Is Femoral Version Associated with Changes in Hip Muscle Strength in Females with Symptomatic Femoroacetabular Impingement?*

A versão femoral está associada a alterações na força dos músculos do quadril em mulheres com impacto femoroacetabular sintomático?

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Abstract

Objective   The aim of the present study was to evaluate the association between femoral anteversion and hip muscle strength in subjects with femoroacetabular impingement syndrome.

Method   The femoral version angles described in the arthro-magnetic resonance images and isokinetic tests were retrospectively evaluated from July 2016 to December 2017. The inclusion criteria were: a) femoral version evaluated by the same radiologist; b) α angle $\geq$ 55°; and c) no limiting pain during the isokinetic test. Flexion/extension, abduction/adduction, and internal/external rotation peak torques were evaluated at 30° per second in 5 repetitions. The correlation between femoral version and muscle strength was evaluated by simple linear regression at a 5% significance level.

Results   A total of 37 females filled the inclusion criteria, and 51 symptomatic hips were evaluated. There was no correlation of the femoral anteversion in the flexion, extension, abduction, adduction, external rotation and internal rotation peak torques.

Conclusion   Femoral anteversion did not show a correlation with hip muscle strength in females with symptomatic femoroacetabular impingement.

Keywords
► femoroacetabular impingement
► muscle strength
► hip joint

Resumo

Objetivo   O objetivo deste estudo foi avaliar a associação da anteversão femoral e da força dos músculos do quadril em indivíduos com síndrome do impacto femoroacetabular.

Método   Os ângulos de versão femoral descritos nas imagens de ressonância magnética articular e os testes isocinéticos foram avaliados retrospectivamente entre julho de 2016 e dezembro de 2017. Os critérios de inclusão foram: a) versão femoral avaliada pelo mesmo radiologista; b) ângulo α ≥ 55°; e c) ausência de dor limitante durante o teste isocinético. Os picos de torque em flexão/extensão, abdução/adução e rotação interna/externa foram avaliados a 30° por segundo em 5 repetições. A correlação entre a versão femoral e a força muscular foi avaliada por meio de regressão linear simples, com nível de significância estatística de 5%.

Palavras-chave
► impacto femoroacetabular
► força muscular
► articulação coxofemoral

Resultados   Um total de 37 mulheres atenderam aos critérios de inclusão. Foram avaliados 51 quadris sintomáticos. Não houve correlação da anteversão femoral nos picos de torque em flexão, extensão, abdução, adução, rotação externa e rotação interna.

Conclusão   A anteversão femoral não foi correlacionada à força dos músculos do quadril em mulheres com impacto femoroacetabular sintomático.

Introduction

Abnormal hip morphologies have been related to several pathologies of the inferior limbs. The prominence of the femur at the head-neck junction (CAM-type) and an excessive coverage of the femoral head by the acetabulum (PINCER-type) are abnormalities that alone or in combination induce the impingement of the femur against the acetabulum (femoroacetabular impingement, FAI) during extreme movements. This impingement may cause labral tears and premature development of osteoarthritis.[1,2]

Another important abnormality of the femur is a low or excessive torsion of the neck. In the first case, the angle between the neck and longitudinal axis of the diaphysis is increased, or the angle between the neck and femoral condyle is decreased ($< 10°$),[3] which induces the external rotation (ER) of the femur. However, in order to maintain the foot pointing forward, the femur is internally rotated, reducing the offset between the anterior rim of the acetabulum and the femoral neck. This morphology decreases the internal rotation (IR) range of motion (RoM), potentiates the impingement,[4] and increases the contact stress of the joint.[5] On the other hand when there is excessive anteversion of the femur, the angle between the neck and longitudinal axis of the femoral diaphysis is decreased, or the angle between the neck and femoral condyle is increased ($> 22°$),[3] which has a direct effect on the knee. The distal femur is positioned in IR, and the patella is turned medially.[4] This position increases the contact pressure and results in patellofemoral syndrome (PFS).[6]

Interestingly, both PFS and FAI pathologies have been related to an imbalance in muscle strength. Subjects with PFS have shown weakness in hip abduction and ER,[7,8] while subjects with FAI have shown weakness in hip abduction, adduction, and ER when compared with asymptomatic con-

trols.[9] Furthermore, a suggestive weakness was observed in the IR, and no difference was observed in extension between symptomatic and asymptomatic subjects.[9] Diamond et al[10] observed an isometric weakness in the abductors and an imbalance in the rotators in subjects with FAI. Comparing symptomatic and asymptomatic contralateral hips, Nepple et al[11] showed deficits in the isometric strength of the abductors and flexors.

