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Range of motion and radiographic analysis of the hip in patients with contact and non-contact anterior cruciate ligament injury

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Abstract
Purpose To compare the range of motion (ROM) and radiography of the hip joints in male patients with contact anterior cruciate ligament (ACL) injury and non-contact ACL injury.
Methods ROM of the ipsilateral hip was evaluated in 35 male patients with contact ACL injury (contact group) and compared to that of 45 male patients with a non-contact ACL injury (non-contact group). Radiographic evaluation of hip joints was also performed to assess the presence of cam and pincer-type deformity .
Results ROM of the hip joint was statistically higher in patients with contact ACL injury. The average sum of hip rotation in the non-contact group was 66.1 ± 8.4° compared to 79.4 ± 10.6° for the contact group ($p < 0.001$). Seventy-seven per cent of patients in the non-contact group had a sum of hip rotation <70° and 93 % had <80°, compared to17.1 and 42.9 % in the contact group ($p < 0.001$). Prevalence of cam or pincer deformity was similar in the groups. Cam or pincer deformity was not more frequent in patients with limited ROM of the hip.
Conclusion Individuals with contact ACL injury had greater ROM of the hip joints than those with non-contact ACL injury. The presence of cam or pincer deformity was similar in both groups and was not related to decreased ROM of the hip joints. These findings may assist the surgeons to identify new risk factors for non-contact ACL injury and, additionally, develop prevention program of injury.
Level of evidence III.

Keywords Anterior cruciate ligament · Risk factors · Injury · Range of motion · Hip joint

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Introduction

Anterior cruciate ligament (ACL) rupture is one of the most common ligament lesions of the knee [1]. The mechanism of ACL injury is complex and even more difficult to reproduce. Studies that have assessed the movement and position of the knee, at the moment of the lesion, show that ACL rupture occurs during an abrupt landing, associated with a rapid change of direction, after initial contact of the lower limb with the ground. At the moment of injury, the knee is positioned in semi-flexion with valgus or varus stress and internal or external rotation [3, 4, 14, 17]. In the majority of cases, ACL injury occurs without physical contact or external trauma to the knee, and only in a few patients, the injury occurs as a result of direct trauma to the knee [1, 3, 20].

Several external and internal risk factors related to ACL tear have already been described. With respect to the most commonly studied risk factors, it is important to note that femoral intercondylar notch stenosis, increase in posterior tibial slope (PTS), hormonal changes during the pre-ovulatory period, and the type of movement during landing were the most prevalent [2, 4, 5, 10, 12, 13, 16, 23–25, 28, 30, 31].

Recently, some authors have observed that decreased range of motion (ROM) of the hip joint may also be associated with a higher risk of ACL rupture [12, 26]. Gomes et al. [12] suggested that limitation of the rotational ROM of

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the hip during the movement could cause the injury, mainly due to a decrease in the internal rotation of the joint, and it can lead to more stress on the knee and consequently on the ACL, leading to a higher probability of lesion. In individuals with contact ACL rupture, the mechanism of injury is different. The rotational restriction of the hip does not impose greater stress on the ACL, and the injury occurs by direct load on the knee. In describing a new risk factor, analysis of associated risk factors that might confuse the results should always be considered. We have assumed that unknown factors that may influence ACL resistance can be partially controlled when individuals with different causes of ACL rupture are compared. By including only male subjects, we also controlled hormonal changes during the pre-ovulatory period as a potential confounding risk factor for ACL injury [30]. Radiographic changes in the hip, such as acetabular osteophytes and head deformity, could decrease the ROM of the hip and are more prevalent in patients with ACL injury [9].

The present research aims to compare ROM of the hip in male patients with contact ACL rupture and patients with non-contact ACL rupture in an attempt to identify new risk factors for ACL injury. The findings of this study may also assist the surgeons in the development of prevention programs of the non-contact ACL injury. The authors have hypothesized that the mobility of hip joint in individuals with non-contact ACL rupture is smaller than those with contact injury of the knee. The research also included radiographic analysis of the hip joint in both groups to investigate potential hip abnormalities.

