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LOWER EXTREMITY MALALIGNMENT AND LINEAR RELATION WITH Q ANGLE IN FEMALE ATHLETES

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ABSTRACT
DANESHMANDI, H.; SAKI, F.; SHAHHEIDARI, S. Lower extremity malalignment and linear relation with Q angle in female athletes. Brazilian Journal of Biomotricity, v. 5, n. 1, p. 45-52, 2011. Lower extremity alignment has been proposed as a risk factor for acute and chronic lower extremity injuries. The aim of this study was to determine the extent to which select lower extremity alignment characteristics are related to the Q angle. One hundred and thirty female athletes were examined for navicular drop, Q angle, genu recurvatum, femoral anteversion, T-F angle, tibiofemoral angle, dorsiflexion, hip internal and external rotation and general joint laxity. The results showed greater tibiofemoral angle, femoral anteversion and hip internal rotation were significant predictors of greater Q angle (p< 0.05). Greater femoral anteversion, hip internal rotation and tibiofemoral angle results in greater Q angle, with changes in tibiofemoral angle having a substantially greater impact on the magnitude of the Q angle compared with femoral anteversion and hip internal rotation. Thus identifying the postural factors that influence Q angle, excessive stress and potential injury is of considerable importance. Clinically this has implications for both preseason screening and clinical treatment of subjects or patients.

Key words: Posture, knee injuries, risk factors, athletes.
INTRODUCTION

Lower extremity alignment has been proposed as a risk factor for acute and chronic lower extremity injuries, including patelafemoral syndrome (POWERS et al., 1995) anterior cruciate ligament injuries (DANESHMANDI et al., 2009; GRIFFIN, 2006; LOUDON et al., 1996; MYER et al., 2008) medial tibial stress syndrome, stress fractures, and plantar fasciitis (HINTERMANN et al., 1998). It has been suggested that biomechanical changes resulting from abnormal alignment may influence joint loads, mechanical efficiency of muscles, and proprioceptive orientation and feedback from the hip and knee, resulting in altered neuromuscular function and control of the lower extremities (DANESHMANDI et al., 2009; SHULTZ, et al., 2009). Accounting for the alignment of the entire lower extremity, rather than a single segment, may more accurately describe the relationship between anatomic alignment and the risk of lower extremity injury, because one alignment characteristic may interact with or cause compensations at other bony segments (HRUSKA et al., 1998; NGUYEN et al., 2009). Alignment of the hip, knee and ankle is thought to play a key role in the load distribution at the knee (GRIFFIN, 2006) and, thus, the tension placed on the capsuloligamentous structures.

The potential interactions among lower extremity alignment variables have been previously described as either “correlated” or “compensatory” postures by Riegger-Krugh and Keysor (RIEGGER-KRUGH et al., 1996) These postures were suggested to result from several factors, such as deviations in skeletal alignment (eg, when the position of one segment depends on the position of an adjacent segment) and changes toward efficient dynamic function (eg, when positioning of the limb is altered to improve neuromechanical efficiency). Among these lower extremity alignment variables, the Q angle has been frequently studied, which is defined as the angle formed by a line from the anterior superior iliac spine to the patella center and a line from the patella center to the tibial tuberosity (LIVINGSTON et al., 1997). As Q angle represent the direction of the quadriceps muscle force vector in the frontal plane, excessive angulation is thought to predispose individuals to injuries caused by abnormal quadriceps forces acting at the knee and patelafemoral joints. Although the Q angle has been suggested as risk factors for injuries (PEFANIS et al., 2009; POWERS et al., 1995) retrospective risk factors studies (DANESHMANDI et al., 2009; LOUDON et al., 1996) have failed to confirm this relationship. The reason for these inconsistent finding may be in part due to the multiple anatomical factors that may influence the magnitude of the Q angle, which may differentially impact how the Q angle relates to dynamic knee function.

It has been suggested that Q angle is a composite measure of pelvic position, hip rotation, tibial torsion, patella position and foot position (JONSON et al., 1997; POWERS et al. 2003). Although a change in any one of these alignment characteristics could theoretically change to position of 1 or more landmarks used measure the Q angle and thus its magnitude, research has yet to examine the collective anatomical contributions to Q angle in athletes.

