Greater Q angle may not be a risk factor of Patellofemoral Pain Syndrome

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Abstract

Background: A greater Q-angle has been suggested as a risk factor for Patellofemoral Pain Syndrome. Greater frontal plane knee moment and impulse have been found to play a functional role in the onset of Patellofemoral Pain Syndrome in a running population. Therefore, the purpose of this investigation was to determine the relationship between Q-angle and the magnitude of knee abduction moment and impulse during running.

Methods: Q-angle was statically measured, using a goniometer from three markers on the anterior superior iliac spine, the midpoint of the patella and the tibial tuberosity. Thirty-one recreational runners (21 males and 10 females) performed 10 trials running at 4 m/s (SD 0.2) on a 30 m-runway. Absolute and normalized knee moment and impulse were calculated and correlated with Q-angle.

Findings: Negative correlations between Q-angle and the magnitude of peak knee abduction moment (R²=0.2444, R=−0.4944, P=0.005) and impulse (R²=0.2563, R=−0.5063, P=0.004) were found. Additionally, negative correlations between Q-angle and the magnitude of weight normalized knee abduction moment (R²=0.1842, R=−0.4292, P=0.016) and impulse (R²=0.2304, R=−0.4801, P=0.006) were found.

Interpretation: The findings indicate that greater Q-angle, which is actually associated with decreased frontal plane knee abduction moment and impulse during running, may not be a risk factor of Patellofemoral Pain Syndrome.

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1. Introduction

Q-angle is defined as the angle between the line connecting the anterior superior iliac spine (ASIS) to the center of the patella, and the extension of a line from the tibial tubercle to the same reference point on the patella (Brattstroem, 1964). An angle greater than 15° for men and 20° for women is considered clinically abnormal (Horton and Hall, 1989). Q-angle has been suggested as a risk factor that could account for the development of lower extremity overuse injuries such as stress fractures (Cowan et al., 1996) or Patellofemoral Pain Syndrome (PFPS) (Messier et al., 1991; Powers, 2003).

PFPS is known as the most common lower extremity injury encountered during running (Fagan and Delahunt, 2008). In their extensive review, Taunton et al. (2002) reported that the knee joint was the most commonly injured joint with almost half of these injuries being due to PFPS. Knee anatomy and various potential risk factors associated with PFPS have been studied in order to understand a possible injury mechanism and develop more effective treatments for injury. Several studies have suggested that a large Q-angle is a significant contributor to differences found between PFPS groups and non-injured groups (Messier et al., 1991; Moss et al., 1992). It has been speculated that enlarged Q-angles increase the lateral pull of the quadriceps muscles on the patella and place medial tensile stress on the surrounding soft tissues at the knee (Neely, 1998). Such increase of the lateral pull of the patella may lead to increased pressure on the lateral facet of the patella causing pain at the anterior knee (Tumia and Maffulli, 2002). However, other case studies (Caylor et al., 1993; Duffey et al., 2000) as well as a prospective study (Witvrouw et al., 2000) have suggested that Q-angle is not related to PFPS. Therefore, whether or not Q-angle is associated with the onset of PFPS in active runners is still under discussion.

The effect of Q-angle on the incidence of PFPS in an active population has been examined in prospective studies (Lun et al., 2004; Witvrouw et al., 2000). Witvrouw et al. (2000) monitored 282 male and female students in physical education classes over a two year period. They found 24 students who developed PFPS. The findings indicated that lower leg alignment, including Q-angle, is not associated with the development of PFPS. They suggested that muscle flexibility, general joint laxity and reflex response time of vastus medialis obliquus and vastus lateralis muscles had a significant correlation with the incidence of PFPS. Lun et al. (2004) measured static lower limb alignment in 87 recreational runners before their training period and observed their injury history over six months of their usual training program. They found no strong evidence that lower extremity alignment is associated with running injuries, including PFPS. On the other hand, a retrospective analysis observed
a total of 2002 patients with running related injuries (Taunton et al., 2002). The data showed that the most dominant overuse injury was PFPS, seen in 331 cases, followed by iliotibial band friction syndrome (168) and plantar fasciitis (158). Varus knee alignment was seen in 32% of PFPS patients while a high Q-angle was seen in only 6% of PFPS patients in their database. A prospective study by Cowan et al. (1996) monitored incidences of overuse injury in 294 male infantry trainees over twelve weeks' training and correlated these with the trainees' anatomic characteristics. They suggested that high Q-angles, more than 15°, increase the risk of overuse injury; however, they did not specify the types of overuse injuries in their study. Therefore, there is no strong support that greater Q-angle is associated with high increases of PFPS in recent prospective and retrospective studies.