Materials and methods

The analysis of ROM of the hip joint was performed in 80 men who had experienced ACL rupture. Thirty-five male patients who had experienced contact ACL injury (contact group) were compared to 45 male patients with non-contact ACL rupture (non-contact group). Mobility of the hip joint was measured in both groups. Individuals from both groups were also assessed and compared according to age, side and nature of lesion, presence of acetabular osteophyte and/or femoral head deformity (cam and/or pincer-type deformity, respectively), intercondylar notch index of the femur (ICI), posterior tibial slope (PTS), and coronal alignment of the knee. The study was conducted between 2010 and 2012.

The inclusion criteria for the study were males aged between 18 and 40 years with a diagnosis of contact or non-contact ACL rupture less than 6 months previously, who agreed to participate in the study and gave written informed consent. Exclusion criteria were history of ACL injury due to hyperextension; any symptoms of pain in the ipsilateral hip; history of pathology or previous surgery involving the ipsilateral hip and/or involved knee; a history of pelvic or lower limb fractures; history of previous ligament injuries and/or previous surgery in the injured knee; clinical and radiographic signs of coxarthrosis and/or gonarthrosis; clinical history of rheumatoid arthritis or polyarthralgias; and the presence of clinical discrepancies of the lower limb length.

Diagnosis of ACL rupture was based on a physical examination and was confirmed by magnetic resonance imaging (MRI) of the knee. Assessment of hip mobility and hip radiographic examinations was performed when the ACL injury was diagnosed.

The authors of the present study defined all lesions caused by direct trauma to the knee as ‘contact ACL injury’, whether due to sports injury, a fall, or a car or motorcycle accident. Individuals who could not accurately describe the trauma that caused their ACL injury were excluded, as were individuals who suffered the injury following the loss of balance caused by the initial physical contact.

ROM of the ipsilateral hip was assessed through four variables of interest: external rotation (ER), internal rotation (IR), abduction (ABD), and summed of rotation (IR + ER). ROM of the hip was measured passively from the neutral point up to the threshold of pelvic movement. One blinded examiner took the measurements using a universal goniometer. The value used was the mean of three measurements for each variable. For the assessment of IR and ER, the patient was posed in supine position with the knee and hip flexed at 90°. ABD was measured with hip and knee extended. During the assessment, the patients were completely relaxed with no pain in the hip or knee joint. The summed rotation (IR + ER) was also assessed using thresholds of 70° and 80° for both groups. These thresholds represent a decrease of at least 10°–20° of sum of rotation. Goniometer-based assessments conventionally used in orthopaedic clinical practice yielded good test–retest reliability, with interclass correlation coefficient higher than 0.9 for IR, ER, and ABD. It would remain the first choice tool for the assessment of hip ROM in the clinic [19].

Pelvis, hip, and knee radiographic examinations were performed for all patients. Anterior–posterior (AP) radiograph of the pelvis with a 15° IR of the lower limbs and lateral hip radiograph were taken to assess the presence of cam and pincer-type deformities [9]. Pincer-type deformity of hip is defined as over-coverage of the femoral head, whereas cam deformity is the loss of sphericity of the femoral head–neck junction [27]. Radiographs of the affected knee were taken in AP, lateral, and Rosenberg views [22]. All radiographic examinations were done using the same equipment, and radiographic data were assessed as digitalized images using the mDicomViewer Professional software (version 1.0.0118).

Anatomical factors associated with a higher incidence of non-contact ACL injuries were radiographically assessed in

Table 1 Characteristics of subjects

Variables[a]	Contact injury group ($n = 35$)	Non-contact injury group ($n = 45$)	p value
Age (years)	28.6 ± 7.6	27.8 ± 7.3	n.s.*
Injury side			n.s.**
Right	23 (65.7)	20 (44.4)	
Left	12 (34.2)	25 (55.5)	
Coronal alignment	2.7 ± 1.8	2.6 ± 2.0	n.s.***
ICI	0.2 ± 0.03	0.2 ± 0.03	n.s.*
PTS	8.6 ± 2.5	7.8 ± 5.6	n.s.***

ICI intercondylar notch width index, *PTS* posterior tibial slope, *n.s.* non-significant

* t test; ** Chi-squared test; *** Mann–Whitney U test

[a] Shown as mean ± standard deviation or n (%)