Determining the anatomical factors that have the potential to impact the magnitude of the Q angle may allow clinicians and researcher to better determine it role in dynamic motion and risk of knee injury. Thus the purpose of this study was to determine the extent to which lower extremity of hip, knee and foot related to Q angle.

MATERIAL AND METHODS

A total of one hundred and thirty female athletes (age 21.8 ± 2.6 years, height 163.5 ± 7.4 cm, weight 63.4 ±9.5 kg and athletic experience 4.7± 3.3 years) volunteered to participate...
in this study. Participants were predominantly college-aged students and had no current injury to the lower extremity or previous history that would affect the alignment of the lower extremity joint (ie, fracture or surgery). After informed consent was obtained the subject’s age, height, activity history and injury history were recorded. The 10 measures of lower extremity alignment (navicular drop, Q angle, genu recurvatum, femoral anteversion, T-F angle, tibiofemoral angle, dorsiflexion, hip internal and external rotation and general joint laxity) were collected by the same examiner who participated each measurement technique during pilot testing until test-retest reliability analysis revealed interclass correlation coefficients greater than 0.85 were obtained for each measure. Three trials of each measure were taken on both the right and left limbs and the mean measure on each side was used for analysis.

**Measurements**

Navicular drop, which is measure of subtalar pronation, was measured using the methods by Brody (1982). This test involves marking the midpoint of navicular tuberosity of the foot with the athlete in a seated position with their knees and hips at 90 degree angles. Subtalar joint neutral is found and maintained and the calliper is used to record the sitting navicular position. The subject then stands up and the calliper is used to take the standing navicular position. Navicular drop is calculated as the difference between the sitting and standing positions. Standing Q angle was measured with the subject in a standing, relaxed position with a standard goniometer (SHULTZ et al., 2008) Q angle represented the angle formed by a line from the anterior superior iliac spine to the patella center and a line from the patella center to the tibial tuberosity. Genu recurvatum represented the sagital plan alignment of the femur (from the central point of the greater trochanter to the central point of the lateral epicondyle) and the shank (from the most lateral point of the proximal joint line of the knee through the lateral malleolus) (MCKEON et al., 2009) measured in non-weight bearing, supine position with a bolster under the distal tibia.

For femoral anteversion the subject was placed in a prone position with the knee flexed to 90 degree. While maintaining the knee in flexion, the examiner used her other hand to palpate the greater trochanter at the point, where it was halfway between its most lateral and medial. A goniometer was used to measure the angle between the vertical axis from the table and the line drawn from the tibial tuberosity to the bisection of the medial and lateral malleolus (GULAN et al., 2004).

For T-F angle the patient lies prone with the knee flexed to 90 degree. The examiner views from above the angle formed by foot and thigh. After the subtalar joint has been placed in the neutral position, noting the angle the foot makes with the tibia (TRIMBLE et al., 2002). The tibiofemoral angle was defined as the angle formed in the frontal plane by the anatomical axes of the femur and tibia. With the goniometer axis over the knee center (midpoint between the medial and lateral joint line in the frontal plane), the stationary arm was aligned along a line from the knee center to a proximal landmark (midpoint between the anterior superior iliac spine and the most prominent aspect of the greater trochanter), and the movable arm was aligned along a line from the knee center to a distal landmark (midpoint between the medial and lateral malleolus) (SHULTZ et al., 2008).

The amount of dorsiflexion Rom measurement was also obtained using a goniometer (JONSON et al., 1997). The subject was positioned in prone with her knees extended and the ankles hanging over the edge of the table and was placed at 90 degree. The subject was then asked to actively dorsiflex the ankle and the angle of maximal dorsiflexion was recorded.

Hip internal and external rotation active ROMs were measured with subjects lying prone
(HERTEL et al., 2004). The subject’s knee was flexed to 90 degree and the moving arm of goniometer was aligned with tibia. The subject then actively internally rotated their hip to its end point and a measure was made in degree. Hip external rotation was then similarly measured.

