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Universidade Iguacu
Itaperuna, Brasil

Available in: http://www.redalyc.org/articulo.oa?id=93021532004
ORIGINAL PAPER (ARTIGO ORIGINAL)

THE STUDY OF LOWER EXTREMITY ALIGNMENT IN ATHLETES WITH AND WITHOUT ACL RECONSTRUCTION

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Submitted for publication: Jul 2011
Accepted for publication: Nov 2011

ABSTRACT
DANESHMANDI, H.; AZHDARI, F.; SAKI, F.; DANESHMANDI, M. S. The study of lower extremity alignment in athletes with and without acl reconstruction. Brazilian Journal of Biomotricity. v. 5, n. 4, p. 248-254, 2011. The purpose of this research was to examine the difference of lower extremity alignment between subjects with and without ACL reconstruction. 20 ACL–injured males (age: 26.5±3.36 yr; height: 178.07±5.43 cm; weight: 77.5±7.72 kg; athletic experience: 7.70±4.41 yr) and 20 non-injured males (age 25.7±2.84 yr, height 178.05±4.47 cm, weight 73.65±8.73 and athletic experience: 7.00 ±3.69 yr) were matched by age, sport and involved limb participated in this study. Subjects were assessed for navicular drop, T-F angle, Q angle, anteversion, knee recurvatum, hip internal and external rotation range of motion, true and apparent leg length. The results showed significant difference between pronation, T-F angle, Q angle, anteversion and hip external rotation in the two groups (p≤0.05).Based on results of this retrospective study, identifying such biomechanical and anatomical factors, which predispose the ACL to injury, are necessary.

Key words: ACL injury, Pronation, Q angle, Athlete.

INTRODUCTION
Each year, an estimated 80,000 to more than 250,000 ACL injuries occur, many of them associated with young athletes aged 15 to 25 years (WOJCIECH et al., 2009). ACL reconstruction is a commonly performed procedure (GRiffin, 2006). The consequences of ACL injury include both temporary and permanent disability with an estimated cost of over US $ 2 billion (GRiffin, 2006). Lower extremity alignment has been proposed as a risk
factor for acute and chronic lower extremity injuries, including patelafemoral syndrome, ACL injuries, medial tibial stress syndrome, stress fractures, and plantar facilities (NGUYEN et al., 2009). It has been suggested that biomechanical changes resulting from abnormal alignment may influence joint loads, mechanical feedback from the hip and knee, resulting in altered neuromuscular function and control of the lower extremities (LOUDON et al., 1996; SHULTZ et al., 2006). However, the relationship between anatomical alignment and ACL injury risk remains poorly understood. Prior investigators have investigated the relationship of malalignments such as foot hyperpronation (BECKET et al., 1992; WOODFORD-ROGERS et al., 1994; LOUDON et al., 1996), quadriceps angle (q-angle) (LOUDON et al., 1996; SHAMBAUGH et al., 1991), leg length discrepancy (SODERMAN et al., 2001; TWELLAAR et al., 1997), and pelvic tilt (LOUDON et al., 1996; TWELLAAR et al., 1997) on risk of knee injury in athletes. These malalignments have been hypothesized to be associated with increased risk of ACL injury because they may place increased strain on the ACL. For example, hyperpronation is associated with increased tibial internal rotation; a large q-angle would be associated with increased knee valgus; a leg length discrepancy would result in hyperpronation on the "short" leg; and pelvic obliquity may be associated with increased hip internal rotation. All of these mechanical consequences could influence the ACL adversely. Most investigators have examined only one alignment factor or a small number of alignment factors. Examining only one or a limited number of alignment factors may not adequately describe the position of the lower extremity. Mostly providing the insufficient information to identify clinical meaningful relationship 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 ACL injury. Because one alignment characteristic may interact with or cause compensations at other bony segments (DANESHMANDI et al., 2011). Thus the purpose of this study was to identify lower extremity alignment differences between athletes with and without ACL reconstruction.

MATERIALS AND METHODS

Participants

A total of 20 physically active males (age: 26.5±3.36 yr; height: 178.07±5.43 cm; weight: 77.5±7.72 kg; athletic experience: 7.70±4.41 yr) with a history of unilateral ACL injury participated in this research. All ACL injuries occurred within 2 years of the onset of the testing. ACL injured subjects had undergone reconstructions and were cleared to participate fully in exercise and sport. 20 physically active males volunteered as controls (age: 25.7±2.84 yr, height: 178.05±4.47 cm, weight: 73.65±8.73 and athletic experience: 7.00 ±3.69 yr). All subjects were free from lower extremity injury or surgery in the 5 months prior from this study. All subjects signed consent.

Measurements

The 9 measures of lower extremity alignment (navicular drop, Q angle, genu recurvatum, femoral anteversion, true and apparent leg length, T-F angle, hip internal and external rotation) were collected by the same examiner who participated in each measurement technique during pilot testing until test-retest reliability analysis revealed interclass correlation coefficients greater than 0.85 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. Navicular drop, which is the measure of subtalar pronation, was measured using the methods of Brody. 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 (BRODY, 1982).