The generalized weakness in hip muscles reported in subjects with symptomatic hips[9] and the recovery of strength after the reduction of pain[12] induced the authors to conclude that the weakness was related to the pain caused by osteoarthritis. Nevertheless, the comparison based in symptoms without an evaluation of hip morphology cannot suggest whether the abnormal morphology responsible for FAI is associated to weakness. The resection of the CAM-type deformity and the reduction of pain were associated to the recovery of strength.[12]

The CAM-type deformity reduces the range of IR, and the increase in motion could be associated to the recovery of internal rotator strength.

However, our hypothesis is that femoral version abnormalities might also be associated to weakness in subjects with CAM-type impingement and symptomatic hips. A simplified model of the anterior fibers of the gluteus medius and minimus to explain the theory of the femoral version-related weakness of the IR is shown in ►**Fig. 1**. The backward-shifted position of the greater trochanter relative to the head with the foot pointed forward in the excessive anteversion of the femur decreases the angle between the muscle vector and the axis of the femoral neck. This position may increase the magnitude of the vector responsible to press the head inside the acetabulum and decrease the vector responsible for the internal torque. Furthermore, the anteversion may be responsible for the
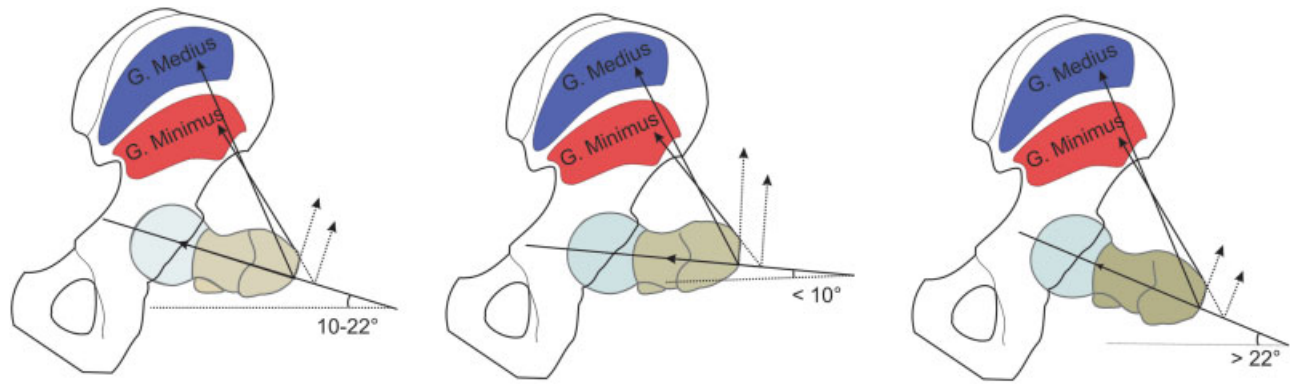
Fig. 1 The posterior view of hip in 90° flexion, and vectors of anterior fibers of gluteus medius and minimus in normal (10–22°), low (< 10°), and high (> 22°) femoral anteversion, respectively. The dot vectors are the responsible for internal rotation movement. The closed angle between femoral axis and muscle vector showed in high anteversion may results in decreased vector responsible for rotation compared to low anteversion. The opposed effect can be shown in low anteversion case.

disadvantageous length-tension relationship between the internal rotators and the psoas.[13] The backward position of the lesser trochanter may elongate the fibers, decreasing the number of actin-myosin cross-bridge formations and the ability to produce the maximal force. On the other hand, when the greater trochanter is shifted into a forward position, the angle between the muscle vector and the axis of the femoral neck is increased. Thus, the magnitude of the vector responsible for the internal torque is increased, and the vector responsible to press the head against the acetabulum decreases.

