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REVIEW

A New Clinical Examination Algorithm to Prescribe Conservative Treatment in People with Hip-Related Pain

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ABSTRACT

Hip-related pain is a common issue in active adults affecting their quality of life, mobility, and overall function, and it can lead to persistent disability. However, diagnosing hip-related pain is challenging due to the many potential sources and causes, including intra-articular and extra-articular pathology, and referred pain from other areas (lumbar or groin related pain). To address this, there is a need for a clinical algorithm based on the best available evidence and expert consensus. This algorithm could guide healthcare professionals in assessing and managing patients with hip-related pain, during the diagnosis, test selection, intervention, monitoring, and promoting collaboration among various healthcare providers. This clinical algorithm for hip-related pain is a comprehensive, flexible, adaptable to different settings, and regularly updated to incorporate new research findings. This literature review aims to establish a clinical algorithm specifically for prescribing exercise treatment to patients with hip-related pain, addressing their individual needs and enhancing their overall care.

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Key Summary Points

The algorithm customizes conservative treatment plans for hip-related pain, addressing the specific patient's condition, such as the nature and location of the pain, contributing factors, and individual health considerations.

The algorithm ensures that treatment recommendations align with the most current and effective evidence-based practices.

The algorithm's targeted nature minimizes the need for unnecessary interventions, reducing healthcare costs associated with trial-and-error treatments.

INTRODUCTION

Hip-related pain is a common complaint among adults, especially those who are physically active or have a history of trauma or osteoarthritis, affecting the quality of life, mobility, and function of the patients, and can lead to chronic disability if not properly

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diagnosed and treated [1, 2]. However, the diagnosis of hip-related pain is challenging, as there are many possible sources and causes of pain, such as intra-articular pathology, extra-articular pathology, or referred pain from other structures [3]. Therefore, it is important to establish a clinical algorithm that can guide the clinicians in the assessment and management of patients with hip-related pain, based on the best available evidence and expert consensus. A clinical algorithm can help to identify the most likely diagnosis, select the appropriate diagnostic tests and interventions, monitor the outcomes and complications of the treatment, and can also facilitate the communication and collaboration among different health professionals involved in the care of patients with hip-related pain, such as primary care physicians, orthopedic surgeons, physiotherapists, radiologists, and rheumatologists [4]. A clinical algorithm for the treatment of patients with hip-related pain should be comprehensive, flexible, and adaptable to different clinical settings and patient preferences. It should also be updated regularly to incorporate new research findings and recommendations. Therefore, the purpose of this review is to establish a clinical algorithm to prescribe exercise treatment for patients with hip-related pain.

HIP-RELATED PAIN CLINICAL EXAMINATION

The clinical diagnosis of patients with orthopedic problems is a complex skill process that primarily consists of patient interview and physical examination. An inadequate subjective history, failure to order appropriate physical examination test, incorrect interpretations of these or failure to create a proper follow-up plan are the most common diagnostic errors [5]. The aim of this systematic and evidence-based examination process is to accurately diagnose hip-related pain. This process has six different stages: (1) subjective history and patient-reported outcome measures; (2) rule out red flags: musculoskeletal and non-musculoskeletal pathology; (3) rule out lumbar spine, pelvic girdle, hip stress fracture pathology, or other groin pain clinical entities; (4) hip architecture determinants; (5) hip-related pathology identification; and (6) hip symptom modification procedure (see Fig. 1). This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

Patient Interview—Subjective History and Patient-Reported Outcome Measures

The patient history remains the keystone of accurate diagnosis and it will provide the diagnosis in most cases. In fact, patient history has been suggested to be instrumental in determining 56–90% of diagnoses in various types of patients [5, 6]. We have to consider the following principles when taking a patient history: allow enough time, be a good listener, know the sport, discover the exact circumstances of the injury, consider the characteristics of patient's pain or psychological factors, among other factors [6].

Usually, an individual with hip-related pain can have an insidious or gradual onset of symptoms [7]. The pain frequently starts in one region and is unilateral, but it can gradually progress to other regions and become bilateral. It can be explained by the complex anatomy of the anterior relations and muscle attachments of the groin region [8]. The localization of pain is important in determining which clinical entity is present and we can use models such as the "3G approach" with specific anatomical landmarks and borders of the groin triangle to accurate differential diagnosis [8].

Patient-reported outcome measures (PROM) are commonly used to capture treatment response and provide aspects of the patients' overall health [9]. According to the biopsychosocial model, disability involves dysfunction in one or more of the following levels: impairment, activity limitations, and participation restrictions. In fact, individuals with hip-related disorders often experience pain, functional impairments, and challenges in performing daily life and sports activities [2]. Furthermore, measurement instruments are