For general joint laxity, the Beighton laxity scale was utilized (MYER et al., 2008). Visual observations were used to assess laxity in different joints throughout the body. Subjects were given a score of 0 (laxity not present) or 1 (laxity present) for the following parameters: opposition of thumb to palmer forearm, hyperextension of 5th metacarpophalageal joint beyond 90 degree, hyperextension of 5th metacarpophalageal joint beyond 10 degree and both palms flat on floor with trunk flexion while maintaining knee extension. The first four criteria were graded separately on the right and left limbs. A total score ranging from 0 to 9 was recorded for each subject.

Multiple linear regression, will all variables entered simultaneously into the model, was used to examine the extent to which the lower extremity alignment variables predicted Q angle.

RESULTS

Mean, standard deviations for each alignment characteristic are presented in table I. Multiple linear regression summary results are presented in table II. once all alignment variables accounted for, greater tibiofemoral angle, anteversion and hip internal rotation were statistically significant predictors of greater Q angle. Considering only these significant predictors, the largest predicted change in Q angle (in term of magnitude of change) was due to tibiofemoral angle, with a predicted 0.41-degree change in Q angle for a 1-degree change in tibiofemoral angle. 1-degree change in femoral anteversion and hip internal rotation predicted a 0.22-degree and 0.05-degree change in Q angle respectively.

Table I - Mean and SD for lower extremity alignment characteristics

<table>
<thead>
<tr>
<th>Alignment characteristic</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q angle</td>
<td>15.45±5.13</td>
</tr>
<tr>
<td>Ante version</td>
<td>15.7±7.01</td>
</tr>
<tr>
<td>Hip internal rotation</td>
<td>38.37±5.61</td>
</tr>
<tr>
<td>Hip external rotation</td>
<td>37.67±5.66</td>
</tr>
<tr>
<td>T-F angle</td>
<td>16.16±5.58</td>
</tr>
<tr>
<td>Navicular drop</td>
<td>7.44±2.16</td>
</tr>
<tr>
<td>Knee recurvatum,</td>
<td>4.27±3.14</td>
</tr>
<tr>
<td>Tibiofemoral angle</td>
<td>10.38±3.43</td>
</tr>
<tr>
<td>General joint laxity</td>
<td>2.04±1.74</td>
</tr>
<tr>
<td>Dorsiflexion</td>
<td>14.16±2.13</td>
</tr>
</tbody>
</table>
DISCUSSION

The primary finding of this study was that alignment of lower extremity is associated with the magnitude of the Q angle. Specifically, tibiofemoral angle, femoral anteversion and hip internal rotation had the strongest association with greater Q angle. These findings support our hypothesis that lower extremity alignment characteristics may change the position of the anatomical landmarks used to measure the Q angle, thus impacting its magnitude. The quadriceps angle is an important indicator of biomechanical function and normal alignment of the lower leg, providing useful information on the functional ability of the lower extremity.

The finding showed tibiofemoral angle was associated with Q angle. Increased tibiofemoral angle, which represents the valgus angle formed by the anatomical axes of the femur and tibia, would move the patella medially relative to the anterior superior iliac spine and tibial tuberosity laterally (POWERS et al., 2003) thus increasing Q angle. Apart from abnormal motions in the transverse plane, excessive frontal-plane motions can influence the patellofemoral joint (POWERS et al., 1995). Most notably, valgus at the knee may increase the Q angle, as the patella would be displaced medially with respect to the ASIS. In comparison, a varus position of the knee could decrease the Q angle, as the patella would be brought more in line with the ASIS.

The Q angle can be influenced proximally through rotation of the femur. As described above, increased femoral internal rotation may result in a larger Q angle, as the patella would be moved medially with respect to the ASIS (femoral rotation relative to the pelvis) and/or the tibial tuberosity (femoral rotation relative to the tibia) Consequently, femoral external rotation could decrease the Q angle, as the resultant line of action of the extensor mechanism would be more in line with the ASIS and the tibial tuberosity (POWERS et al., 2003). Femoral anteversion on the other hand represents a medial torsion of the femur as

