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Is restricted hip movement a risk factor for anterior cruciate ligament injury?

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Abstract

Restricted hip movement along with femoroacetabular impingement (FAI) has been reported to be an important risk factor in anterior cruciate ligament (ACL) injury. We performed a literature review assessing the evidence that FAI, or restricted hip movement, contributes to the likelihood of sustaining an ACL injury to provide an evidence-based and comprehensive update on the relationship between these pathologies. Studies were divided into three categories: clinical studies, radiological studies and cadaveric studies. Clinical studies primarily assessed the limitations to hip movement in patients with ACL injury, and numerous studies of this kind have demonstrated a relationship between restricted movement and ACL injury. Radiological studies have been able to demonstrate a higher number of bony hip abnormalities in patients with ACL injury. However, due to variable results within these studies, it is unclear which kinds of bony abnormality are specifically associated with an increased risk of ACL injury. Cadaveric studies have demonstrated that peak ACL relative strain was inversely related to the range of internal rotation of the femur, thus providing a potential mechanism for this relationship. In conclusion, clinical and radiological studies have established a correlation between restricted hip and ACL injury, but have been unable to demonstrate an increased risk of future ACL injury in individuals with restricted hip movement. Future prospective cohort studies are necessary to confirm this. Additionally, these findings highlight the need for a thorough clinical assessment of the hip when assessing patients with an ACL injury.

Keywords

anterior cruciate ligament (ACL), femoroacetabular impingement (FAI), range of movement of the hip, restricted hip movement, sports medicine

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Introduction

Injury of the anterior cruciate ligament (ACL) is a life-altering event and a common end to many athletes' professional careers.[1] Given the high frequency of ACL injuries which is over 40 per 100,000 person-years,[2] a better understanding of the mechanisms underlying this pathology is required in order to improve prevention strategies and reduce financial burden of this injury.[3,4] Although the majority of research into ACL injury has focused on the knee, there is a growing consensus that alterations in the kinetic chain of the trunk, hip, knee, ankle and foot may have a significant contribution to ACL injury.[5] As such, investigation into hip pathology as a risk factor for ACL injury has become an area of increasing research.

Recently, advances in biomechanics have demonstrated the reciprocal influence of hip and knee tension, highlighting that restrictions in internal rotation of the hip can increase strain in the ACL.[6,7] One such cause of restricted internal rotation is femoroacetabular impingement (FAI). In a recent prospective study, of patients presenting with groin pain, 17% were diagnosed to have FAI.[8] FAI is a

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pathomechanical condition caused by an altered osseous morphology of the acetabulum and/or the head–neck junction of the femur.[9,10] These alterations lead to repeated abutment of the femoral head–neck junction against the acetabular rim, increasing the risk of acetabular labral and chondral pathology, and eventually arthritis of the hip.[11–15] FAI is also theorized to increase resistance to femoral internal rotation during dynamic manoeuvrers, thereby increasing the risk of ACL rupture.[7]

The aim of this descriptive review article was to assess the evidence behind FAI, or restricted hip rotation-induced ACL injury, and to highlight areas of future research.

The articles analysed were divided into three categories: (1) clinical studies, (2) radiological studies and (3) cadaveric studies.

Clinical studies

Gomes et al. were the first to investigate the association between decreased range of hip movement and non-contact ACL injury, in a prognostic case-control study using clinical assessment of 50 male footballers with ACL injuries.[16] All rotational ranges of hip movement (external rotation and internal rotation, as well as their sum) were significantly decreased in patients with ACL rupture when compared with control subjects, except for mean external rotation when adjusted for age. Though this study was only able to assess hip movements after ACL injury, it was the first to suggest that physical abnormalities of the hip may be a contributing factor to ACL injury.

Further research by the same group focused on ACL re-rupture following reconstruction surgery – a problem previously attributed to failure of adequate reconstruction or inadequate rehabilitation.[17] In this study, 28 male football players presenting with non-contact ACL re-rupture after reconstruction were retrospectively examined for restriction in hip movements. A significantly lower mean internal–external rotational range of hip movement was found in the re-rupture group when compared with a non-injured control group. The authors concluded that a restrained hip joint may facilitate the occurrence of ACL injuries, a hypothesis supported by high rates of bilateral ACL injury in the study population.