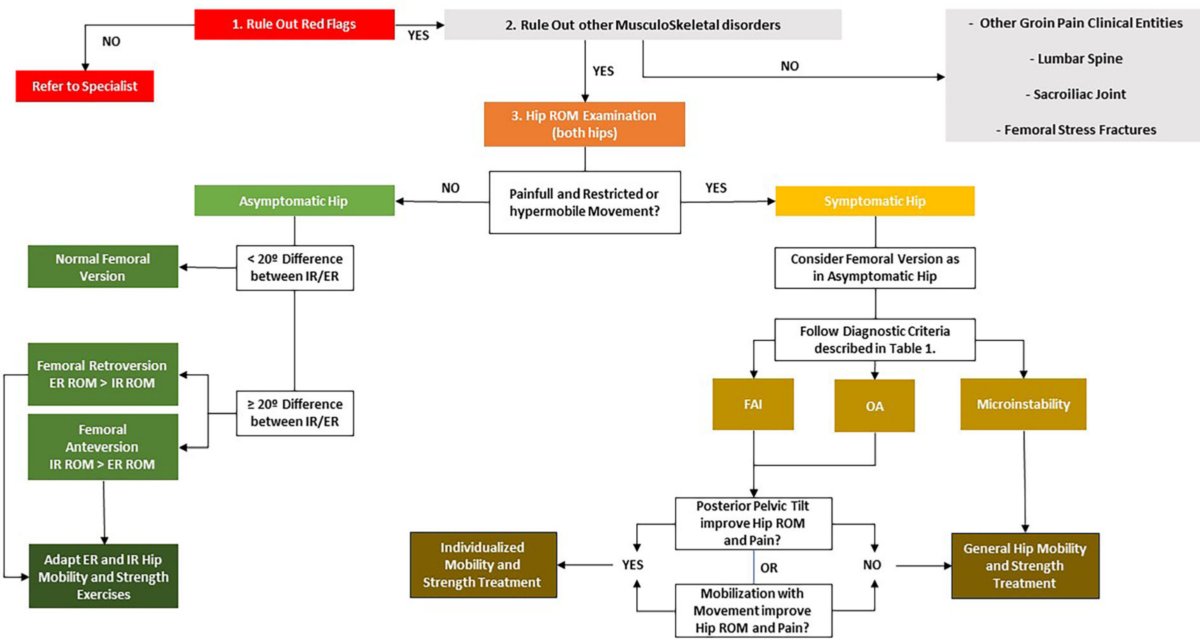

Fig. 1 Clinical examination algorithm to prescribe conservative treatment in hip-related pain. *ER* external rotation, *FAI* femoroacetabular impingement, *IR* internal rotation, *OA* osteoarthritis, *ROM* range of motion

frequently used and recommended to support clinical decision-making, healthcare policies, and reimbursement processes. This necessitates the systematic collection of these measurement instruments in the clinical setting, which is why these measurement instruments must be valid and possess appropriate psychometric properties [2].

Since several self-administered questionnaires have focused on patients with osteoarthritis or those undergoing hip arthroplasty with a limited activity level that may not be applicable to young patients with different expectations (e.g., Harris Hip Score, Hip disability and Osteoarthritis Outcome Score, Oxford Hip Score, or Lequesne Index Severity for Osteoarthritis of the Hip), the international Hip Outcome Tool (iHOT-33) was developed to measure physical function and quality of life in young and active patients with hip pathology [2]. Subsequently, Griffin et al. developed a shortened version of the iHOT-33 called the iHOT-12, which is based on 12 items from the original version and covers four domains: (1) symptoms and functional limitations, (2) sports and leisure activities, (3) work-related concerns, and (4) social, emotional, and lifestyle issues [10, 11]. Furthermore, the Hip Outcome Score (HOS) questionnaire was initially designed to assess surgical treatment outcomes in patients with hip pain but has also demonstrated high reliability in patients with femoroacetabular impingement (FAI) syndrome and labral tears [12, 13]. These questionnaires have proven to be valuable tools for assessing initial functionality and for monitoring patients with hip-related pain during their follow-up [13, 14].

Rule Out Red Flags and Musculoskeletal and Non-musculoskeletal Pathology

Groin or anterior hip region is a common area for various serious and non-musculoskeletal conditions. The presence of certain signs and symptoms (e.g., a history of trauma, fever, unexplained weight loss, burning during urination, night pain, prolonged corticosteroid use, and a history of cancer) that suggest the possible existence of more severe medical issues is referred to as “red flags.” A thorough clinical examination and a standardized medical questionnaire are necessary to rule out oncological, urological, gynecological, or rheumatological conditions (e.g., prostatitis, genital herpes, or appendicitis) [5, 15]. A musculoskeletal pathology to consider is femoral head osteonecrosis, which can result from prior injuries or common risk factors such as prolonged corticosteroid use, chronic alcohol consumption, and connective tissue diseases, especially systemic lupus erythematosus, although its etiology can be idiopathic. When these risk factors are present alongside deep progressive inguinal pain that worsens with axial loading of the femur, it is necessary to rule out femoral head osteonecrosis [16]. It is important for the clinician in the decision-making process to recognize these conditions to refer to the corresponding specialist.

Rule Out Lumbar Spine, Pelvic Girdle, Hip Stress Fracture Pathology, or Other Groin Pain Clinical Entities

Once red flags are ruled out, the next stage is to attempt to rule out lumbar spine, pelvic girdle, hip stress fracture pathology or others groin pain clinical entities. Repeated and/or sustained lumbar movements test (e.g., flexion, extension, or side-bending) can be performed to determine patterns of pain provocation (centralization and peripheralization) related to lumbar spine pathology. According to the literature, if repeated and/or sustained movements do not reproduce symptoms, the lumbar spine can be ruled out. It has high sensitivity (SN) [90] and small negative likelihood ratio (LR−) (0.12) [5, 17].

Once lumbar spine has been ruled out, the pelvic girdle region or sacroiliac joint should be assessed. The reliability of pelvic palpation tests used to assess sacroiliac joint movement is poor [18]. Pain provocation-based clinical special test have the best diagnostic accuracy for sacroiliac joint [5, 19]. Therefore, Laslett's cluster (compression, distraction, Gaenslen's, thigh thrust and sacral thrust test) is performed. If tests do not reproduce symptoms, the pelvic girdle or sacroiliac joint pathology is ruled out. SN and LR− were 91 and 0.08, respectively [18, 19].

Another pathology to consider in anterior hip pain is stress fractures of the femur, pubic rami, or acetabulum. Patients with stress fractures of the pubic ramus experience pain in the front of the hip that extends medially to the adductor region. Acetabular fractures are uncommon but should be considered when a stress pelvic injury is suspected. Stress fractures of the femoral neck can be challenging to detect clinically, but in the patient's history, there may be signs of swelling and/or effusion with pain that worsens during activity or at night [16]. Stress fractures are frequently observed in endurance athletes or young and healthy recreational runners. Insufficiency-type stress fractures are seen in elderly patients with osteoporosis. It has been described that the Patellar-Pubic Percussion Test (PPPT) and the fulcrum test are the most reliable tests during physical examination [20]. The PPPT appears to be an effective diagnostic test for hip-related fractures due to high SN [92] and small LR− (0.06) [21]. A stethoscope is placed over the pubic symphysis while the examiner either taps or places a tuning fork on the patella. If there is no difference in percussion note, femoral neck fracture can be ruled out. Moreover, the fulcrum test is performed in combination with PPPT. The examiner places one forearm under the thigh and pushes the dorsum of the knee down with the opposite upper extremity. A positive test requires a bone scan to confirmation of a femoral stress fracture. If tests do not reproduce symptoms, femoral stress fracture can be ruled out. SN and LR− were 100 and 0, respectively [21, 22].