Therefore, the sum of the vector changes and disadvantageous length-tension relationship may be enough to alter hip muscle strength when subjects with excessive and low femoral anteversion are compared. Taking this into account, the present study evaluated the correlation of the femoral version with isokinetic muscle strength in females with symptomatic CAM-type impingement.

Methods

Subjects

The sample of the present study was composed of subjects that were evaluated in our institute between July 2016 and December 2017. The inclusion criteria were having had the arthro-magnetic resonance image evaluated by the same radiologist, having pathological CAM-type FAI, and being able to execute the movements required in the isokinetic protocol without excessive pain (visual analog scale [VAS] < 4). All subjects provided their consent for the use of the data. Previous approval for the conduction of the study was obtained from the Ethics in Research Committee of our institution.

Assessment of Hip Morphology

All of the hip morphology evaluations were performed through arthro-magnetic resonance imaging (GE Infinity, GE, Boston, MA, US). After anesthesia with 5 mL of lidocaine 2%, an 18-mL physiologic buffer solution and 0.4 mL of gadoteric acid were injected into the hip. The scans were performed using T1 sequences with 0.3 cm of thickness and

saturation of the axial fat at the axes of the femoral neck, and at the sagittal and coronal planes. Coronal short tau inversion recovery (STIR) images with fat saturation, 0.5 cm of thickness and axial proton density were also acquired. The femoral version was measured drawing a line crossing the center of the femoral neck and another line crossing both posterior condyles. The presence of CAM-type impingement was evaluated through the α angle. The α angle was measured drawing a line crossing the axis of neck and another line crossing the head-neck junction and the center of the femoral head. An angle $\geq 55°$ was considered positive for CAM-type impingement.[14,15]

Assessment of Muscle Strength

The concentric peak torque was evaluated using a System 4 pro isokinetic dynamometer (Biodex Medical System, Shirley, NY, US). The manufacturer's protocols were followed for the flexion/extension and abduction/adduction movements. The supine position was adopted to evaluate the flexor and extensor muscle strength. The RoM was set as near as possible to 5° of flexion in order to avoid contact of the thigh with the chair. The upper limit was set at between 60° and 70°. The abduction and adduction movements were performed in lateral decubitus. The lower position was set at 0° of adduction, and the RoM was set between 45° and 55°. Gravity correction was performed at the lower limit of the RoM for the flexion/extension and abduction/adduction movements. The IR and ER were evaluated in a seated position with the hip and knee fixed at a flexion of 90°. The dynamometer axis was adjusted to the longitudinal axis of the femur and attached to the leg above the medial malleoli. To avoid any adduction and abduction movements during the test, the hip and the distal thigh were immobilized. The subjects themselves defined the RoM in order to avoid any feeling of pain. The minimum RoM accepted was of 20°. Gravity correction was not necessary. A warm-up session of five repetitions was performed for all movements. The peak torque was recorded over 5 repetitions with 30° per second of velocity, which were performed 2 minutes after the warm-up.

Table 1 Sample description

Description	Mean	Standard deviation	Minimum	Maximum
Femoral version angle (degree)	17	7.8	0	31
Alpha angle (degree)	60	6.39	55	86
Age	36	8.23	24	52
Height (m)	1.63	0.06	1.5	1.78
Body mass (kg)	63	8.32	51	98

Statistical Analysis

The peak torque data was normalized by body mass. The correlation between the femoral version and the peak torque was evaluated adjusting a simple linear regression curve, and the analysis of variance was used to evaluate the significance of the regression. The significance level was set at 0.05.

Results

A total of 37 females fulfilled the inclusion criteria. A total of 23 females had unilateral symptoms, and 14 subjects had bilateral symptoms. Thus, 51 hips were evaluated. The data of the femoral anteversion angles and the characteristics of the subjects are summarized in ►Table 1. There was no correlation between the femoral version angle and the flexion ($p = 0.59$), extension ($p = 0.22$), abduction ($p = 0.75$), adduction ($p = 0.61$), and ER ($p = 0.17$) peak torques. A weak correlation between the femoral version and the IR ($p = 0.013$; $r_{adjusted} = 0.10$) peak torque was observed (►Fig. 2).