Tainaka et al. also investigated the association between non-contact ACL injury and limited range of hip movement in a case-control study of 40 ACL-injured patients and controls.[18] Using clinical data, odds ratios of hip internal and external rotational ranges were calculated and adjusted for age, sex, body mass index and sporting preference. It was found that limited internal and external rotational range of hip movement was significantly associated with a history of non-contact ACL injury. The adjusted odds ratio of a non-contact ACL injury for a 10° increase in sum internal hip rotation (right and left) was 0.18 and for a 10° increase in sum external rotation was 0.23. These low odds ratios thus show that the probability of non-contact ACL injury greatly decreases with increases in internal and external rotation.

A further cohort study by Bedi et al. yielded similar results.[19] Using a study population of 324 American football players, they demonstrated that a reduction in internal rotation of the hip was associated with a statistically significant chance of previous ACL injury. A post-estimation calculation of odds ratios for ACL injury based on decreases in internal rotational range of movement in the hip demonstrated that a 30° reduction in left hip internal rotation was associated with 4.06 and 5.29 times greater chance of ACL injury in the ipsilateral and contralateral limbs, respectively. However, they were unable to demonstrate significant correlation between injury and restricted internal rotation of the right hip. The authors attributed this discrepancy to either an inadequate power of the study or to positioning of specific demands of the athletes, citing the need for further studies to assess laterality. In addition to odds ratio analysis, this study also utilized an in silico biomechanical model to investigate the effect of FAI on the peak relative ACL strain developed during a pivot landing. Using this model, they demonstrated an increase in peak anteromedial ACL strain as hip internal rotation was decreased, thus suggesting that increased strain may explain the increased risk of ACL injury found in their study.

In a case-control study evaluating the rotational range of movement of the hips in 80 male patients with contact or non-contact ACL injury, Lopes et al. were able to demonstrate that the range of movement of the hip joint was significantly reduced in patients with non-contact ACL injuries.[20] The average sum of hip rotation in the non-contact ACL injury group was 13.3° smaller when compared with the contact ACL injury group. Furthermore, 77% of patients in the non-contact ACL injury group displayed a sum of hip rotation of less than 70°, compared with only 17.1% in the contact group.

In a prognostic prospective cohort study by VandenBerg et al., 25 ACL-injured and 25 control patients matched by age and gender were examined to determine the range of internal rotation of the hip.[21] The ACL injury group included patients with an ACL rupture within the previous 3 months with no prior lower extremity injuries or ligamentous laxity. The average sum of hip rotation (internal + external) in patients with an ACL tear was 12.3° lesser when compared with patients without an ACL tear. Additionally, the average hip internal rotation in patients with an ACL tear was 7° lesser than in patients without an ACL tear. Statistical analysis of clinical assessment revealed that for every 10° increase in hip internal rotation, the odds ratio of having an ACL tear decreased by a factor of 0.419.

Although all of the studies discussed thus far have been able to establish a relationship between reduced hip movements and previous ACL injury, they all retain the same limitation – restriction of movement is only assessed after injury. Given the reciprocal relationship between hip and knee biomechanics, it is impossible to determine whether reduced hip movement leads to increased risk of ACL injury, whether ACL injury leads to reduced movement of the hip or a combination of the two. As such, future clinical studies into the relationship between ACL injury and restricted hip movements should adopt a prospective cohort focus, thus allowing temporalization of the pathological process.

Radiological studies

In addition to the clinical studies described above, several studies have investigated the relationship between FAI and ACL injury using radiological analysis. Gomes et al. investigated abnormal bony morphology in 50 patients with a decreased range of movement of the hip below an 80° cut-off point and a non-contact ACL injury.[22] This study found that 56% of these patients had bone abnormalities around the hip joint and categorized them into four groups. The first group, which constituted 24% of all patients assessed, displayed pericapsular calcifications or acetabular osteophytes at the hip joint causing a pincer-type impingement. The second morphological group were those with femoral neck deformities leading to a cam-type impingement and accounted for 10% of those assessed. Combined femoral neck and acetabular disorders were found in 18% of patients, and in 4% of patients an acetabular roof excavated the femoral neck, producing a groove giving it a protrusio effect. However, given the lack of a control group in this study, the incidence of bony abnormalities cannot be compared to a non-injured cohort and its significance is unclear.