Another source of anterior hip pain are groin pain clinical entities that were divided into four defined clinical entities: adductor-related, pubic-related groin pain, inguinal-related and iliopsoas-related [23, 24]. Moreover, athletes can present multiple clinical entities as a source of groin pain.

Adductor-related groin pain is the most common clinical entity in sports that involve kicking or twisting movements [25]. The diagnostic criteria for adductor-related groin pain are adductor tendon origin tenderness and pain on resisted adduction testing [23, 24]. Palpation of the adductor tendon origin has showed very good intra and inter-rater agreement ($K > 0.80$) [26]. Absent tenderness at the adductor origin has shown high SN [93] to rule out adductor-related groin pain [27]. Resisted hip adduction testing using hand-held dynamometry has been shown good intra and inter-rater reliability in various testing positions (e.g., 0°, 45°, and 90° of hip flexion) [28, 29]. It has been suggested that there are differences in hip adductors muscles activation due to its hip flexor or extensor role [29]. Adductor longus has greatest activation at 45°, adductor magnus at 0° and 45°, gracilis at 45° and pectineus at 90° of hip flexion [30]. However, it is difficult to isolate adductor muscles due to multiple force vectors across the groin region [31]. Magnetic resonance imaging (MRI) evaluation is necessary to correlate clinical signs and may accurate diagnosis [32]. Abnormal adductor imaging and pubic bone marrow edema (BMO) are common MRI findings in (a)symptomatic soccer players [30]. The presence of pubic BMO is closely correlated to the site of pain, with the diagnosis of adductor origin pathology and several resisted adduction tests [27].

Another clinical entity that may cause groin pain is the pubic-related groin pain [23]. The proposed diagnostic criteria used on this clinical examination process are pubic symphysis tenderness, pain on pubic stress tests, pain on resisted adduction testing and pain on resisted abdominal contraction [23, 24]. Pubic symphysis palpation has showed good to very good intra and inter-rater agreement [26]. Pubic symphysis tenderness is associated with the presence of BMO. Absent tenderness at the pubic symphysis is the most accurate criteria to rule out pubic-related groin pain due to high SN and small LR− [27]. The pubic stress test or "crossover test" has been shown to have very good reliability during testing shear forces across pubic symphysis [27]. The squeeze test at 0° of hip flexion has been associated with pubic aponeurosis injury [27]. It has also shown higher levels of force output and torque production of adductor muscles in comparison to other positions, maximizing pubic symphysis stress [33, 34]. A positive test should be considered if pain over central pubic symphysis on Squeeze test is present. During the physical examination, the clinician should consider assessing an antalgic or waddling gait, or anteroposterior pelvic radiographs to demonstrate chronic degenerative changes at the pubic symphysis joint with the standing single leg stance (flamingo view) radiographs [35]. Moreover, resisted abdominal contraction have showed good to very good intra and inter-rater agreement [26].

Another musculoskeletal condition that can be a source of pain is neuropathies of the femoral, obturator, ilioinguinal, or genitofemoral nerves, which can cause pain in the anterior hip region. Tensioning of the femoral nerve is a neurodynamic maneuver used to detect neuropathy and is performed with the patient lying in a prone position while the knee is passively flexed. Reproduction of neurological symptoms is considered a positive test. Neuropathies of the obturator, ilioinguinal, or genitofemoral nerves are associated with previous surgical history of total hip arthroplasty or inguinal hernia repair.[3, 36].

Inguinal-related groin pain has a prevalence ranging from 2 to 40% [37, 38]. As well as in others clinical entities, different diagnostic criteria have been proposed. The diagnostic criteria for inguinal-related groin pain are tenderness of the inguinal canal, pain with Valsalva maneuver, coughing or sneezing, pain on resisted abdominal contraction, pain relief with block injection and no palpable inguinal hernia [23, 24]. Resisted abdominal contraction reliability has previously been cited. Ultrasound-guided nerve block injection has been found to be a reliable diagnostic approach and can provide near complete pain relief [39, 40]. Moreover, physical therapy can be an effective treatment following surgery [38].

The last clinical entity that we consider is the iliopsoas-related groin pain, with a prevalence ranging from 2.4 to 32% in sports that require repetitive kicking and sprinting [23, 41]. The diagnostic criteria are hip flexor complex tenderness, pain on hip extension stretch (modified Thomas test) and pain on resisted hip flexion in different positions [23, 24]. Hip flexor complex palpation and hip flexor stretch has showed very good intra and inter-observer agreement [26]. The modified Thomas test have demonstrated moderate to good reliability to assess hip flexor flexibility and pain [42–44]. Resisted hip flexor strength using hand-held dynamometer has been shown very good reliability in various testing positions [45]. Hip flexion leverage must be considered due to changes in muscle force or length, pelvic tilt, and abdominal muscles activation [31]. Recently, a new hip flexor flexibility assessment, the reactive hip flexor test, has shown excellent reliability to examine the interaction of both limbs, similarly during running or sprinting [46].

Once red flags, lumbar spine, pelvic girdle, hip stress fracture pathology and other groin pain clinical entities have been ruled out, the next stage is to continue with a focused clinical examination to determine hip morphology.

Hip Architecture Assessment

This part of the clinical algorithm both hips must be examined to explore the femoral version of the symptomatic and asymptomatic hip and to differentiate between various hip-related pain pathologies such as FAI syndrome, hip osteoarthritis and hip microinstability in order to prescribe an individualized treatment. This stage is highly important due to hip treatment is closely guided by the clinical examination [4, 47].