Discussion

The aim of the present study was to evaluate the correlation between the femoral version and the concentric isokinetic strength of the hip muscles. The results showed no effect of the version on flexion, extension, abduction, adduction, and ER strength; they also showed a weak correlation with IR strength in females with pathological CAM-type FAI.

The action of the rotator muscles depends on the relative position between the femoral and the pelvic insertions, which determines the vector of the muscles related to the rotational axis of the femur. The muscles with their vector in front of the rotational axis of the femur on the horizontal plane are responsible for the IR when the hip is at 0° of flexion. The main internal rotator muscles are the anterior fibers of the gluteus medius and minimus,[16] pectineus, and tensor fasciae latae. The adductor longus and brevis are secondary internal rotators.[17] With a 90° hip flexion, the posterior fibers of the gluteus medius and the anterior fibers of the gluteus maximus also become internal rotators, increasing the internal moment compared with 0° of hip flexion.[17,18]

Cibulka et al[19] evaluated the effect of the asymmetric RoM on the IR of the hip rotator muscles. Asymptomatic subjects with a greater ER RoM when compared with the IR RoM (ER > IR), and subjects with the opposite characteristics (ER < IR) were evaluated. Although the authors did not evaluate hip morphology, the first pattern is similar to the pattern of RoM observed in subjects with low femoral anteversion, in whom the offset between the femoral neck and the anterior acetabular rim is short, resulting in low IR RoM, and the offset related to the posterior rim is large, resulting in high ER RoM,[3,20] as shown in ►Fig. 1. The second pattern is similar to the pattern observed in subjects with excessive anteversion, in whom the offset between the femoral neck and anterior acetabular rim is large, and the offset related to posterior acetabular rim is short, resulting in a greater IR RoM when compared with the ER RoM.[3,20] Subjects with ER > IR showed a higher isometric force of IR when compared with subjects with ER < IR when the angle of ER RoM used to measure the force was similar between them.[19] The explanation used by the authors was that the muscle fibers were more elongated in the ER < IR pattern than the fibers in the ER > IR pattern for this RoM. The authors also observed that when the force of the IR was measured with the foot pointing forward (see ►Fig. 1 for clarity), the subjects with ER > IR had more strength than the ER < IR subjects.

Previous studies had suggested that excessive anteversion may affect the abduction strength. The electromyography of the hip muscles showed that asymptomatic athletes with excessive anteversion have reduced isometric electromyography activity of the gluteus medius during abduction associated to the ER test in the lateral decubitus position.[21] Another study performed a finite-element analysis of a hip prosthesis wrongly positioned in excessive anteversion, and it showed a slight decrease in the moment arm and force generation abilities of the abductors, and an increase in the force of the flexors.[22]

Although we did not evaluate the existence of PFS in our sample, a relationship between excessive anteversion and weakness in the hip muscles has been suggested as a cause of PFS, due to the resultant internal rotation of the distal femur when the foot is pointing forward.[4] Subjects with PFS have shown this femoral positioning during dynamic activities such as running[23] and squatting.[24] This biomechanics has been associated to the inability of the gluteus maximus to counterbalance the IR, since subjects with PFS have shown a weakness in the abductors and external rotators.[7,8]