Table 2 Range of motion of the hips

Variables	Contact injury group ($n = 35$) mean ± SD	Non-contact injury group ($n = 45$) mean ± SD	p value*
IR	35.6 ± 5.7	28.6 ± 5.7	<0.001
ER	43.7 ± 6.6	37.5 ± 4.3	<0.001
IR + ER	79.4 ± 10.6	66.1 ± 8.4	<0.001
ABD	51.0 ± 7.3	46.5 ± 7.2	0.007

* t test

all individuals. Analysis and adjustment of these probable confounding factors were performed, and the results of the two groups were compared. Anatomical tibiofemoral alignments in the coronal plane, posterior tibial slope, and intercondylar notch width index were assessed in all patients. Coronal femorotibial alignment was measured in degrees for a weight-bearing AP view. Intercondylar notch index, notch width divided by condylar width, was measured using the Rosenberg view and assessed by the method described by Souryal and Freeman [25]. PTS is defined as the angle between a line perpendicular to the mid-diaphysis of the tibia and the posterior inclination of the tibial plateaus [8].

The research was approved by the University's Institutional Review Board (#171/2010).

Statistical analysis

Sample size calculation was based on the difference between two means. With a standard deviation of 15° [12], a difference of 10° to be detected, 5 % significance level, 80 % statistical power, and a two-tailed test, the minimum sample size necessary for each group was estimated to be 35. Statistical analysis of the data was performed using SPSS for Windows v.14 (SPSS Inc., Chicago, IL). t tests were used to compare the means of parametric quantitative variables (age, ICI, ER, IR, IR + ER); the Mann–Whitney U test was used for nonparametric variables (coronal alignment, PTS), and the Chi-squared test was used to compare frequencies (side, cam, and pincer deformity).

Results

The mean age of patients was similar for both groups. Mean time between the occurrence of injury and assessment was 3.8 ± 2.7 months for the contact group and 4.5 ± 2.9 months for the non-contact group. Of the contact group, 22 patients were injured during sports activity (soccer), 12 in motorcycle accidents, and one during a stair fall. There was no statistically significant difference between the groups in terms of anatomical alignment of the knee in the coronal plane, intercondylar notch width index (ICI), or PTS. The characteristics of subjects and measurements are provided in Table 1.

There was a statistically significant difference between the groups in terms of ROM of the hip joints, for all the assessed variables. The mean measurements of hip ROM are summarized in Table 2.

Evaluation of ROM of hips joints considering only rotations using the stated thresholds showed that individuals with a non-contact ACL rupture were 8.57 times more likely to have an IR + ER <80° and 3.7 times more likely to have an IR + ER <70° (Fig. 1).

The prevalence of cam and pincer-type deformity in both groups is shown in Tables 3, 4, and 5.

Discussion

The most important finding of the present study was that patients with non-contact ACL rupture have had a lower range of motion (IR, ER, and sum of rotation) of the ipsilateral hip compared with patients who had ACL injury after direct trauma on the knee. These results make us conclude that the decrease in ipsilateral hip rotation may contribute to a greater chance of non-contact ACL rupture. These findings may assist the surgeons to identify new risk factors for non-contact ACL injury and, additionally, to develop a prevention program of the injury.

The contribution of the hip joint to the genesis of ACL injuries has been investigated in previous studies [6, 9, 12, 18, 26]. All of them tried to identify changes in the lower limb and other factors that might be related to a higher risk

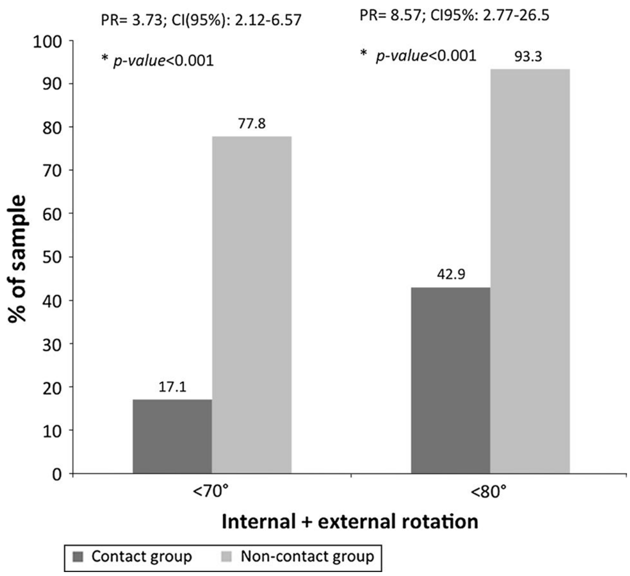

Fig. 1 Prevalence of individuals with range of hip rotation categorized by cutting points of 70° and 80°