The range of motion (ROM) of the hip exhibits significant interindividual variability due to the high morphological variability of the femur and acetabulum, as previously discussed. Several studies have demonstrated that hip morphology strongly influences hip ROM, and that a person's hip morphology can be determined through passive hip ROM [48–51]. Femoral version (FV), an angle defined as the orientation of the femoral neck axis in relation to the medial–lateral axis across the posterior femoral condyles, has emerged as a potentially crucial factor in hip pain development [48, 50–54]. Normal FV ranges from 0° to 30°, with most studies reporting results between 8° and 20° [49, 51, 55]. Reduced FV (retroverted hips) increases the risk of hip pain and limited range of motion [49, 56], while increased FV (anteverted hips) is associated with various hip conditions [57]. Previous research has noted a strong association between hip ROM and FV, as indicated by several studies [48, 50, 51, 54]. This observation has raised the possibility that FV could potentially be predicted from hip ROM measurements in clinical contexts, as suggested by studies cited above. Chadayammuri et al. [48] found that hip ROM significantly predicts femoral torsion and acetabular version. Specifically, internal rotation ROM (both in a neutral hip position and at 90° of hip flexion) was greater in hips with combined femoral anteversion and acetabular anteversion, while external rotation ROM was correspondingly reduced in such hip morphology. Conversely, internal rotation ROM was lower in hips with femoral retroversion and acetabular retroversion, with opposite trends observed for external rotation ROM. Multivariate analysis indicated that internal rotation ROM in a neutral hip position and patient age were independent predictors of the femoroacetabular torsion-version combination index [48]. Several previous studies have indicated a significant association between internal rotation ROM and femoral torsion or acetabular version [49, 58, 59]. Audenaert et al. [49] showed that 75% of the variance observed in internal rotation ROM measurements at 90° of hip flexion could be attributed to femoral head sphericity, acetabular coverage, and femoral torsion in a cohort study of 30 patients without hip pathology, FAI symptoms, and asymptomatic individuals. Furthermore, Kelly et al. [60] reported that internal rotation at 90° of hip flexion gradually increased by at least 5° between patients with femoral retroversion, normal femoral torsion, and femoral anteversion.

Mechanically, hip internal rotation creates a mechanical conflict between the anterolateral femoral neck-head junction and the acetabulum, whereas external rotation results in a posterior impingement occurring extra-articularly between the greater trochanter and ischium [61] and intra-articularly between the femoral neck-head junction and the posterior-inferior acetabular surface [62]. Several studies have shown that a 10° increase in anterior pelvic tilt (acetabular retroversion) leads to a mechanical conflict between the femur and acetabulum, reducing internal rotation ROM [63–65]. Additionally, Ejnisman et al. [66] observed that hips with excessive femoral anteversion were twice as likely to have a labral tear extending beyond the three o'clock position. Another significant finding from the study by Chadayammuri et al. [48] was that abduction ROM was not associated with the degree of femoral torsion or acetabular version. External rotation ROM in a neutral hip position has been shown to depend on the degree of femoral torsion, rather than central acetabular version. This confirms previous studies suggesting that limitations in neutral hip position external rotation ROM primarily result from posterior impingement between the greater trochanter and ischium, with minimal contribution from the acetabular rim [62]. Therefore, limitations in passive ROM are largely determined by bone alignment, rather than pain or apprehension due to intra-articular and extra-articular pathology, as previously suggested [46–48].

For the clinical examination process a $> 20°$ of difference between external and internal rotation ROM in 90° of hip flexion or neutral position was established to determine femoral version [51]. Cibulka determined that discrepancies of 30° between hip internal and external rotation ROM could indicate the possibility of abnormal femoral version. To illustrate, if the range of motion for internal rotation exceeded that of external rotation by 30°, it might suggest the presence of excessive femoral anteversion. However, it is important to note that the 30° threshold was primarily derived from studies conducted mainly with children [67].

Additionally, apart from influencing hip ROM, alterations in FV, whether increased or decreased, have the potential to impact the moment arms of muscles and modify muscle architecture. Such alterations may result in changes in hip muscle strength [31, 68, 69]. Two systematic reviews have highlighted the presence of muscle weakness in patients with FAI syndrome when compared to healthy controls [70, 71]. Muscle torque generation is influenced by both muscle length and the muscle moment arm. The muscle moment arm is defined as the perpendicular distance between the muscle's line of action and the instantaneous center of joint rotation. This concept considers both the length of the muscle moment arm and the muscle's line of action. Patients with hip dysplasia displayed significant adaptations in the length of the muscle's moment arm, while the muscle's line of action was affected to a lesser extent [72]. Specifically, the reduced length of the muscle's moment arm in their hip abductor muscle suggests a mechanical disadvantage for this muscle group [31].

Alterations in FV, whether increased or decreased, can affect both muscle length and the muscle moment arm at the hip joint, leading to changes in muscle strength. The greater strength reduction in anteverted hips might be attributed to an excessive decrease in gluteus maximus muscle length (which is already decreased in the neutral position), while the moment arm length increased from zero to 30° of external rotation [54]. This dependence of hip rotator muscle strength on hip test position has been demonstrated previously [73], and it is important for clinicians to be mindful of this factor when conducting hip strength assessments. In summary, understanding the role of FV in hip range of motion and muscle strength may have implications for clinical practice and patient management. Figure 2 shows the different femoral version and hip-related ROM.

Hip-Related Pathology Assessment

Patients experiencing anterior hip pain often localize their discomfort to the anteromedial region of the inguinal area, commonly referred to as the "C" sign during physical examination [3]. In older patients with limited hip range of motion, primary consideration should be given to hip joint osteoarthritis (OA), whereas in younger patients with anterior hip pain, conditions such as acetabular labral tears, femoroacetabular impingement (FAI) syndrome or hip microinstability should be considered [5].