Our results did not show any effect of the different version angles on the isokinetic torque of the external rotators, abductors, and flexors. We hypothesized that the lateral decubitus position in the open chain used to evaluate the isokinetic strength of abduction may enable the adjustment of a more favorable orientation of muscle fibers to develop
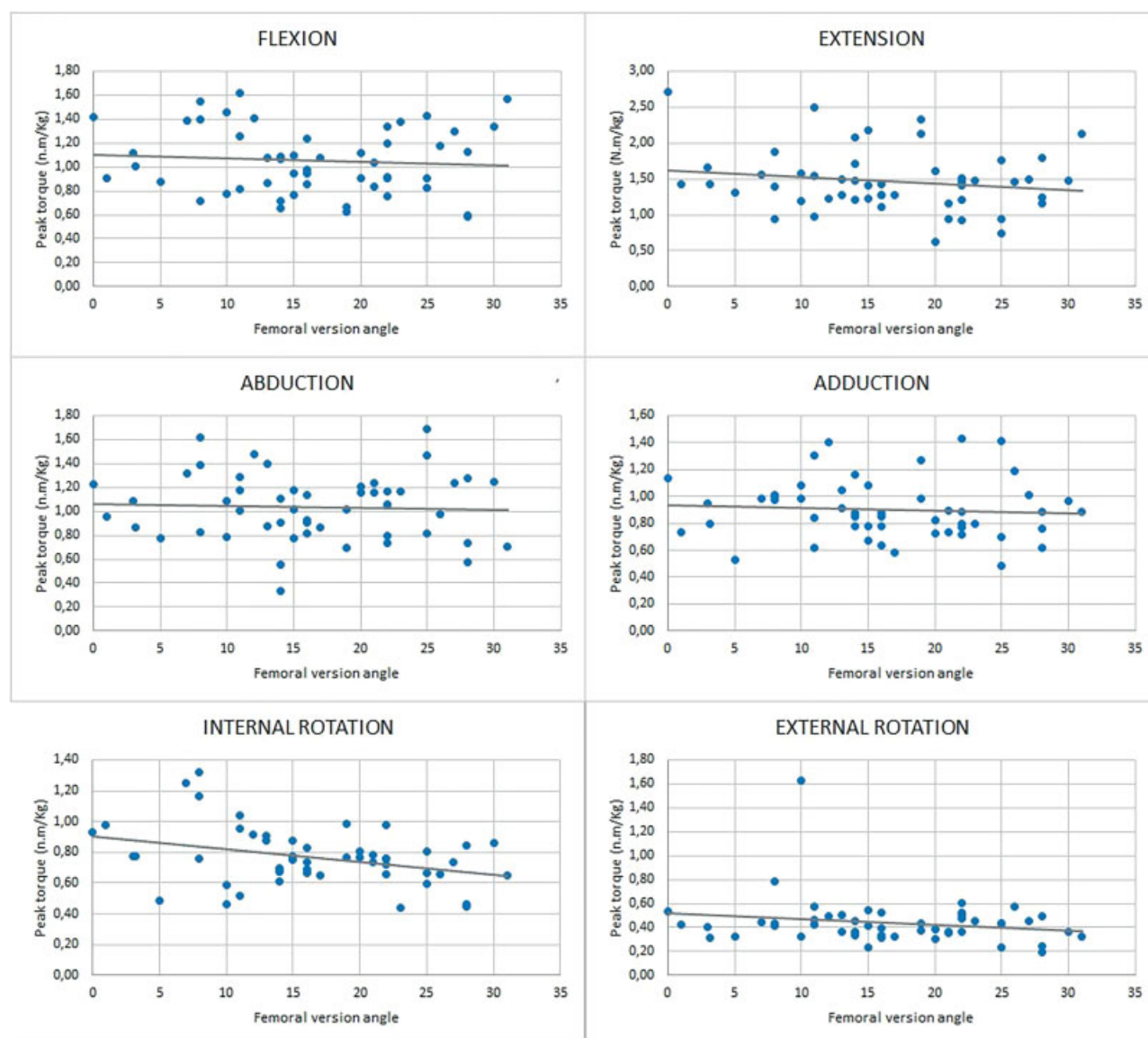
Fig. 2 Dispersion of flexion, extension, abduction, adduction, internal rotation, and external rotation peak torque (N.m/Kg) versus femoral version angle.

the maximal force. A possible deficit of the abductor related to femoral version may become evident when the muscles act eccentrically to stabilize the drop of the pelvis in the frontal plane and control the IR moment, such as observed in subjects with PFS.[6,25]

These findings show that femoral version is not a determinant factor for muscle weakness. Moreover, they are in line with studies that have shown that abnormal femoral anteversion does not change the outcomes after arthroscopy for FAI.[4,26] However, in order to better understand the effect of femoral version, further studies should consider evaluating asymptomatic hips to avoid the bias of pain in the maximal development of the torque. Although no limiting pain was reported (VAS < 4), the IR movement with 90° of flexion may impinge the femur against the acetabulum, triggering pain. Therefore, it is not possible to guarantee that pain did not influence the maximal peak torque devel-

opment. The lack of a control group is the major limitation of the present study.

Conclusion

Femoral version did not show a correlation with the strength of flexion, extension, abduction, adduction, ER and IR in symptomatic females with FAI.

Conflicts of interest
The authors have none to declare.

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