Table 3 Prevalence of hip deformities

Type of hip deformity[a]	Contact injury group ($n = 35$)	Non-contact injury group ($n = 45$)	p value
CAM	13 (38.2)	20 (43.5)	n.s.**
PINCER	10 (29.4)	15 (32.6)	n.s.**

n.s. non-significant

** Chi-squared test

[a] Shown as n (%)

Table 4 Prevalence of hip deformities in patients by range of hip rotation (<70° vs. ≥70°)

Type of hip deformity[a]	IR + ER < 70°	IR + ER ≥ 70°	p value
CAM			
Contact group	12 (41.4)	1 (16.7)	n.s.**
Non-contact group	5 (50.0)	15 (42.9)	n.s.**
PINCER			
Contact group	8 (27.6)	2 (33.3)	n.s.**
Non-contact group	4 (40.0)	11 (31.4)	n.s.**

n.s. non-significant

** Chi-squared test

[a] Shown as n (%)

of ACL lesions [12, 18, 23, 26, 28]. However, factors that may contribute to ACL rupture in certain individuals are not yet entirely understood. The movement during which the injury typically occurs involves a valgus moment in the knee, landing, and sudden change of direction in relation to body inertia [5, 18, 20]. Some experimental models have shown that the valgus moment, associated with a deceleration over the semi-flexed knee, is the main factor contributing to ACL lesion [6, 18].

Table 5 Prevalence of hip deformities in patients by range of hip rotation (<80° vs. ≥ 80°)

Type of hip deformity[a]	IR + ER < 80°	IR + ER ≥ 80°	p value
CAM			
Contact group	6 (30.0)	7 (46.7)	n.s.*
Non-contact group	1 (33.3)	19 (45.2)	n.s.*
PINCER			
Contact group	6 (30.0)	4 (26.7)	n.s.*
Non-contact group	2 (66.7)	13 (31.0)	n.s.*

n.s. non-significant

* Fisher's exact test

[a] Shown as n (%)

Some authors have found that the ipsilateral position of the hip during sidestep movement might have an influence over this valgus moment of the knee joint. Internal rotation associated with flexion of the hip, on initial contact of the limb with the ground, might be related to an increase in the valgus moment in the knee. In addition, the increase in IR of the hip might compromise the balance of the medial muscle groups of the lower limb such that it would result in a valgus load over the knee. However, the increase in IR of the hip can also be understood as only one factor in the change of direction of the body, or as a result of inertia in the lower limb [18].

The present study compared the static ROM of the hip joint in patients with contact ACL rupture and patients with non-contact ACL injury. Patients with contact ACL injury showed a higher ROM of the hip, with respect to IR, ER, sum of rotation, and ABD. These results are in accordance with those observed in previous studies, in which athletes with non-contact ACL injury showed a decreased ROM of the hip compared to a control group without ACL injury [12, 26]. In a previous study [12], the average sum of rotations of the hip in patients with non-contact ACL injury was 68.4 ± 13.8°; this was similar to the result of 66.1 ± 8.4° found in the present study. Small variations are accepted in measurements of ROM using a goniometer. In a systematic review, van Trijffel [29] concluded that interobserver reliability of the measurements of passive movements of the joints of the lower limb is low, and precise measurements of ROM of the knee and hip are not possible. In another study, comparing the validity and reliability of the measurements of the ROM of the hip, performed with a goniometer and an electronic tracking system, the authors found that measurements performed with a goniometer generally overestimate the ROM by measuring intersegmental angles rather than true hip ROM [19]. Uncontrollable rotational movements, pelvic tilt, and positioning of the goniometer were the main factors involved in the variability of ROM measures. Primarily, when the hip rotation is being evaluated in 90° of flexion, the examiner should be aware of this and try to avoid the tilt and rotation of pelvis and malpositioning of goniometer. Nevertheless, these same authors concluded that the goniometer remains the instrument of choice for the measurement of ROM of the hip in clinical practice because of the advantages such as simplicity, low cost, and time saving [19].