FAI

FAI is defined as a motion-related clinical disorder of the hip with a triad of mechanical symptoms (anterior hip pain and sensations of locking, clicking or stiffness), clinical signs and relevant radiological findings [74]. Its clinical presentation based on radiological findings is divided into two types of morphologies: (1) CAM-type FAI, characterized by a non-spherical bony prominence or bump at the junction of the femoral neck with the femoral head; (2) PINCER-type FAI, characterized by an excess of acetabular coverage, either focal or diffuse, over the femoral head [75].

The prevalence of CAM-type morphology ranges from 4 to 17% in the population and is influenced by age, gender, ethnicity, physical activity, and the presence or absence of symptoms [76]. It is more common in men, occurring in 13–72% of asymptomatic men and in 0–11.7% of asymptomatic women [77–79]. Various studies report that this morphology is less prevalent in East Asian individuals compared to other ethnic groups [80, 81]. CAM-type morphology gradually develops during skeletal maturation until adulthood and is influenced by physical activity [82–84]. It has been observed that professional athletes have a higher prevalence compared to sedentary individuals. Furthermore, the presence of this morphology in asymptomatic individuals increases the relative risk of developing hip pain by 4.3 times [85]. Regarding the incidence of PINCER-type morphology between men and women, some studies report small differences [86, 87]. Various studies have not shown any association between PINCER-type morphology and ethnicity [80, 88, 89]. The prevalence in individuals engaged in different sports varies considerably, ranging from 1 to 74% [78, 80, 90, 91].

Both CAM and PINCER morphologies can lead to the development of acetabular labral tears, with a prevalence of these tears ranging from 22 to 55% in individuals with hip pain [92] and being common in asymptomatic individuals [93]. Various studies have reported that symptomatic labral tears are more frequent in women than in men [94, 95]. Most labral tears have an insidious onset of symptoms and are characteristic in sports such as soccer, tennis, hockey, or artistic disciplines like ballet, where rapid movements in the frontal or horizontal plane of the hip are performed [96]. The etiology of labral tears is diverse, including traumatic, congenital, degenerative, capsular laxity-related, and idiopathic factors [97–99]. Therefore, labral tears have a multifactorial etiology, so the factors mentioned above and different FAI morphologies should be taken into

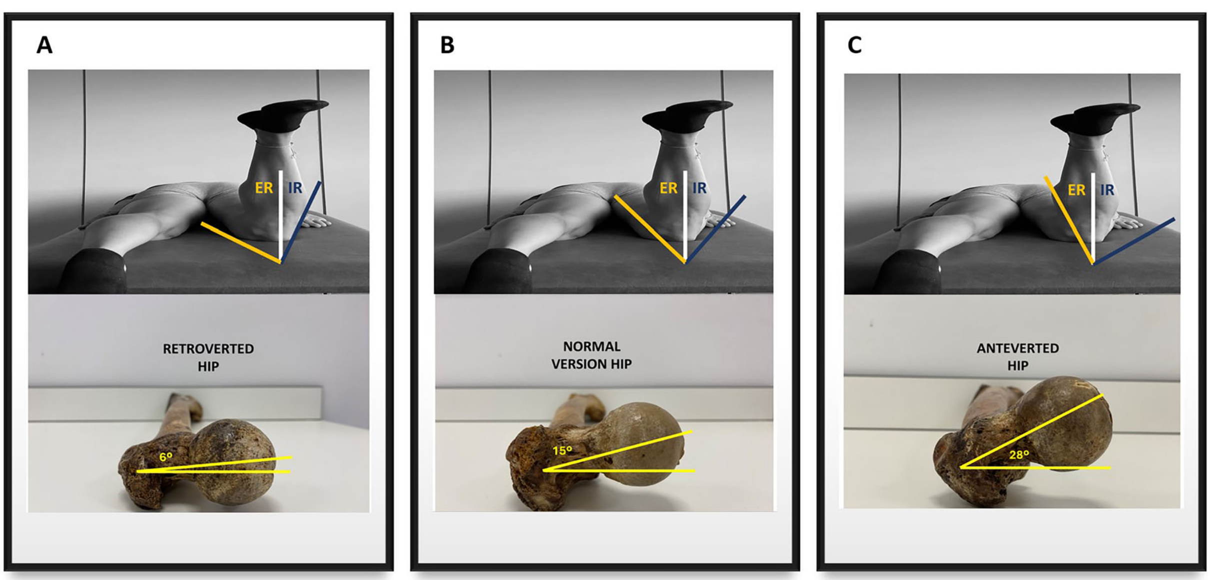

Fig. 2 Different femoral versions and hip range of motion. **A** Retroverted hip; **B** normal version hip; **C** anteverted hip. *ER* external rotation, *IR* internal rotation

consideration when symptoms related to labral tears appear.

One of the clinical signs present in patients with FAI and labral tears is a limitation in hip ROM. It has been observed that patients with labral tears exhibit restrictions in hip ROM [95]. The most significant limitation often occurs in hip rotation [100–102], but various studies have also shown limitations in hip flexion [102, 103], adduction [102], and abduction [101, 102] of the hip. However, there is controversy regarding the extent of ROM limitations in patients with FAI. Two systematic reviews have reported different conclusions regarding the effect of FAI on hip ROM [71, 104]. Diamond et al. [104] suggest that patients with FAI have reduced ROM in the directions where hip impingement occurs, while Freke et al. [71] reported that hip ROM was not different between individuals with FAI symptoms and their respective controls. The different methodologies used to assess hip ROM (goniometer, inclinometer, or 3D motion analysis systems) and the low methodological quality of some studies may explain the different conclusions in the two systematic reviews.

In addition to limitations in ROM, it has been described that patients with FAI may exhibit lower muscle strength values. Freke et al. [71] reviewed six studies on muscle weakness in patients with FAI and concluded that, overall, hip muscle strength is altered. However, studies comparing FAI patients with control subjects have not reached a consensus on which muscle groups are most affected [70, 105–107]. Casartelli et al. [106] demonstrated that patients with FAI had significantly lower isometric voluntary strength in the hip abductors, adductors, flexors, and external rotators. Diamond et al. [70] only found differences in the hip abductors. Additionally, Nepple et al. [107] pointed out that patients with FAI with strength deficits in hip flexion had larger labral tears.