### Table II - Regression summary results when predicting Q angle based on other alignment characteristics

<table>
<thead>
<tr>
<th>Alignment characteristic</th>
<th>B</th>
<th>SE</th>
<th>t Value</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>6.544</td>
<td>3.274</td>
<td>1.999</td>
<td>0.049</td>
</tr>
<tr>
<td>Ante version</td>
<td>0.225</td>
<td>0.068</td>
<td>3.312</td>
<td>0.001*</td>
</tr>
<tr>
<td>Knee recurvatum</td>
<td>-0.050</td>
<td>0.060</td>
<td>-0.835</td>
<td>0.406</td>
</tr>
<tr>
<td>Hip external rotation</td>
<td>0.001</td>
<td>0.043</td>
<td>0.031</td>
<td>0.975</td>
</tr>
<tr>
<td>T-F angle</td>
<td>0.084</td>
<td>0.058</td>
<td>1.449</td>
<td>0.151</td>
</tr>
<tr>
<td>Navicular drop</td>
<td>-0.201</td>
<td>0.171</td>
<td>-1.177</td>
<td>0.242</td>
</tr>
<tr>
<td>Hip internal rotation</td>
<td>-0.050</td>
<td>0.104</td>
<td>2.264</td>
<td>0.026*</td>
</tr>
<tr>
<td>Tibiofemoral angle</td>
<td>0.411</td>
<td>0.081</td>
<td>5.058</td>
<td>0.000*</td>
</tr>
<tr>
<td>General joint laxity</td>
<td>-0.138</td>
<td>0.132</td>
<td>-1.050</td>
<td>0.296</td>
</tr>
<tr>
<td>Dorsiflexion</td>
<td>-0.187</td>
<td>0.117</td>
<td>-1.695</td>
<td>0.114</td>
</tr>
</tbody>
</table>

(*) Significant at p< 0.05
the femoral neck is projected forward relative to femoral condyles (GULAN et al., 2000). Excessive femoral anteversion would essentially place the femur into a more medially rotated position, potentially resulting in a medial displacement of the patella.

The results also showed Hip internal rotation was associated with Q angle. Hip internal rotation would effectively displace the anatomical axes of the femur into adduction and the tibia into abduction, thereby increasing the tibiofemoral angle. Further, abnormal gait patterns resulting from increased hip internal rotation can also indirectly lead to compensations in other parts of the lower extremity, such as a compensatory external rotation of the tibia on the femur (MAGEE, 1992) in turn would position the tibial tuberosity more laterally, resulting in an increased Q angle. Pantano et al (PANTANO et al., 1995) has shown that sex differences in anatomical characteristics contribute to greater Q angle in females. They report that subjects with a high Q angle had a greater pelvic width to femur length ratio compared with subjects with a low Q angle. Structural abnormalities at the hip may predispose an individual to knee valgus. An example is coxa vara, which is defined as a femoral neck-shaft angle less than 125°. In addition, a wider-than-normal pelvis has the potential to increase valgus at the knee, as the angulation of the femur in the frontal plane would have to be greater to maintain a normal stance width (MAGEE., 1992). Furthermore, a wider pelvis also would move the center of mass of the body more medial to the hip joint center, thereby increasing the adduction moment created by gravity during stance. In the presence of hip abductor weakness, such an increase and/or poor neuromuscular control can be addressed.

We did not found significant relationship between tibial torsion, navicular drop and recurvatum with Q angle. We hypothesized that greater tibial torsion and pronation (as measured by navicular drop) would also predict Q angle magnitude. This was based on previous studies that reported an excessive pronation is associated with internal tibial rotation, knee recurvatum and increased knee valgus and therefore suggested to result in greater Q angle. As previous studies examining Q angle as a risk factor for knee injuries have reported inconsistent finding (DANESHMANDI et al., 2009; GRIFFIN, 2006; HERTEL et al., 2004; SHAMBAUGH et al., 1991) identifying the anatomical factors that may influence the anatomical landmarks from which the Q angle is derived may help clarify its role in dynamic knee function. In addition, we acknowledge that other anatomical and postural measures could potentially influence Q angle (eg, coxa vara, patella mobility, muscular properties, and knee version) and impact dynamic motion and knee injury risk. Future study with a large scale, different sports, sex, age groups and activity levels are needed.

PRACTICAL APPLICATIONS

Excessive Q angle has been identifying as a risk factor for knee injuries. Identifying the postural factors that influence Q angle, excessive stress and potential injury is of considerable importance. Clinically this has implications for both preseason screening and clinical treatment of subjects or patients. The evidence suggesting a link between tibiofemoral angle, anteversion and hip internal rotation with Q angle.

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