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Uncertain predictive value of traditional diagnosis for femoroacetabular impingement in young people. Is this a pure pathology or a morphological and functional sneaky feature?

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Summary

Femoroacetabular impingement (FAI) is a pathological condition with an underestimated prevalence both in general adult population and in young and sportive people. Predisposing factors are still not clear, but it seems related to a previous pathology leading to hip osteoarthritis. Considering FAI as a pure anatomical dysfunction it could be absolutely reductive. Symptoms seem to be linked to a late onset of clinical presentation of damage to histological and anatomical structures of the hip joint, both in femoral and in pelvis portions. Anatomical features can vary and mixed between several forms of alterations. Clinicians and physicians should conduct their studies in an early approach to discover prior signs of anatomical and functional sneaky features that occur prior to symptoms. In the literature, the use of classical and well known clinical and radiological tests has been demonstrated to lead to a late diagnosis; it is also linked to a poor sensitivity. Arthro-MRI has been proposed as an innovative thorough method to properly evaluate the anatomical pattern, but recognized targets and methodology are still missing. In addition, this does not underline the functional patterns and dysfunction, characteristic of young people suffering from this clinical entity. Biomechanical evaluation, both in kinematic and in kinetic studies, may represent a correct means to evaluate people with pathological family history or predisposing factors to discover the early features of FAI and hypothesize treatment and prevention pathways.

Key words: femoroacetabular impingement, diagnostic instruments, biomechanical evaluations

Introduction

Femoroacetabular impingment (FAI) is a relatively new clinical diagnosis. Previous literature has reported an estimated 10-15% prevalence rate of FAI in the general population, although this range can be estimated from 10 to 39% depending upon the criteria used for diagnosis [1]. FAI has been recognised as a source of hip pain in young adults and as a dysfunction with labral tears in adults. It has implicated as cause of development of hip osteoarthritis (OA) resulted by repetitive micro-traumas to the hip joint that cause mechanical wear of the articular cartilage and/or labral fibrocartilage [2]. The pathological mechanism involves abnormal repetitive abutment of the anterior femoral head neck junction on the acetabular rim during internal rotation and flexion of hip. This leads to a series of degenerative changes including disruption of the labrum and delamination of the acetabular articular cartilage [3]. In recent years, emerged evidence has supporting the theory that FAI may be a precursor of early hip osteoarthritis in up to 40% of patients with diagnosis of idiopathic OA of the hip [4]. Recent studies have identified radiographic findings of FAI in asymptomatic populations suggesting that not all people with FAI will progress to OA or require surgery [5]. The diagnosis of FAI can be challenging because of the diversity of the affected patient population and the wide spectrum of disease patterns. For surgeons, clinical diagnosis is a challenge. In fact, the abnormalities found in patients with FAI can be also anatomical features in an asymptomatic young male or female. Ganz et al. found that up to 90% of young patients who develop degenerative joint disease of the hip have an underlying early structural problem [6]. Furthermore, in the literature different studies have shown that the anatomical abnormalities by radiological evaluation can be found in patients without any positivity to clinical tests; at the same time, symptomatic patients at the beginning of painful pathology have already ostheochondral lesions, acetabular rim lesion, and pseudocystis [7]. Different authors, in prevalence studies, found a high prevalence of clinical findings and radiological features of FAI in young athletes, especially football players, with prevalence of the cam type. In many studies, athletes have a higher prevalence of anatomic abnormalities without clinical signs of impingement [8]. This situation seen as FAI can be an anatomical feature in young active people with respect to a clear pathology. In this paper, we review several critical aspects into diagnostic landscape of this particular clinical entity; in this way, we try to underline the poor reliability of standard diagnostic instruments for a pathology that is almost recognized too late.