These muscular imbalances in the trunk and hip muscles can lead to a change in pelvic posture. There are various definitions used to describe pelvic tilt. In physical therapy research, it generally refers to the angle formed by a horizontal line and a line bisecting the anterior–superior iliac spine and posterior-superior iliac spine in the sagittal plane. Changes in pelvic tilt have been correlated with various musculoskeletal conditions related to the lumbar spine [108], pelvis [109], and knee [110]. There is controversy in studies investigating changes in pelvic tilt posture in hip musculoskeletal pathologies [111]. Hip ROM is influenced by the position of pelvic tilt; several studies, using different methodologies, have shown that an increase in anterior pelvic tilt results in a decrease in hip flexion and internal rotation ROM, while an increase in posterior pelvic tilt increases hip flexion and internal rotation ROM [63, 65, 112, 113]. Greater anterior pelvic tilt increases lumbar lordosis, whereas posterior pelvic tilt has the opposite effect. Previous studies have investigated muscle activities during pelvic tilt movements using electromyography [114–117]. Regarding anterior pelvic tilt, it depends on the activity of the erector spinae, multifidus, iliopsoas, rectus femoris, tensor fasciae latae, and sartorius muscles. As for posterior pelvic tilt, it has been observed that the movement depends on the activity of the rectus abdominis, external oblique, internal oblique, and gluteus maximus muscles [117].

Hip ROM and muscle strength vary, and their utility in diagnosing FAI is limited. Therefore, diagnostic precision values are primarily associated with special orthopedic clinical tests. The flexion-adduction-internal rotation (FADIR) test is the most useful for ruling out FAI rather than confirming it [16, 22, 74]. This test replicates the early mechanical contact between the femoral head and the anterosuperior portion of the acetabulum, where acetabular labral tears are more commonly found. The FADIR test has been shown to have high SN (0.94) and low SP (0.09) in diagnosing FAI in patients with groin pain or symptoms suggestive of hip pathology [118, 119].

Finally, regarding radiological findings, FAI is divided, as mentioned earlier, into two types of morphology. Most CAM deformities are located at the anterosuperior junction of the femoral head-neck. To detect a CAM-type deformity in this region, both anteroposterior and lateral hip radiographic projections are needed [82]. According to available evidence, an alpha angle of $\geq 60°$ is currently the most appropriate for classifying CAM-type morphology [120]. On the other hand, PINCER-type morphology is associated with acetabular overcoverage due to increased acetabular depth, such as coxa profunda or acetabular protrusion. If it is focal, it may be due to acetabular retroversion or a prominent posterior edge. Therefore, the anterior or anterosuperior acetabular rim generally creates contact with the femoral neck, potentially causing associated symptoms and a higher risk of acetabular labral lesions [121].

Hip Microinstability

Hip microinstability is a relatively new and often underestimated pathology characterized by excessive hip mobility that goes beyond the normal range, leading to pain and impairments in hip stability [122]. It is distinct from hyperlaxity by the presence of pain and differs from traumatic macroinstability as it develops gradually due to repeated microtrauma, particularly in individuals engaged in activities requiring flexibility and excessive hip range of motion, such as dancing or gymnastics [123, 124]. This condition is challenging to identify but can result from a combination of factors, including anatomic abnormalities in bone structure, capsule-ligament issues, muscle deficits, and even iatrogenic causes like surgical procedures, such as capsulotomy during hip arthroscopy [125]. Morphological abnormalities in bone structure, such as inadequate acetabular coverage and femoral abnormalities, can contribute to microinstability. These abnormalities can be identified through X-rays and computed tomography (CT) scans. Acetabular dysplasia, defined by a lateral center–edge angle below 25°, is a notable risk factor. Other parameters, like the acetabular roof angle, anterior center–edge angle, and various indices, can also indicate potential risk [124, 126]. Magnetic resonance arthrography can reveal the presence of a capsular defect, thinning of the capsule, or labral pathology [127].

Capsule-ligament structures, including the joint capsule, iliofemoral ligament, ischiofemoral ligament, pubofemoral ligament, and the ligamentum teres, contribute significantly to hip stability. The iliofemoral ligament, in particular, plays a dynamic stabilization role during hip movement [128–130]. The labrum acts as a secondary stabilizer of the hip, increasing joint congruence and maintaining femoral head suction in the acetabulum. Patients with microinstability often exhibit a hypertrophic labrum [131, 132]. Muscles, including the iliopsoas, iliocapsularis, tensor fasciae latae, rectus femoris, and adductor muscles, provide a contention effect against microinstability. Muscle hypertrophy can occur in response to structural abnormalities [133]. Microinstability can also result from iatrogenic causes, including surgical interventions that alter the anatomy or stability of the hip. These can include excessive acetabular wall resection, labrum or ligamentum teres resection, and extensive capsulotomy [134].

Diagnosing microinstability involves a combination of patient history, clinical examination, and imaging. Patients often report pain in the inguinal fold and a sensation of instability during activities that stress the hip. Clinical examination may reveal hyperlaxity and limitations in hip motion. Several clinical tests, such as Beighton score, the log-roll test, anterior apprehension test, prone instability test, axial distraction or abduction-hyperextension-external rotation tests can be used to screen for hip microinstability [127, 135]. Patients with hip microinstability exhibited notably increased ROM compared to both symptomatic and asymptomatic groups without hip microinstability. In symptomatic patients, those with a hip flexion + rotation arc of $\geq 200°$ were highly likely to display positive intraoperative findings indicative of hip microinstability [135]. In summary, microinstability is a complex hip condition that arises from a combination of anatomical, structural, and functional factors. Its diagnosis and management require a comprehensive evaluation of the patient's history, clinical presentation, and imaging findings.