Despite the results described above, radiological analysis of 25 ACL-injured and 25 non-injured patients' hip radiographs by VandenBerg et al. revealed no difference in the frequency of hip dysplasia or cam-type morphology between these groups.[21] However, ACL-injured patients showed a significantly greater incidence of the positive posterior wall sign and the positive ischial spine sign – radiological markers of pincer-type FAI. In contrast to these findings, Lopes et al. in a case-controlled study of 80 contact and non-contact ACL-injured patients found no difference in the frequency of cam or pincer deformity, despite the previously discussed differences in the movement of the hip of the whole group.[20]

The α angle, describing asymmetry of the shape of the femoral head–neck junction and measured in the region of the femoral head–neck junction, is a commonly used measure of impingement in cam lesions, with α angles greater than 55° considered abnormal.[23,24] By measuring the α angle on anterior–posterior radiographs, Philippon et al. in a study of 48 patients with ACL injury and 42 controls were able to demonstrate that the ACL-injured patients had a significantly higher α angle on the injured side when compared with the non-ACL-injured controls.[25] Additionally, over 90% of the ACL-injured patients had α angles greater than 60°, compared with only 35% in the control group. In further analysis, they discovered that patients with an α angle over 60° were 27 times more likely to be in the ACL injury group than those with α angles of 60° or less. It was hypothesized that patients with elevated α angles may have a diminished ability to accommodate overall internal rotation moments of the lower extremity at the hip, thus exposing the knee to greater rotational stresses and increasing the probability of ACL injury.

Similar to the clinical studies described previously, studies utilizing radiological assessment of individuals with ACL-injured hip have only been able to establish a correlation between previous ACL injury and bony abnormalities. Prospective cohort studies are necessary to establish whether bony abnormalities lead to an increased risk of future ACL injury. Furthermore, the variable results found in the studies described above necessitate larger controlled studies to establish which types of deformity most strongly correlate with ACL injury.

Cadaveric studies

Although the studies discussed previously have been able to demonstrate a robust relationship between reduced hip movement and ACL injury, they offer no insight into the mechanisms of this association. In order to investigate the potential mechanisms of FAI-induced ACL injury, Beaulieu et al. utilized cadaveric specimens to simulate a single-leg pivot landing with varying limits to internal femoral rotation.[26] In this study, a series of pivot landings were simulated in 10 male and 10 female human knee specimens using an apparatus that applied a twice-bodyweight load to the knee, inducing knee compression, a flexion moment and an internal tibial torque. The range of internal femoral rotation was limited in four settings (locked at 0°, limited to 7°, limited to 11° or no limitation) with rotation resisted by two springs to recreate the resistance of the hip rotator muscles. The anteromedial ACL strain was quantified with a differential variable reluctance transducer, and a linear mixed model was used to determine the relationship between peak anteromedial ACL relative strain and range of internal rotation of the femur. It was found that peak anteromedial ACL relative strain was inversely related to the available range of internal rotation of the femur, with strain increasing 1.3% for every 10° decrease in rotation. The authors calculate that this relationship equates to a 20% increase in peak relative strain in an athlete with a 10° deficiency in internal rotation. Additionally, Beaulieu et al. were able to demonstrate a difference in peak strain between the male and female specimens, with peak ACL strain in female specimens shown to be 45% larger on average than the male specimens, regardless of the limitations to internal rotation. The authors suggest that the increase in peak ACL strain with decreased femoral internal rotation increases the risk of ACL rupture with pivoting activities.

Table 1. Summary of literature.