Morphological aspects

The conceptual model of FAI implies an abnormal contact between the femur and acetabular rim at the end of range of motion, particularly the flexion [9]. FAI may result from two major forms of anatomical abnormalities and two distinct types have been described: the cam type based on the anomalous morphology occurring in the femur and pincer type resulting in abnormal morphology or orientation of the acetabulum; the majority of patients presenting with FAI have a combination of cam and pincer types [10]. In the cam type, typical in young active males, the predominant abnormality is in the contour of the anterior/superior femoral head-neck junction with a normal morphology of the acetabulum; the etiology is not completely understood. This junction is either flattened or convex in the cam type. In addition, the femoral head may become somewhat aspherical due to this morphologic abnormality [11]. During motion, especially flexion, the non-spherical portion of the femoral head has an abnormal contact under the acetabular rim, which can result in damage predominately to the acetabular cartilage in the anterosuperior rim. The repetitive micro-traumas to the joint causes mechanical wear of articular cartilage and/or labral cartilage and consequently causes pain and a decrease in flexion and internal rotational range of motion [12]. In the second FAI type, pure pincer type, typical in middle-age and older women, the predominant abnormality is related to the morphology of the acetabulum with a normal head-neck junction. The abnormalities include acetabular retroversion, anterior and/or lateral over-coverage, and protrusio acetabulae [13]. These conditions increase the depth of the acetabulum or the circumferential over-coverage of femoral head. During motion, the impact of the femur head against the acetabular rim leads to pincer abutment and acetabular lesions into the rim [14].The typical lesion of pincer type is the degeneration of labrum with, sometimes, a consequent intra-substance cyst or ossification of the rim. These conditions create an additional deepening of the acetabulum and worsening of the over-coverage [15]. The lesions in pincer type are more often anteriorly for the repetitive abutments that can result in chondral injury in postero-inferior acetabulum.

In the pincer FAI, the articular cartilage lesions are typically limited in a small region of acetabular rim, while cam impingement is characterized by deeper cartilage lesions (also large flap) and more extensive labral tears caused by the greater degree of articular compression from the non-spherical femoral head [16].

Limits in clinical diagnosis

The clinical presentation of FAI can be variable: patients often report groin pain associated with athletic activities, prolonged walking, or prolonged sitting. Therefore, there is a slow onset of groin pain with or without mi-nor trauma. Thus, the pain starts gradually or can develop after repetitive minor traumas in young adults to middle-aged, active adults, but the diagnosis can be made in adolescents as well [17]. Pain can occur in the knee, low back, or buttock substantially broadening the population potentially affected by FAI. All these aspects emphasize the extremely variable presentation of FAI [18].

The hip flexion is limited in some case to less than 45°, but it can also be equal to the asymptomatic side. The gait patterns can range from normal to a slightly antalgic limp.

Although different tests are available for clinical examination, the main tests used for diagnosis are the impingent test and postero-inferior impingement. The anterior impingement sign is a useful practice made to recreate cam and pincer FAI-related pain. It's performed by placing the patient supine and the hip is flexed to 90°, internally rotated and adducted, resulting in reproduction of the patient's symptoms. A positive test leads to direct contact between the femoral neck and acetabular rim. This test has often been associated to a good sensitivity, but a true statistical assessment of the sensitivity and specificity of this test is lacking [19]. The postero-inferior impingement sign is performed putting the patient supine at the edge of the examination table, the hip is extended and slightly externally rotated with the knee flexed. The test is positive with reproduction of symptoms: the patient feels pain or demonstrates apprehension [20].

The clinical evaluation of FAI have several limits for a clinical diagnosis, and different studies have report on the limits of clinical signs and their sensitivity or sensibility; clinical signs and hip examination tests have an uncertain reliability [21]. There is evidence for about only 45% of patients having hip pain and only 25% of patients feeling pain during the flexion/adduction and compression test. Flexion-120°/adduction/IR pain is the most frequent clinical sign found during evaluation of patients with suspected FAI (75%); flexion/adduction/IR limitation is evidenced in a range of patients from 34 to 51% [22].