Hip Osteoarthritis

Osteoarthritis is the leading source of hip discomfort and reduced quality of life in older individuals, typically affecting those aged 50 and above with a prevalence ranging from 0.4 to 27%. Interestingly, there is considerable variation in reported hip OA prevalence, with men tending to exhibit a higher rate of radiographic hip OA [136]. In individuals diagnosed with hip osteoarthritis (OA), a reduction in hip internal rotation and hip flexion range is associated with various factors, including the presence of hip osteophytes, morning stiffness, male gender, higher body mass index (BMI), and hip pain [137].

Structural abnormalities, such as defects in cartilage and the existence of bone marrow lesions in the anterior and central superolateral regions of the hip joint, may signify initial damage in the progression of hip OA. Those with hip OA typically display diminished femoral-head cartilage volume, along with an increased prevalence of cartilage defects and bone marrow lesions [138]. Higher BMI is linked to an elevated risk of hip OA, with a consistent risk magnitude observed for both men and women (risk ratio = 1.11) [139]. Living in a community marked by high poverty levels is independently associated with the presence of radiographic OA in one or both hips, while lower educational attainment is independently linked to symptomatic OA in one or both hips (odds ratio [OR] = 1.44) [140]. Individuals with higher bone mass and hip OA have a higher occurrence of osteophytosis and excessive bone formation compared to those with lower bone mass (osteophytosis OR = 2.12, subchondral sclerosis OR = 2.78) [141, 142]. Additionally, individuals with a genetic predisposition to end-stage hip OA tend to exhibit an increased presence of clinical OA signs [140]. Interestingly, individuals experiencing hip pain often lack radiographic signs indicative of hip OA, such as osteophytes or joint space narrowing. Conversely, many individuals with radiographic evidence of hip OA do not experience hip pain [143].

Hip OA is presented with moderate hip anterior or lateral pain on the side during weight-bearing activities, morning stiffness lasting under 1 h upon waking, hip internal rotation range limited to less than 25° or restricted internal rotation and hip flexion by 15° compared to the nonpainful side, and/or increased hip pain during passive hip internal rotation [144]. The cluster of Sutlive is a set of five clinical assessment items used to help make a preliminary diagnosis of hip osteoarthritis in patients who are experiencing one-sided hip pain. This prediction rule is designed to minimize the necessity for X-ray imaging and offers clinicians a useful tool for starting early conservative treatment [144].

Moreover, clinicians should measure balance performance and assess activities that indicate the likelihood of falls in adults with hip osteoarthritis, particularly in cases of reduced physical function or a heightened fall risk due to a previous history of falls. To evaluate activity limitations, participation constraints, and changes in the patient's functional status throughout their treatment, healthcare providers should employ reliable and valid physical performance assessments. These assessments may encompass tests such as the 6-min walk test, 30-s chair stand, stair measure, timed up-and-go test, self-paced walk, timed single-leg stance, 4-square step test, and step test [136]. Table 1 summarizes all clinical criteria of FAI, hip microinstability and hip OA.

Hip Symptom Modification Procedure

Once the patient's hip pathology has been diagnosed, the symptom-modification procedure with mobilization with movement (MWM) and pelvic tilt modification (specially for hip OA and FAI) will be performed to improve symptom-provoking movement if hip mobility was needed and allowed due to hip bony morphology.

Mobilization with Movement

Traditionally, hip traction has been used in the setting of arthrography to increase intra-articular joint space and visualize cartilage [145]. Joint mobilization and manipulation techniques are frequently employed and recommended for patients diagnosed with hip OA. Within this treatment approach, manual traction is applied along the femur's longitudinal axis, commonly referred to as long-axis mobilization or manipulation.

Table 1 Diagnostic criteria for anterior hip-related pain

	FAI	Hip microinstability	Hip OA
Age	Young—middle (physically active)	Young—middle (physically active)	Elderly (60–75 years)
Symptoms	Anterior hip pain Clicking, locking, or giving away	Anterior hip pain Apprehension Instability with gait	Anterior hip pain Pain that decreased with continued walking Pain getting in/out of a car Difficulty reaching the foot of the symptomatic leg while dressing
Pain provocative movements	Hip internal rotation Hip flexion Hip adduction	Hip extension Hip external rotation	Hip internal rotation Hip flexion Hip adduction
Orthopedic physical examination tests	FADDIR test	AB-HEER test HEER test Prone instability test	Sutlive's cluster (3 or more positive tests)
Hip range of motion	$< 85^\circ$ TRROM	$\geq 200^\circ$ hip flexion + TRROM	$\leq 25^\circ$ hip internal rotation
Radiological findings	Cam, pincer, or mixed morphology Anterior labral tears	Ligamentum teres tears Anterior labral tears Dysplastic morphology	Marginal osteophytes and joint space narrowing

AB-HEER abduction, hip extension and external rotation, *FADDIR* flexion, adduction and internal rotation, *FAI* femoroacetabular impingement, *HEER* hip extension and external rotation, *TRROM* total rotation range of motion

Prior research has documented positive results associated with the longitudinal manipulation or mobilization of the hip joint [146–148]. During long-axis mobilization or manipulation, the leg is gently moved in a caudal direction, effectively creating separation between opposing joint surfaces. This maneuver has the potential to enhance the width of the joint space (JSW) and alleviate stress on the joint cartilage by redistributing the load. Mulligan's Mobilization with Movement (MWM) integrates an additional glide force (longitudinal, inferior, anterior, posterior, or lateral) with an active or passive movement [149]. Numerous studies with a low risk of bias have demonstrated positive clinical outcomes in terms of pain relief and improved function when employing MWM in individuals with hip osteoarthritis [150, 151]. Beselga et al. [151] observed an immediate enhancement in pain levels, hip range of motion (ROM), and physical function tests following a single MWM intervention compared to a placebo. Additionally, Zemadanis et al. [150] presented compelling evidence of both immediate and sustained improvements (up to 3 months) in Visual Analog Scale (VAS) scores and lower extremity function scale after six interventions over a 2-week period, coupled with home exercises involving MWM, in contrast to a placebo. Consequently, there exists moderate-quality evidence supporting the advantageous effects of MWM on pain and function in patients with hip osteoarthritis.