Standing Q angle was measured with the subject in a standing, relaxed position with a standard goniometer (SHULTZ et al., 2008). The 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 sagittal plane 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). Measurement was done in non-weight bearing, supine position with a bolster under the distal tibia (MCKEON et al., 2009).

For femoral anteversion the subject was placed in a prone position with the knee flexed to 90 degrees. 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 position. 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).

Apparent leg length was measured from the umbilicus to medial malleolus, while true leg length was measured from the ASIS to the medial malleolus (HERTEL et al., 2004). Both measures were taken with subjects lying supine.

For T-F angle, the patient lies prone with the knee flexed to 90 degrees. The examiner views the angle formed by the foot and thigh from above. After the subtalar joint has been placed in the neutral position, the angle the foot makes with the tibia is noted (TRIMBLE et al., 2002).

Hip internal and external rotation active ROMs were measured with subjects lying prone. The subject’s knee was flexed to 90 degrees and the moving arm of goniometer was aligned with the tibia. The subject then actively internally rotated their hip to its end point and a measure was made in degrees. Hip external rotation was measured similarly (HERTEL et al., 2004). Data was analyzed using independent t-test to compare the injured and un-injured groups.

RESULTS
Mean and standard deviations for each alignment characteristic are presented in table 1. Results of the pilot study for each anatomical measure are listed in table 2. When comparing those with and without a history of ACL injury, significant group differences ($\rho \leq 0.05$) were found for: Q angle, T-F angle, navicular drop and antroversion and hip external rotation (Table 3).
Table 1 - Mean and SD of variables in injured and non-injured subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Injured group Mean (SD)</th>
<th>Control group Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navicular drop</td>
<td>8.15 (2.05)</td>
<td>4.85 (0.74)</td>
</tr>
<tr>
<td>Q angle</td>
<td>13.8 (1.05)</td>
<td>12.15 (0.67)</td>
</tr>
<tr>
<td>Genu recurvatum</td>
<td>2.3 (1.41)</td>
<td>2.05 (1.35)</td>
</tr>
<tr>
<td>Femoral anteversion</td>
<td>14.75 (1.91)</td>
<td>13.45 (1.66)</td>
</tr>
<tr>
<td>True leg length</td>
<td>93.45 (4.19)</td>
<td>93.02 (3.83)</td>
</tr>
<tr>
<td>Apparent leg length</td>
<td>101.7 (4.56)</td>
<td>101.25 (4.25)</td>
</tr>
<tr>
<td>T-F angle</td>
<td>12.30 (1.17)</td>
<td>14.15 (1.66)</td>
</tr>
<tr>
<td>Hip internal rotation</td>
<td>29.75 (4.71)</td>
<td>30.85 (4.92)</td>
</tr>
<tr>
<td>Hip external rotation</td>
<td>29.5 (4.75)</td>
<td>32.4 (4.04)</td>
</tr>
</tbody>
</table>

Table 2 - ICC and SEM for each anatomical measure

<table>
<thead>
<tr>
<th>Variable</th>
<th>ICC</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navicular drop</td>
<td>0.91</td>
<td>0.62</td>
</tr>
<tr>
<td>Q angle</td>
<td>0.92</td>
<td>0.73</td>
</tr>
<tr>
<td>Genu recurvatum</td>
<td>0.92</td>
<td>0.63</td>
</tr>
<tr>
<td>Femoral anteversion</td>
<td>0.88</td>
<td>0.91</td>
</tr>
<tr>
<td>True leg length</td>
<td>0.84</td>
<td>0.53</td>
</tr>
<tr>
<td>Apparent leg length</td>
<td>0.84</td>
<td>0.59</td>
</tr>
<tr>
<td>T-F angle</td>
<td>0.89</td>
<td>0.98</td>
</tr>
<tr>
<td>Hip internal rotation</td>
<td>0.89</td>
<td>1.11</td>
</tr>
<tr>
<td>Hip external rotation</td>
<td>0.84</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Table 3 - The results of t-test for comparison of alignments in injured and control groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Injured mean (SD)</th>
<th>Control group mean (SD)</th>
<th>T-test (P value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navicular drop</td>
<td>8.15 (2.05)</td>
<td>4.85 (0.74)</td>
<td>0.000*</td>
</tr>
<tr>
<td>Q angle</td>
<td>13.8 (1.05)</td>
<td>12.15 (0.67)</td>
<td>0.000*</td>
</tr>
<tr>
<td>Genu recurvatum</td>
<td>2.3 (1.41)</td>
<td>2.05 (1.35)</td>
<td>0.572</td>
</tr>
<tr>
<td>Femoral anteversion</td>
<td>14.75 (1.91)</td>
<td>13.45 (1.66)</td>
<td>0.028*</td>
</tr>
<tr>
<td>True leg length</td>
<td>93.45 (4.19)</td>
<td>93.02 (3.83)</td>
<td>0.229</td>
</tr>
<tr>
<td>Apparent leg length</td>
<td>101.7 (4.56)</td>
<td>101.25 (4.25)</td>
<td>0.240</td>
</tr>
<tr>
<td>T-F angle</td>
<td>12.30 (1.17)</td>
<td>14.15 (1.66)</td>
<td>0.000*</td>
</tr>
<tr>
<td>Hip internal rotation</td>
<td>29.75 (4.71)</td>
<td>30.85 (4.92)</td>
<td>0.479</td>
</tr>
<tr>
<td>Hip external rotation</td>
<td>29.5 (4.75)</td>
<td>32.4 (4.04)</td>
<td>0.004*</td>
</tr>
</tbody>
</table>