An increasing body of evidence confirms the prevalent idea in literature about diagnosis and characteristics of FAI: in fact, hip symptoms may initially be intermittent but become more frequent as labral disease and articular degeneration progress. There is a recently proposed concept describing FAI as abnormal anatomic relationships within the hip joint that may lead to articular damage; the anatomic abnormalities lead to pathologic contact and shearing forces at the acetabular labrum and cartilage during physiological hip motion. It is only when these forces lead to cartilage wear or labrum wear and eventually osteoarthritis that clinical signs became evident and FAI can be considered as a pathology. On the contrary, without degenerative conditions onto either cartilages or rim, abnormal anatomical features of pure FAI may be often present, even if recognition is generally missing [23].

Role of imaging and its limits

As mentioned, there is poor correlation between pain and radiographic findings of FAI without an evidence of a single radiographic predictor of pain. Plain radiography remains the preferred diagnostic tool. Different studies have shown that diagnosis requires accurate radiographic representation of the proximal femur on AP-view to be clinically reliable [24]; on AP radiographs, femoral rotation, which may alter the appearance of the proximal femur, may substantially decrease the clinical reliability of these parameters [25]. Additionally, other parameters, such as the lateral centre-edge angle (LCEA) and medial proximal femoral angle (MPFA), both originally validated on AP radiographs, have been adapted in diagnosing FAI and used to predict the progression of OA. Monazzam et al. characterized the potential effect of femoral rotation on AP alpha angle, LCEA, and MPFA on AP hip radiographs. They found that the alpha angle decreased with progressive IR of the femur and increased with ER; similar to the alpha angle, the MPFA increased with ER and decreased with IR, but in contrast to the alpha angle no large variation of the LCEA with femoral rotation was found. The increase in MPFA with IR is related to the physics of conventional AP radiography: traditional bi-planar radiography uses a diverging conical x-ray beam that results in the magnification of structures that are closer to the x-ray beam, which in the case of AP radiographs, are the more anterior structures. In fact, as the proximal femur internally rotates, the greater trochanter becomes more anterior and therefore will be magnified relative to the femoral head; the greater trochanter proximal tip becomes more vertical on the AP radiograph relative to the center of the femoral head and therefore decreases the MPFA. In conclusion, the effect of femoral rotation on the alpha angle and MPFA is characterized by a linear decrease in measurement with IR. The LCEA shows minimal variation with femoral rotation and no clear effect can be characterized. Global availability of plain radiographs is of strong positive value, but the variable measurements found with femoral rotation show the importance of standardizing limb positioning and rotation while obtaining these radiographs because of diagnostic and treatment implications [26]. In the literature there is a discrepancy in reporting the prevalence for cam, pincer, or mixed FAI and in particular the correlation between clinical findings and radiological signs of impingement. Few studies have evaluated the correlation between clinical elements and radiological evaluation: there are few systematic analyses comparing studies of asymptomatic, symptomatic individuals, and athletes in order to determine differences in radiographic signs of FAI [27,28]. A systematic review by Mascarenhas et al. in 2015 evaluated the prevalence of FAI among athletes, symptomatic, and asymptomatic patients with particular attention to radiographic findings and correlation of radiological measurements with clinical elements. In symptomatic patients, cam-type impingement was found in an average of 49 ± 21.2% of patients, pincer-type impingement in 28.5 ± 19.2%, and mixed-type in 40.2 ± 18.0%. The mean alpha angle was 67.4 ± 8, labral tears were reported in 27.6 ± 9.2 of patients, and the crossover sign was reported in 18.2%. A high percentage of symptomatic subjects demonstrated an increased angles, labral tears, and epiphyseal torsion angles compared to asymptomatic normal volunteers. In fact, the evidence of FAI in asymptomatic people is lower, but absolutely relevant with respect to symptomatic patients, with a mean angle of 47.0 ± 2 and a positive crossover sign reported in 28.5 ± 15.8%. The prevalence of cam-type was 22.4 ± 6.2 of all asymptomatic patients, while pincer-type was detected in 57% and mixed-type was found in 8.8 ± 5.1% [29]. Multiple studies reported that cam-type and mixed-type impingements are related to a male predominance among symptomatic patients; additionally, several studies have suggested different results regarding the prevalence of pincer-type in males and females [30,31]. For symptomatic hips, in males there was a tendency to show significantly larger angles as well as a tendency of FAI in painful hips and bilateral involvement [32]. Studies involving athletes showed that mixed FAI was the most represented type and a higher percentage of males showed radiologic evidence of FAI compared to females. Radiological parameters showed that labral tears were reported in 49.8 ± 21.4% and a crossover sign was present in 64.5 ± 18.6% [33].