Reiman and Matheson [152] showed different self-mobilization and muscle re-education techniques to improve hip mobility and improve symptoms. These techniques are based on available evidence and clinical experience. Their protocol is proposed to integrate self-mobilization techniques into a multimodal home program that includes warm-up, stretching, dynamic exercises, and neuromuscular control. Therapist supervision and follow-up are recommended.

During the decision-making process, if a particular movement (e.g., hip flexion or internal rotation) results in the complete or partial reduction of symptoms and improve the hip ROM with MWM, the hip mobility management of the patient should include self-hip mobilization techniques with an accessory glide force, provided that the hip's bone morphology allows for it. It is crucial to take into consideration the presence of FAI syndrome or the degree of hip osteoarthritis, as these factors may influence the suitability and effectiveness of such techniques.

Pelvic Tilt Modification

Furthermore, another approach to guide hip mobility management are dynamic changes in pelvic tilt (anterior or posterior pelvic tilt) to improve hip ROM and symptoms.

Pelvic tilt angle is the multifactorial result of muscle tone [153], pain [154], bone morphology [155], and adjacent joint mobility [156]. A reduction in posterior pelvic tilt in patients with hip pain have been observed during kinematic assessment of various basic functional movements, such as walking [157], unilateral step down [158], and performing a squat [159, 160]. Significant differences in pelvic tilt have also been identified during high-speed direction changes in populations with athletic pubalgia or groin pain [161]. It has been proposed that an increased anterior pelvic tilt in patients with FAI could contribute to an increase in symptoms during squats or stepping down, initiating early hip joint contact between the femur and acetabulum [63, 112]. In combination, increased anterior pelvic tilt and reduced hip extension may indicate an unconscious attempt to maintain a more "flexed" hip to avoid increased tensile forces in the anterior hip.

This increased anterior pelvic tilt has been associated with a loss of ROM, especially during hip flexion and internal rotation at 90° of hip flexion in simulated studies [63, 113]. Ross et al. [63] conducted a three-dimensional study and demonstrated that increased posterior pelvic tilt was associated with increased ROM in hip internal rotation and flexion in patients with FAI. This is an important finding, as these patients could potentially improve hip ROM limitation by increasing posterior pelvic tilt. Supporting this theory, several studies in elite skiers with/without CAM-type morphology [64, 65] have shown that hip internal rotation ROM is reduced when the pelvis tilts anteriorly during an upright posture, suggesting that anterior pelvic tilt may produce biomechanical changes within the hip joint.

We can assume that pelvic tilt is a modifiable factor in patients with FAI that may prevent the development of degenerative changes in the hip. In this regard, it has been demonstrated that a multimodal program in healthy individuals (manual therapy, stretching, and muscle strengthening) over 6 weeks can reduce anterior pelvic tilt during walking, increase hamstring muscle flexibility, and trunk muscle endurance [162]. FAI rehabilitation programs include lumbo-pelvic exercises and general hip muscle strengthening, but improving anterior pelvic tilt has not been identified as a target in patients who improve their hip ROM during physical examination [163]. Recently, Brekke et al. [164] have demonstrated that feasible exercise programs targeting anterior pelvic tilt have shown potential benefits for patients with acetabular retroversion, particularly those experiencing moderate hip-related pain. Considering anterior pelvic tilt as a component of future interventions in patients with FAI may be worthwhile.

Given the aforementioned considerations, during the decision-making process, whether a reduction in anterior pelvic tilt results in an improvement of pain symptoms and increase hip ROM during various painful and restricted movements in patients with FAI or hip OA during physical examination. If improvements in patients' signs and symptoms are observed, treatment aimed at enhancing hip ROM and hip self-reported quality of life may involve addressing posterior pelvic tilt.

General Exercise Treatment

The role of strength training or general exercise treatment have been proposed by several authors for patients with FAI [165, 166], hip OA [167, 168], and hip microinstability [169, 170] for improving self-reported pain, quality of life and hip strength. Several studies have reported strength deficits in various hip-related muscle groups in patients with hip-related pain. These findings suggest specific deficiencies in muscle groups such as hip flexors [106, 171, 172], with the iliopsoas appearing to be particularly affected, as well as hip extensors [171, 172], where previous research has indicated weakness in the gluteus maximus. Additionally, studies confirm strength deficits in hip abductors [70, 106, 107, 173]. Similarly, research has shown muscle strength deficits in hip external rotators, with these muscles playing a crucial role in hip stability and function [106, 173–175]. These findings underscore the importance of including hip muscle strengthening as a fundamental component of rehabilitation for patients with hip-related pain, irrespective of their specific hip morphology.

However, current exercise protocols often do not consider variations in femoral torsion when prescribing treatment plans. Frasson et al. [54] showed that hip with excessive femoral antetorsion were weaker than hips with femoral retroversion for hip external rotation at 30° of hip flexion, abduction and adduction, and weaker than normal hip femoral version for extension, supporting the theory of previous research [31]. Muscles play a central role in generating movement, and a thorough comprehension of their structure and function is essential for accurately identifying sources of abnormal movement and specific muscle groups to target during exercise interventions for hip-related pain [176]. Muscle architecture also plays a crucial role in assessment and targeting of specific muscles. For instance, the gluteus medius achieves remarkable force production despite its relatively small size by packing numerous short fibers in parallel. However, this design means that the muscle is not optimized for generating very high forces across a wide range of lengths or hip positions. In essence, understanding the unique characteristics of each muscle and femoral torsion helps guide clinical evaluation and exercises-based strategies.

CONCLUSIONS

Therefore, the present clinical algorithm for hip-related pain is a comprehensive, flexible, adaptable to different settings, and regularly updated to incorporate new research findings. The combination of physical examination methods with evidence-based rehabilitation principles to restore optimal hip ROM, strength and stabilize the surrounding musculature constitutes the foundation of clinical rehabilitation for patients dealing with hip-related pain. The ongoing utilization of fundamental scientific investigations, clinical education, and research into outcomes will contribute further insights and advancements for treating hip-related pain.

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Declarations

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