Knee abduction impulse is quantified by integrating the resultant moment–time curve and represents the cumulative twisting load during the entire stance phase of running. Previous studies have suggested that joint moment, as measured by an inverse dynamics approach, is an indirect measure of joint loading (Andriacchi, 1994; Hurwitz et al., 1998; Schipplein and Andriacchi, 1991; Stefanyshyn et al., 2006). It has been suggested that knee abduction impulse is a good indicator of cumulative torque or twisting loads on the knee in the frontal plane (Stefanyshyn et al., 2006). Frontal plane knee abduction moment and impulse may be related to the development of PFPS since the disorder occurs on the lateral aspect of the patella (Cutbill et al., 1992). Stefanyshyn et al. (2006) have shown in both retrospective and prospective studies that PFPS patients exhibit greater knee abduction impulses than comparable healthy runners. Since Q-angle affects knee alignment in the frontal plane, the moment arm distance between knee joint center and the external ground reaction force during the stance phase may change, and the frontal plane knee abduction moment or impulse could also change. However, it is questionable whether Q-angle affects frontal plane knee moment and impulse in a manner that may be related to the onset of PFPS in an active sports population. Furthermore, whether Q-angle is associated with the dynamic internal loading of the knee is unknown since lower limb alignment is measured in a static situation (Harrington, 1983). We hypothesized that Q-angle would not be correlated with frontal plane knee moment or impulse during the stance phase of running. The purpose of this investigation was to determine the relationship between Q-angle and the magnitude of knee abduction moment and impulse in healthy subjects.

2. Methods

Thirty-one recreational runners (21 males and 10 females; mean age: 26.5 years (SD 5.2); mean mass: 73.4 kg (SD 10.3); mean height: 176.0 cm (SD 5.2)) with no history of lower extremity symptoms or injuries were recruited for this experiment. The subjects completed a written consent form approved by the institutional ethics review committee.

The Q-angle of the right leg was determined statically by using a goniometer with markers attached on the ASIS, patella center and tibial tuberosity. Each subject was asked to stand with their feet three inches apart and aligned against a wooden block (Cowan et al., 1996). Q-angle was measured as the angle between a line from the tibial tuberosity through the midpoint of the patella and a line from the ASIS through the midpoint of the patella.

Three-dimensional kinematics of the right leg were quantified for each subject while running. Nine reflective markers (3 per segment) were attached to the following anatomical positions: proximal medial upper leg, medial lateral upper leg, distal medial upper leg, proximal lateral lower leg, mid-tibial crest, distal lateral lower leg, posterior shoe heel, distal shoe heel, and the lateral side of the shoe below the lateral malleolus (Fig. 1). The three-dimensional spatial positions of the markers were collected using a system of six high-speed video cameras (Motion Analysis Corp., Santa Rosa, CA, USA) at sampling rate of 240 Hz.

Ground reaction force data were sampled at 2400 Hz using a force platform (Kistler AG, Winterthur, Switzerland) simultaneously with the kinematics of the subjects. Subjects performed eight to ten successful running trials with wearing the same neutral running shoes (size US 9–10) and their running speed was controlled at 4 m/s (SD 0.2) using photocells (Banner Engineering Corp., Minneapolis, MN, USA).