Discussion

Reviewing the literature, we can affirm that cam-type is more frequent in symptomatic and athletic subjects, while no difference was found for pincer-type FAI [34,35]; the mixed type prevails in athletes and asymptomatic patients. In the literature, the most represented sports involved in FAI are football, soccer, and ice hockey. In football players, the angle is an important predictor factor of hip pain; mixed type is the most common type and also the majority of football players showed radiological evidence of FAI, but a greater variability was found in literature; soccer players are the athletes most involved by FAI with a predominance of males compared to female players and a higher percentage of radiological evidence in males. Regarding radiological findings, the mean angle is greater in symptomatic subjects compared to athletes and asymptomatic subjects, while for the other signs there were no significant differences, including positive crossover sign [36,37]. Nepple et al. reported that the maximum angle was significantly greater in males (mean 70.8°) than in females (mean 57.6°) with a significantly more disability for women despite having less deformities and intra-articular disease [38]. Although females have greater acetabular and femoral anteversion, early cartilage changes and a lower evidence of clinical signs, while men have advanced cartilage changes and labral disease; pincer-type is more common in males than female by clinical and radiographic diagnosis [39]. Some systematic reviews have reported a male predominance for cam and mixed deformity (overall distribution M/F is 14:1, pincer type distribution M/F is 1:3); other studies evidenced that angle poorly discriminates symptomatic and non-symptomatic individuals, but increasing alpha angles have a strong association with decreased function pain, and have a good predictive role for the development of OA [40]. A systematic review has shown that two-thirds of asymptomatic subjects have a pincer morphology type, although among the studies included the morphologic criteria for the pincer type were poorly defined [41]. Another diagnostic option to evaluate soft tissue hip injuries in patients undergoing workup for FAI is MRI. MRI can reveal intra-articular soft tissue disease commonly seen with FAI, such as the acetabular labrum and articular cartilage damage. In addition to soft tissue structures, MRI can be used to identify bone-pathomorphology, such as cam deformities, acetabular version, femoral head-neck offset, and femoral anterior-torsion [42]. MRI is critical to obtain imaging of the hip with a good resolution in order to accurately assess the hip joint and soft tissue structures; it can be also used to assess the overall health of articular cartilage [43]. The most important role of preoperative MR evaluation in patients affected by FAI is accurate assessment of extension of damage. MRI is more sensitive than radiographs alone or in association with axial MRI; it has a determinant role for the planning of head-neck osteoplasty [44]. Finally, it is useful for evaluation of symptomatic or therapy-resistant cases without evidence of impingement at radiographs. MRI has several limitations in a complete assessment of FAI; in fact, it has a lower diagnostic utility for the assessment of chondral lesions because of limited cartilage thickness; it cannot show 3D hip geometry or the close apposition between the femoral head and acetabular cartilage layers [45].

