and hip external rotator muscles that are responsible for resisting hip adduction and internal rotation of the femur, and subsequent increased Q-angle (Powers, 2003).
Theoretically, excessive pelvic anterior tilt resulting from lack of abdominal stabilization also leads to internal rotation and adduction of the femur (Leetun, Ireland, Willson, Ballantyne, & Davis, 2004). Core instability, such as hip adduction, femoral internal rotation, and anterior pelvic tilt may lead to problems with lower extremity stability and alignment (Ireland, 2002). Core instability due to weakness of abdominal muscles allows the pelvis to tilt anteriorly and subsequent internal femoral rotation (Kendall, McCreary, & Provance, 1993; Tyler, Nicholas, Mullaney, & McHugh, 2006).

METHOD: A total of 45 participants (23 males; 22 females) were recruited from local intercollegiate athletic teams and fitness clubs in the Fargo, North Dakota area. Prior to the study, participants completed a general information and PFPS screening questionnaire. The questionnaire included demographics, physical activity patterns, history of lower extremity injuries, and a visual analogue scale to assess pain. Participants were assigned to one of two groups on the basis of presence or absence of PFPS symptoms, and two Q-angle measurements from each leg and two abdominal strength measurements were recorded.
Q-angle was measured in a standing position using a universal goniometer following the procedures described previously (Wilson & Kitsell, 2002). Abdominal muscle strength was measured with the double-leg lowering test (DLLT). To complete the DLLT an aneroid sphygmomanometer (Mabis DMI Healthcare, Addison, TX, USA) was placed directly beneath the umbilicus to monitor the control of posterior pelvic tilt. A flat board on which a magnetic inclinometer (Dasco Pro, Waterbury, CT, USA) attached was wrapped immediately proximal to the patella to provide a flat surface for inclinometer attachment. To begin the actual test trial, the subject's legs were passively placed into a position of 90 degrees of hip flexion or maximum flexion without tilting the pelvic anteriorly while the knees were positioned in full

extension and the pelvis was maintained in a posteriorly tilted position. The sphygmomanometer was inflated to 40mm Hg, and then the subject was instructed to lower both legs simultaneously to the table without Valsalva maneuver while maintaining knee extension and posterior pelvic tilt. The loss of posterior pelvic tilt was measured when the pressure reached 20mm Hg, the examiner read the score of the inclinometer.
Two Q-angle measurements from each leg and two abdominal strength measurements were recorded and the mean of the two trials was used for statistical analysis. All statistical analyses were performed by using SPSS (Version 14.0 for Windows, SPSS Inc., Chicago, Illinois, USA). Pearson's correlation coefficients (r) were computed to examine the relationships between abdominal flexor strength and Q-angle. Independent t-tests were used to compare Q-angle, and abdominal flexor muscle strength of both subject groups and both genders. The alpha level was set at $p<0.05$ for all analyses.

RESULTS: Descriptive statistics (age, Q-angle, and DLLT) for the entire sample is shown in Table 1.

Table 3: Descriptive statistics.

	n	Minimum	Maximum	M	SD
Age (years)	45	18	43	22.13	5.25
Q-angle (degrees)	45	3.50	26.50	16.01	5.34
DLLT score (degrees)	45	7	76	49.80	16.41

DLLT score=Score of double-leg lowering test.

Out of the 23 male subjects, only three participants were found to have PFPS. Thirteen of the 22 female subjects were found to have PFPS. No significant difference was found in standing Q-angle between the males and the females ($t=-1.63$, $p=0.11$). Therefore, male-female combined Q-angles data were used when comparing the Q-angle between PFPS and non-PFPS subjects. No significant difference was found in standing Q-angle between PFPS subjects and non-PFPS subjects ($t=0.512$, $p=0.611$).
There was a significant difference in DLLT score between genders ($t=-4.29$, $p<0.0001$). Therefore, the male subjects and the female subjects were separated when examining DLLT scores. Since there were only 3 males with PFPS, the means of DLLT between PFPS subjects and non-PFPS subjects were calculated and examined (PFPS mean=51.83 ±17.96, non-PFPS mean=39.50 ±15.42). There was some difference in means in the females in DLLT score between PFPS subjects and non-PFPS subjects ($t=1.798$, $p=0.087$), but it was not statistically significant.
Among the male subjects, there was a significant correlation between DLLT score and Q-angle ($r=0.62$, $p<0.001$). The correlation found between DLLT score and Q-angle in the female subjects was not significant ($r=0.22$, $p=0.33$). However, two female subject's DLLT scores were found to be outliers. When they were eliminated from the analysis a significant correlation between DLLT score and Q-angle was found ($r=0.519$, $p=0.019$).