A one second standing trial was collected at a neutral position using the video system for the one second sample. Each subject was asked to stand still in a position with feet pointing anteriorly and approximately hip width apart. The knee-joint center was identified by two reflective markers, one from the lateral femoral epicondyle and the knee and a second at the center of the patella. The ankle-joint center was determined by the mid-point of two markers on the lateral and medial malleolus (Park et al., 2009). After joint centers had been defined, they were assumed to be the same during biomechanical data collection.

The kinematic and kinetic data were filtered using a second-order low-pass Butterworth filter with a cutoff frequency of 12 Hz and 50 Hz, respectively (MacLean et al., 2006). Subsequently, both the kinematic and kinetic data were imported into a Kintrak program (Motion Analysis Corp., Santa Rosa, CA, USA) for further analysis. Three-dimensional joint angular motions were determined using a joint coordinate system (Cole et al., 1993). Knee joint kinetics were calculated for the stance phase of running using the Newton–Euler inverse dynamics approach. Internal knee abduction moments were calculated and represent the torque or twisting loads on the knee in the frontal plane. Internal abduction impulse was quantified by integrating the moment–time curve and thus represents the cumulative twisting load during the entire stance phase (Stefanyshyn et al., 2006). Means were calculated from eight to ten successful trials for each subject. Pearson’s Correlation Coefficients were used to determine relationships between Q-angle and frontal plane knee moment and impulse; the peak knee abduction moment (Nm) and impulse (Nms) and normalized peak knee abduction moment (Nm/kg) and impulse (Nms/kg) using Matlab, 6.5.1 (Math Works Inc., Natick, MA, USA).

2.1. Repeatability of Q-angle measurement

The repeatability of the Q-angle measurement was determined by an intraclass correlation coefficient (ICC) with Cronbach’s alpha model to evaluate the extent of agreement between the two measurements. Eighteen subjects (8 males and 10 females; mean age: 25.3 years (SD 3.42); mean mass: 71.0 kg (SD 10.7)); mean height: 175.3 cm (SD 6.2)) participated in the two measurements (first measurement: 13.9° (SD 4.3); second measurement: 13.8° (SD 4.0)). The intratester reliability for the measurement showed good repeatability.
of the measurement ($R = 0.97, P = 0.001$). Thus, the tester in this study showed a high reliability of the Q-angle measurement.

3. Results

The thirty-one subjects were found to have an average Q-angle of 12.9° (SD 4.3), ranging from 5° to 20° (males: 11.2° (SD 4.1), females: 16.4° (SD 2.3)). There were negative correlations between Q-angle and the magnitude of peak knee abduction moment ($R^2 = 0.2444, R = -0.4944, P = 0.005$) and impulse ($R^2 = 0.2563, R = -0.5063, P = 0.004$). Furthermore, negative correlations between Q-angle and the magnitude of weight normalized knee abduction moment ($R^2 = 0.1842, R = -0.4292, P = 0.016$) and impulse ($R^2 = 0.2304, R = -0.4801, P = 0.006$) were found (Fig. 2).

4. Discussion

The purpose of this study was to determine the relationship between Q-angle and knee abduction moments and impulses during the stance phase of running. We found negative correlations between Q-angle and knee joint moment and impulse, indicating that greater Q-angle is actually associated with smaller frontal knee joint moment or impulse during running.

It has been suggested that greater Q-angles tend to create a greater lateral pull on the patella when compared to smaller Q-angles (Powers, 2003). Several studies speculate that an increase in Q-angle may contribute to excessive lower limb motions (Heiderscheit et al., 1999). A large Q-angle may lead to excessive pronation and increased tibial internal rotation, changing the patella tracking, thus causing PFPS. However, previous investigators have produced little evidence to suggest that Q-angles have an influence on movement changes.

Moreover, it has been reported that a greater Q-angle has a minimal effect on altering lower limb kinematics (Stergiou et al., 1996). A recent study reported that the Q-angle magnitude does not increase the peak segment or joint angles in the sagittal and transverse planes during running but no data were available for changes in the frontal plane (Heiderscheit et al., 2000).