Potential role of biomechanic evaluation

Several studies have reported varied results in evaluation of hip kinematics and kinetics in patients with cam FAI that may be altered by predisposing factors and compensatory strategies associated with FAI [46]. Biomechanical analysis conducted in some studies showed that patients with FAI exhibit decreases in sagittal frontal and transverse plane hip kinematics and make frontal plane pelvis motion lower compared to healthy controls [47]. Fewer studies have performed kinematic evaluations in people with cam FAI during tasks involving large hip flexion excursions; a decreased sagittal plane hip motion and peak hip internal rotation during stair climbing in patients with FAI compared to healthy controls have been reported [48]. Lamontagne et al. in 2009 reported decreased total plane sagittal pelvis excursion during a maximum depth squat task in persons with cam FAI compared to healthy controls [49]. Some authors showed that diminished total sagittal pelvis excursion during squatting significantly distinguished in symptomatic cam FAI patients from other groups (symptomatic with cam morphology, asymptomatic group with cam morphology, and asymptomatic without cam morphology). Kumar et al. in 2014 reported greater peak hip adduction and greater internal rotator moments in a preliminary investigation of people with FAI and control subjects during a deep squat task [50].

Other researchers have documented that individuals with FAI show hip muscle weakness: this suggests that impaired muscular control may can lead to altered kinematics in these patients [51].

Furthermore, in addition to kinematics, evaluation of hip kinetics may provide indirect information regarding muscular control. Bagwell et al. compared three-dimensional hip kinematics and kinetics during deep squatting between people with cam

FAI and age and sex matched controls; then they compared the sagittal pelvis and femur angles at the time of peak hip flexion between groups to determine the kinematics used to achieve hip flexion. In the study, diminished squat depth, decreased peak hip internal rotation, and a more anteriorly tilted pelvis at the time of peak hip flexion have been described as associated elements. Concerning adductor moments, there were no differences in the mean hip adductor moment or mean hip external rotator moment between groups, no differences in peak hip flexion or peak hip abduction between groups were seen, but they did show decreased mean hip extensor moments compared to the control group [52].

It has been demonstrated that a decreased hip internal rotation decreases the hip extensor muscle activity and this aspect may contribute to alter the posterior pelvis tilt [53]. This condition may contribute to impingement approximating the femoral head-neck junction with the acetabulum. However, at present, standard parameters in kinematic and kinetic analysis to make a correct and complete biomechanical exam of hip movement are not available. In recent years, biomechanical evaluations have been proposed as a predictive exam for correct early diagnosis of FAI and early treatment approaches.

Conclusions and future perspective

Several clinical and radiological exams, tests, and comparisons have been proposed in the literature and clinical practice in the last years. At the moment, diagnosis of FAI is always too late because of damage at chondral layers, bone structures, and fibrocartilage rim that are already present at the moment of discovery.

It is still not known if FAI may be linked to a predisposing genetic pattern. It is also unclear how microtraumas, biomechanical patterns, overuse, and daily activities can influence the onset of symptoms. At any rate, we do know that the onset of symptoms is a late discovery of anatomical or functional dysfunction linked to FAI.

The classical diagnostic methods have shown to have several limits, both in sensitivity and in clinical practice. More studies are necessary to show functional abnormalities that appear before anatomical and morphological damage and clinical evidence of FAI.

Arthro-MRI seems to be a promising new method, but there is still a lack of methodology and targets for FAI.

Biomechanical functional evaluations have been described as an early method of study in order to anticipate the onset of pure pathology. Nonetheless, these cannot be used as a global screening, but decisional flow-charts based on clinical practice and more systematic guidelines and scientific evidence is needed.

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Conflict of interest statement

All the Authors declare no conflict of interest.

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Ethical consideration

This study doesn't include experimental procedures onto patients. The study conforms to the principles laid down in the World Medical Association's Declaration of Helsinki and its later revisions. The study was approved by the local Research Ethics Committee.

Authors' contribution

RP, FM, LMDG: wrote the manuscript down; PC, AC: collected the data. PA: designed the study. All the Authors read and approved the final manuscript.

Availability of data and materials

This is a review, so all the data are available at references. The datasets used and/or analyzed during the current study are also available from the corresponding author.

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