DISCUSSION: PFPS is believed to be one of the most common musculoskeletal problems among active adults (Taunton, et al., 2002), and magnified Q-angle is considered as one of the causes of PFPS (Schulthies, et al., 1995; Emami, et al., 2007). Anterior pelvic tilt could limit external rotation of the femur, and subsequently increase Q-angle (Hruska, 1998).
Key findings of this study were that there was a significant difference in abdominal flexor strength between genders, and that there was a significant correlation between abdominal strength and Q-angle in both genders. However, PFPS subjects did not demonstrate any significant differences compared to non-PFPS subject in abdominal strength.
No significant differences were found in Q-angles between PFPS symptomatic knees and those without PFPS in this study. The results of previous studies regarding difference between symptomatic knees and asymptomatic knees were not consistent; some found a difference (Emami, et al., 2007), but others did not (Thomee, Renstrom, Karlsson, & Grimby, 1995; Livingston & Mandigo, 1999). The Q-angle measurement technique might have

contributed to our findings. In addition, the clinical questionnaire and special tests used to classify the subjects into PFPS and non-PFPS groups may not have been as accurate as diagnostic imaging or clinical diagnosis made by physicians, which might have misclassified the subjects.

A statistically significant difference was found in DLLT score between males and females in this study. The mean of abdominal strength in the entire sample of this study was 49.80° ±16.41° which was similar to the results observed previously (Lanning et al., 2006).

Differences between abdominal strength measured by DLLT between PFPS and non-PFPS groups were examined. Although there was a trend, no significant difference in DLLT scores between PFPS subjects and non-PFPS female subject groups was found. Therefore, this result refutes the hypothesis that there is a difference in abdominal strength between people with PFPS and those without PFPS.

In male subjects, there was a significant correlation between DLLT scores and Q-angles ($r=0.624$, $p<0.001$). When the two female outliers were eliminated, there was a significant correlation between DLLT scores and Q-angles in females ($r=0.519$, $p=0.019$). This finding shows that there is a relationship between Q-angles and abdominal flexor strength in both genders, and supports other studies (Ireland, Willson, Ballantyne, & Davis, 2003; Russell, Palmieri, Zinder, & Ingersoll, 2006). Therefore, core instability might be a factor of the lower extremity instability (Leetun, et al., 2004).

CONCLUSION: The results of this study suggests that measuring only Q-angle or abdominal flexor strength as predictors of PFPS is not enough; PFPS could be a multi-factorial problem. Leg length difference, misalignment of patella itself, muscular dysfunction around the knee joint, muscular tightness around the patella, VMO activating timing, and patellar instability might have contributed to produce PFPS signs and symptoms that was indicated by the screening questionnaire completed prior to the measurements.

However, this study showed there was a difference in abdominal flexor strength between genders, and there was a correlation between abdominal flexor strength and Q-angle regardless of PFPS. Therefore, it is speculated that anterior pelvic tilt might influence Q-angle through internal rotation and adduction of the femur. This finding could draw additional attention to the control of pelvic tilt by abdominal flexor strength when addressing Q-angle issues. The main limitation of this study was the number of male PFPS subject recruited. To better assess the relationship in Q-angle between PFPS and non-PFPS subjects, more PFPS subjects, especially male PFPS subjects, need to be recruited in future research. Although researchers have often focused on Q-angle, the results of this study showed additional attention to the structures located proximal and distal to the knee is needed when treating knee pathologies. Therefore, a training focus on abdominal strength and motor control by conducting pelvic stabilization exercises may reduce the risk of patellofemoral pain and knee injuries.

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