	Clinical assessment	Radiological assessment	Cadaveric assessment
Gomes et al.[16]	Rotational range of hip movement was decreased in patients with ACL rupture		
Gomes et al.[17]	Rotational range of hip movement was decreased in patients with ACL re-rupture		
Tainaka et al.[18]	Limited rotational range of hip movement was associated with a history of non-contact ACL injury		
Bedi et al.[19]	1.Limited internal rotation of the hip was associated with a previous ACL injury 2.Peak anteromedial ACL strain increased as hip internal rotation was decreased (in silico model)		
Lopes et al.[20]	Mean rotational range of hip in the non-contact ACL injury patients was 13.3° smaller when compared with the contact ACL-injured patients	No difference in the frequency of cam or pincer deformity between contact and non-contact ACL-injured patients	
VandenBerg et al.[21]	The odds ratio of having an ACL tear decreased by a factor of 0.419 for every 10° increase in hip internal rotation	1.No difference in the frequency of hip dysplasia or cam-type morphology between ACL-injured and non-injured patients 2.ACL-injured patients showed a greater incidence of the positive posterior wall sign and the positive ischial spine sign	
Gomes et al.[22]		56% of ACL-injured patients with a rotational range of hip less than 80° had bone abnormalities around the hip	
Philippon et al.[25]		ACL-injured patients had a significantly higher α angle on the injured side when compared with controls	
Beaulieu et al.[26]			Peak anteromedial ACL relative strain was inversely related to the available range of internal rotation of the femur
Beaulieu et al.[27]			The specimens with limited range of internal rotation of the femur had a higher risk of ACL failure than the specimens with free range of rotation

ACL: anterior cruciate ligament.

In a further cadaveric study by this group, 32 human knee specimens from 8 male and 8 female donors were tested using a custom-built testing apparatus capable of simulating repeated single-leg pivot landings with a four-times-bodyweight load. Such action was able to induce knee compression, knee flexion and internal tibial torque.[27] These test loads were applied to each pair of specimens – in one knee with limited internal femoral rotation (i.e. the femoral rotation device was locked) and in the contralateral knee with free range of rotation of the femur and two springs to simulate the hip rotator muscles. The landings were repeated up to 100 trials or until the ACL failed. It was found that the specimens with limited range of internal rotation of the femur had a significantly higher risk of failure than the specimens with free range of rotation, further supporting this group's previous hypothesis that impingement-induced strain on the ACL increased the risk of rupture. Similar to their previous results, they also found a significant difference between the male and female cadaveric specimens, with higher failure rates demonstrated in the female cadavers.

Summarized literature review is shown in Table 1.

Conclusion

There is some clinical, radiological and cadaveric evidence to support the proposed role of restricted hip movement leading to ACL injury. Clinical and radiological studies assessing the risk of ACL injury have clearly demonstrated an association between restriction of internal and external rotation of the hip and the likelihood of previous ACL injury. However, prospective cohort studies are required to establish restricted hip as a risk factor for ACL injury. Furthermore, biomechanical in silico simulations and cadaveric studies have provided evidence for a mechanism of restricted hip-induced strain on the ACL, highlighting the importance of restrictions in internal rotation. These insights will hopefully lead to targeted post-reconstruction rehabilitation protocols in cases where there is no morphological abnormality in the hip bony leading to the limitation in movement, thus helping prevent both ACL injury and ACL re-rupture. These studies also highlight the importance of clinical examination of the rotational range of movement of the hip when assessing patients with ACL injury.