It is important to highlight that there were methodological differences between this study and previous ones [12, 26]. To describe a new risk factor, we must access and control the risk factors that are already known, which may confound the results. In the present research, measurable risk factors, such as intercondylar notch stenosis and PTS, were assessed and controlled. By restricting the study to male patients, we also excluded another confounding risk factor, the hormonal factor, which is related to a higher incidence of ACL rupture in women during the pre-ovulatory period [2, 18].

The prevalence of radiographic changes in the ipsilateral hip was no different in the contact and non-contact groups. Radiographic changes in the hips were observed in 56 % of patients with non-contact ACL injury, and a decrease in ROM of the hip joint was also observed [9]. These authors suggested that clinical and radiological assessment of the hip joint should be included in the management of ACL injuries. In another study [21], the alpha angles of both hip joints of patients with isolated ACL injury were compared with those of an uninjured control group. The alpha angle of the hip is formed between a line perpendicular to a line joining the centre of the femoral neck and the centre of the femoral head and the point where the femoral head loses its circumference. An alpha angle greater than 60° is considered abnormal. Patients with ACL injury were found to have a significantly larger alpha angle than the control group. It is important to note that ROM of the hip was not assessed in this study. In an epidemiological study of professional soccer players [11], radiological abnormalities in the hips were observed in 72 % of men and 50 % of women. The ROM of the hip was not assessed in this study either. The authors concluded that the prevalence of radiographic abnormalities in the hips is high, and that, this information may be the first step towards a better understanding of the biomechanics of lower limb injuries.

Considering the hip as a spheroid joint, the presence of bone deformities around the femoral head or the acetabulum may impair normal excursion of the bones in hip ROM [15]. In the present study, the presence of cam or pincer-type deformity was not related to the cause of ACL injury. Further prospective studies are needed to clarify this issue.

All studies that have evaluated the association between decreased ROM of the hip and ACL injuries were performed with soccer players. It is still not well understood whether any particular sport is associated with a progressive reduction of hip rotation. The present authors believe that sports that require cutting and pivoting, such as handball, basketball, and soccer, might cause progressive limitation of rotational movements of the hip. This limitation could be related to the higher incidence of ACL rupture in these patient groups. The movement that causes ACL rupture is complex with an association of deceleration, varus or valgus, internal or external rotation, and change of direction. At the time of injury, we can consider that the trunk rotates on the lower limb resting on the ground, and the limitation of hip mobility may lead to more stress over the knee, and consequently on the ACL, leading to a higher probability of lesion. De Castro et al. [7], when evaluating soccer players who underwent a stretching program to increase ROM of the hip, concluded that soccer players show a progressive decrease in ROM of the hip. After intervention, only an improvement in ER in the non-dominant limb was observed. Prospective studies, involving stretching the hip joint, should be conducted to assess the relationship between an increase in hip mobility and a reduction in the incidence of ACL rupture.

The decrease in ROM of the hip found in individuals with non-contact ACL should be considered a risk factor associated with the genesis of the injury. These findings can be considered the clinical relevance of the present study. However, it is important to highlight that some observations limit our conclusions. It is a limited cohort, and other confounder risk factors for ACL injury may be involved. Cross-sectional studies present problems of temporal directionality between exposure and endpoint. An opposite causal relationship between the decrease in ROM of the hip and ACL injury remains a possibility. As previously noted, the method used to measure mobility of the hip, although widely accepted, is subject to variability [19, 29].

Further controlled studies using a prospective design involving athletes with decreased hip ROM, who are exposed to risk activities, should be conducted. It is also necessary to assess the role of preventative programs that include joint stretching exercises and investigate whether hip surgical procedures influence the incidence of new injuries. Furthermore, patients undergoing ACL reconstruction surgery, who present with hip joint abnormalities, should be followed-up.

Conclusions

Patients with contact ACL injuries have a larger ROM of the ipsilateral hip than patients with non-contact ACL injuries. The decreased ROM of the hip may be a newly identified factor associated with a higher risk of ACL rupture.

More defined understanding of the interaction between knee and adjacent joints can contribute to improve the results of prevention programs of ACL injury. Evaluation of the hip joint should be part of the routine assessment of patients with ACL injury.

Conflict of interest The authors declare that they have no conflicts of interest.

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