Increased resultant moment using an inverse dynamic approach has been indicated as a risk factor of joint diseases (Hurwitz et al., 1998; Schipplein and Andriacchi, 1991). Studies have found that a higher force in the medial compartment of the knee is associated with degenerative changes of the joint such as medial knee osteoarthritis and PFPS (Andriacchi, 1993; Hurwitz et al., 1998; Stefanyshyn et al., 2006). Particularly, frontal plane internal knee abduction moments or impulses, have been identified as potentially playing a role in the development of PFPS in runners (Stefanyshyn et al., 2006). Increased muscle forces, higher passive structure loads, or a combination of the two surrounding the knee creates high knee abduction moments and impulses in the frontal plane. Thus, there is speculation that the increase of these frontal plane moment and impulse coincide with an increase in loads and stresses on the lateral facet of the patella. In turn, this may result in an activation of pain fibers in the bone and development of PFPS (Stefanyshyn et al., 2006).

If Q-angle influences joint alignment in the frontal plane during running, it may create different frontal plane knee moment. However, no studies have investigated the relationship between Q-angle and joint kinetics at the knee during the stance phase of running. The current findings indicate that negative correlations exist between Q-angle and frontal plane moment and impulse at the knee.

Reduction of knee joint moment has been proposed as an effective intervention for degenerative overuse joint injuries (Briem and Snyder-Mackler, 2009; Fisher et al., 2007; Mundermann et al., 2008).
movement. Fig. 3 shows that greater $Q$-angle may lead to relatively decreased knee abduction moment as a moment arm between the knee joint center and the resultant ground reaction force decreases. Therefore, a greater $Q$-angle may not be related to the increased knee abduction moment in the frontal plane during running.

A previous six month prospective study investigated whether kinematic and kinetic variables during running are related to the onset of PFPS (Stefanyshyn et al., 2006). Researchers found that runners with PFPS show significantly greater knee abduction moment and impulse compared to uninjured healthy runners over a six month period. Their findings indicated that approximately 120–140 Nm of knee abduction moment or 15–20 Nms of knee abduction impulse during running at 4.0 m/s may induce PFPS over time.

Our results showed that a $Q$-angle greater than 15° is not associated with greater knee kinetics in the frontal plane, actually showing relatively low knee abduction moment and impulse (knee abduction moment: 34–133 Nm, knee abduction impulse: 2.2–15.2 Nms) in the relationship between $Q$-angle and knee frontal kinetics during running. We observed that a few subjects who have a $Q$-angle lower than 15° showed higher than the proposed threshold of knee moment. This suggests that these subjects would be more at risk for a higher level of injury in terms of their joint kinetics during running. However, in the current study, it is unknown what kinematic variables during dynamic situation are associated with high moment at the knee. Further study is warranted to investigate what characteristics of running style or kinematic variables would contribute to higher knee joint moment and impulse in the frontal plane during running.

4.1. Limitations of the study

There are some potential limitations we should address in this investigation. Of the thirty-one subjects, two of the male subjects displayed relatively high variability in joint kinetics. As we recruited young runners at a recreational level, some individuals may not have been as consistent in their running performance as the others. We also introduce a non-homogenous population to the study as we recruited both males and females for testing. It is known that there are differences in running mechanics between males and females (Ferber et al., 2003). However, we were not focused on gender-specific joint injuries but intended to investigate the relationship between $Q$-angle and joint kinetics in a healthy population including males and females with a relatively wide range of $Q$-angles. Furthermore, it is unknown whether the magnitude of $Q$-angle is associated with the level of knee kinetics during a dynamic situation since it is a static alignment measured in bilateral standing (Harrington, 1983).

5. Conclusions

Our findings indicate that $Q$-angle is related to the magnitude of knee joint kinetics in the frontal plane during running, showing negative correlations between $Q$-angles and knee frontal plane moment and impulse. This suggests that a greater $Q$-angle may not be a risk factor for PFPS which may result from increased knee moment and impulse during running. Further studies would be necessary to investigate the relationship between running kinematics and loading mechanics in order to understand the injury mechanism of PFPS.

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