(*) Significant at p< 0.05

DISCUSSION

The results of our study suggest that there was a significant difference between navicular drop, Q angle, antversion and hip external rotation in the groups with and without ACL reconstruction. There was a significant difference between excessive pronation in the two groups. This finding is in agreement with other retrospective studies. Beckett et al examined two groups of 50 athletes, a group with ACL injury and a group with normal knees. The ACL injured subjects had navicular drop test scores higher than non-injured subjects (BECKET et al., 1992). Woodford-Rogers et al examined 14 football players and...
eight gymnasts with ACL injuries and compared them with an age-sex-sport-matched control group. They also found an increase in navicular drop in the ACL-injured group, suggesting an increase in subtalar joint pronation (WOODFORD-ROGERS et al., 1994). Similarly Loudoun et al and Hertel et al found that navicular drop was significantly related to having a history of ACL injury (LOUDON et al., 1996; HERTEL et al., 2004). Motion of the subtalar joint is triplanar with simultaneous motion occurring in the three cardinal planes (frontal, transversal, and sagital). When the foot is fixed to the support surface during closed kinetic chain activities, transverse plane motion of subtalar joint pronation is translated into internal rotation motion. Excessive internal tibial rotation during closed kinetic chain activities with a flexed knee can lead to excessive internal tibiofemoral rotation and stress to the ACL, a common mechanism of non-contact injuries (TRIMBLE et al., 2002).

The results showed subjects with ACL injury had higher Q angles than non-injured subjects. The average angle for females is 15 degrees and only 10 degrees for males. Theoretically, larger Q angles, signal increases in the lateral pull of the quadriceps muscle on the patella and put medial stress on the knee (MAGEE, 1992). At this greater angle, forces are concentrated on the ligament for stability each time the knee rotates. This increases the rotational forces on the ACL, raising the probability of a tear. A large Q angle also results in a more pronated foot, further stressing the knee (GARG et al., 2009). The results of this study is in agreement with Shambaugh’s study. Shambaugh et al found that the average Q angles of athletes sustaining knee injuries were significantly larger than the average Q angles for players who were not injured (SHAMBAUGH et al., 1991). Because lower extremity alignment cannot be altered, no recommendation can help minimize the athlete’s risk of ACL rupture; however, the dynamic position of the tibia can be improved with internal rotation exercises for the tibia (e.g. medial hamstrings) (GARG et al., 2009).

The finding showed subjects with ACL injury history had lesser hip external rotation than normal subjects. These results agreed with other studies (JOAOL et al., 2008). Joaol reported decrease in hip range of motion was greater in the group with ruptured ACLs than in the control group. However Hertel et al did not find a significant difference between hip rotations in subjects with and without ACL injury history (HERTEL et al., 2004).

The results also showed significant difference between anteversion in the two groups. Larger hip anteversion has been suggested to result from inadequate regression of anteversion from infancy to adulthood. While reasons for a lack of regression are unknown, heredity has been suggested to play a role, as increased hip anteversion is frequently present in the mother of children with increased hip anteversion. Behavioral factors that increase stress on the medial femoral growth plate through childhood have also been suggested to contribute to excessive hip anteversion. These include sitting in the “reverse tailor” position and frequent in-toe belly sleeping (NGUYEN et al., 2009).

We did not identify a significant difference between either leg length in subjects with and without ACL reconstruction. We included these variables in our study because they had not been extensively examined in previous studies of lower extremity structural alignment and ACL injury risk. We hypothesized that limbs shorter than the contralateral side may be more associated with ACL injury risk because the shorter limb would tend to pronate, and thus rotate, more than longer limbs. These hypotheses were refuted.

**PRACTICAL APPLICATIONS**

In conclusion, identifying the postural factors that predispose the ACL to 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 suggests a link between the Q angle, anteversion, hip external rotation and navicular drop with stress building in the ACL.

ACKNOWLEDGMENT

The authors gratefully acknowledge all subjects who cooperated in this investigation.

REFERENCES


SHULTZ, S. J; NGUYEN, A. D; SCHMITZ, R. J. Differences in lower extremity anatomical alignment and postural characteristics in male and females between maturation groups.