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References

1. Waldén M, Hägglund M, Magnusson H, et al. ACL injuries in men's professional football: a 15-year prospective study on time trends and return-to-play rates reveals only 65% of players still play at the top level 3 years after ACL rupture. *Br J Sports Med* 2016; 50: 744–750.
2. Mall NA, Chalmers PN, Moric M, et al. Incidence and trends of anterior cruciate ligament reconstruction in the United States. *Am J Sports Med* 2014; 42(10): 2363–2370.
3. Brophy RH, Wright RW and Matava MJ. Cost analysis of converting from single-bundle to double-bundle anterior cruciate ligament reconstruction. *Am J Sports Med* 2009; 37: 683–687.
4. Lohmander LS, Englund PM, Dahl LL, et al. The long-term consequence of anterior cruciate ligament and meniscus injuries: osteoarthritis. *Am J Sports Med* 2007; 35: 1756–1769.
5. Griffin LY, Albohm MJ, Arendt EA, et al. Understanding and preventing noncontact anterior cruciate ligament injuries: a review of the Hunt Valley II meeting, January 2005. *Am J Sports Med* 2006; 34: 1512–1532.
6. Posthumus M, Collins M, September AV, et al. The intrinsic risk factors for ACL ruptures: an evidence-based review. *Phys Sports Med* 2011; 39: 62–73.
7. Pollard TCB, Villar RN, Norton MR, et al. Femoroacetabular impingement and classification of the cam deformity: the reference interval in normal hips. *Acta Orthop* 2010; 81: 134–141.
8. Röling MA, Mathijssen NMC and Bloem RM. Incidence of symptomatic femoroacetabular impingement in the general population: a prospective registration study. *J Hip Preserv Surg* 2016; 3(3): 203–207.
9. Griffiths EJ and Khanduja V. Hip arthroscopy: evolution, current practice and future developments. *Int Orthop* 2012; 36(6): 1115–1121.
10. Khanduja V and Villar RN. Arthroscopic surgery of the hip: current concepts and recent advances. *J Bone Joint Surg Br* 2006; 88(12): 1557–1566.
11. Alshameeri Z and Khanduja V. The effect of femoro-acetabular impingement on the kinematics and kinetics of the hip joint. *Int Orthop* 2014; 38: 1615–1620.
12. Imam S and Khanduja V. Current concepts in the diagnosis and management of femoroacetabular impingement. *Int Orthop* 2011; 35: 1427–1435.
13. Bedi A, Kelly BT and Khanduja V. Arthroscopic hip preservation surgery: current concepts and perspective. *Bone Joint J* 2013; 95–B: 10–19.
14. Fayad TE, Khan MA and Haddad FS. Femoroacetabular impingement: an arthroscopic solution. *Bone Joint J* 2013; 95–B: 26–30.
15. Khanduja V and Villar RN. The arthroscopic management of femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc* 2007; 15: 1035–1040.
16. Gomes JLE, de Castro JV and Becker R. Decreased hip range of motion and noncontact injuries of the anterior cruciate ligament. *Arthrosc J Arthrosc Relat Surg* 2008; 24: 1034–1037.
17. Gomes JLE, Palma HM and Ruthner R. Influence of hip restriction on noncontact ACL rerupture. *Knee Surg Sports Traumatol Arthrosc* 2014; 22: 188–191.
18. Tainaka K, Takizawa T, Kobayashi H, et al. Limited hip rotation and non-contact anterior cruciate ligament injury: a case-control study. *Knee* 2014; 21: 86–90.
19. Bedi A, Warren RF, Wojtys EM, et al. Restriction in hip internal rotation is associated with an increased risk of ACL injury. *Knee Surg Sports Traumatol Arthrosc* 2016; 24: 2024–2031.
20. Lopes OV, Gomes JLE and de Freitas Spinelli L. Range of motion and radiographic analysis of the hip in patients with contact and non-contact anterior cruciate ligament injury. *Knee Surg Sports Traumatol Arthrosc* 2016; 24: 2868–2873.
21. VandenBerg C, Crawford EA, Sibilsky Enselman E, et al. Restricted hip rotation is correlated with an increased risk for anterior cruciate ligament injury. *Arthrosc J Arthrosc Relat Surg* 2017; 33: 317–325.
22. Gomes JLE, Palma HM and Becker R. Radiographic findings in restrained hip joints associated with ACL rupture. *Knee Surg Sports Traumatol Arthrosc* 2010; 18: 1562–1567.
23. Johnston TL, Schenker ML, Briggs KK, et al. Relationship between offset angle alpha and hip chondral injury in

femoroacetabular impingement. *Arthrosc J Arthrosc Relat Surg* 2008; 24: 669–675.

24. Nötzli HP, Wyss TF, Stoecklin CH, et al. The contour of the femoral head–neck junction as a predictor for the risk of anterior impingement. *J Bone Joint Surg Br* 2002; 84: 556–560.
25. Philippon M, Dewing C, Briggs K, et al. Decreased femoral head–neck offset: a possible risk factor for ACL injury. *Knee Surg Sports Traumatol Arthrosc* 2012; 20: 2585–2589.
26. Beaulieu ML, Oh YK, Bedi A, et al. Does limited internal femoral rotation increase peak anterior cruciate ligament strain during a simulated pivot landing? *Am J Sports Med* 2014; 42: 2955–2963.
27. Beaulieu ML, Wojtys EM and Ashton-Miller JA. Risk of anterior cruciate ligament fatigue failure is increased by limited internal femoral rotation during in vitro repeated pivot landings. *Am J Sports Med* 2015; 43: 2233–2241.