RESIDENT'S CASE PROBLEM

ANDREA B. AUSTIN, DPT[1] • **RICHARD B. SOUZA,** PT[2]
JOHN L. MEYER, DPT[3] • **CHRISTOPHER M. POWERS,** PT, PhD[4]

Identification of Abnormal Hip Motion Associated With Acetabular Labral Pathology

Hip pain can disrupt functional mobility regardless of one's age. Hip osteoarthritis (OA) is among the most common causes of hip pain and disability in middle-aged and older adults.[5] Recent literature suggests that acetabular labral pathology secondary to femoroacetabular impingement (FAI) is a precursor to early-onset hip OA.[2-3,14,20-21,23,28,39-40] Acetabular labral pathology frequently presents in highly active individuals in the second, third, and fourth decades of life.[28] While labral injury can occur due to an isolated traumatic event, it is more commonly associated with a gradual onset due to repetitive microtrauma. FAI is a suggested mechanism for repetitive stress labral injuries.[4,6,12,19] With advances in magnetic resonance imaging (MRI) capabilities and arthroscopic surgical procedures for the hip, acetabular labral pathology is being identified and addressed surgically at a rapidly increasing rate.[24,25]

STUDY DESIGN: Resident's case problem.

BACKGROUND: Recent literature has suggested that acetabular labral pathology secondary to femoroacetabular impingement (FAI) may be a precursor to early-onset hip osteoarthritis. The purpose of this resident's case problem was to explore the extent to which abnormal movement at the hip is a possible contributor to acetabular labral pathology.

DIAGNOSIS: The patient was a 25-year-old female with a 4-year history of anterior-medial groin pain. Based on a combination of the clinical examination and magnetic resonance imaging findings, she was given a diagnosis of acetabular labral tear by her orthopaedic surgeon and referred to a physical therapist for assessment. Movement analysis during a single-leg step down, running, and a drop jump maneuver revealed excessive hip adduction and internal rotation on the involved side, which reproduced her symptoms. Application of a hip-strapping device resulted in decreased hip adduction and internal rotation, and an immediate decrease in symptoms.

DISCUSSION: The reduction in pain secondary to controlling hip motion suggests that excessive frontal and transverse plane hip motions may contribute to FAI. Accordingly, physical therapy intervention aimed at controlling and reducing hip adduction and internal rotation during activities may be indicated in patients who present with this movement pattern associated with anterior hip/groin pain.

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FAI occurs in the presence of femoral and/or acetabular bony morphological abnormalities leading to excessive contact between the femoral head-neck junction and the acetabular rim.[21,36] Femoral abnormalities lead to cam-type impingement while abnormal acetabular morphology causes pincer-type impingement.[1,8,21] Cam impingement occurs as a result of a nonspherical femoral head contacting the acetabular rim. Most often, the labral attachment site is damaged, which can eventually lead to a total detachment of the labrum and/or osteoarthritic changes at the impingement site.[11,21,40] Chronic slipped capital femoral epiphysis, femoral head anteversion, coxa vara, extreme coxa valga, and residual childhood conditions, such as Legg-Calve' Perthes disease, have been identified as possible causes of cam impingement.[1,8,10,12,21]

In the case of pincer impingement, increased bony-cartilaginous abutment is due to an acetabular abnormality. In this condition, abnormal stress on the acetabular labrum can result in bony prolifera-

[1]Physical Therapist, Kern and Associates Physical Therapy, Santa Monica, CA. [2]Postdoctoral scholar, Department of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA. [3]Director of Rehabilitation, Department of Athletic Medicine, University of Southern California, Los Angeles, CA; Adjunct Assistant Professor, Department of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA. [4]Associate Professor, Department of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA. Dr Powers acknowledges a financial interest in the S.E.R.F Strap that was used as part of this resident's case problem. Address correspondence to Dr Christopher M. Powers, Division of Biokinesiology and Physical Therapy, University of Southern California, 1540 E. Alcazar St, CHP-155, Los Angeles, CA 90089-9006. E-mail: powers@usc.edu

tion, further exacerbating the problem.[1] Pincer impingement typically occurs with acetabular retroversion, coxa profunda, or acetabular protrusion.[1,8,12,37]

In both cam and pincer impingement, bony abutment occurs with the combined movement of hip flexion, adduction, and internal rotation.[1,8,21] Although the literature in this area reports a high incidence of bony morphological abnormalities in individuals with known acetabular labral pathology, less is known about the movement patterns underlying these injuries.[9,27,28,42] More importantly, it is unclear why some individuals with morphological abnormalities develop pathology, while others with the same structure do not. One possible explanation may be the interaction between bony morphology and movement patterns at the hip. For example, it is conceivable that individuals with bony morphological abnormalities have a narrower tolerance for abnormal hip motions than those with normal hip anatomy. Therefore, it is reasonable to hypothesize that dynamic movement into excessive hip flexion, adduction, and/or internal rotation may lead to pathology in an individual with abnormal bony anatomy, while the same abnormal movement pattern may be entirely benign in the individual with normal hip anatomy.

Given the established relationship between FAI and early onset hip OA, it is important for the physical therapist to recognize potential movement patterns that may contribute to FAI. Accordingly, the purpose of this resident's case problem was to examine the movement patterns at the hip of an individual with acetabular labral pathology. In our analysis, we explored her clinical and radiological findings, as well as her treatment history. Finally, as this individual was referred to the Musculoskeletal Biomechanics Research Laboratory at the University of Southern California for motion analysis testing, we examined her hip kinematics during functional tasks to assess the relationship between specific movement patterns and subjective reports of pain.

DIAGNOSIS

Patient Characteristics and Past Medical History

The patient was a 25-year-old, female graduate student (height, 170 cm; body mass, 68 kg) with a 4-year history of right hip and anterior-medial groin pain. Other than her current symptoms, she reported being healthy, with no current or pre-existing medical conditions. For the first 3 years, the pain was described as being activity dependent. Over the last year, she reported a progression to constant pain limiting all recreational activities (ie, running, step aerobics, kickboxing), as well as limited sitting tolerance to less than 30 minutes. The increase in severity of symptoms prompted her to seek medical care from her family medicine physician. At that time, she was given a diagnosis of right hip pain secondary to hip flexor strain and was referred to a physical therapist.

Her first bout of physical therapy treatment included manual interventions to improve hip range of motion, orthotic prescription to address a leg length discrepancy, and therapeutic exercises aimed at improving the neuromuscular control of the hip and pelvis. The patient was seen for a total of 7 visits over a period of 9 weeks; however, she did not report any improvements in her symptoms with this course of treatment.

Examination

The patient was seen at a different physical therapy facility approximately 2 weeks after completing her initial episode of physical therapy. Given the patient's age, current presentation, past history, and lack of improvement following this initial episode of physical therapy, the possibility of an acetabular labral tear was considered. There is limited evidence supporting various physical examination techniques to identify intra-articular pathology of the hip, particularly acetabular labral tears. The literature includes a description of the scour test, log roll test, impingement test, and FABER test.[17]

FIGURE 1. Scour test. The examiner moves the patient's hip through a range of motion from hip flexion and adduction to hip extension and abduction, while adding a compressive force through the hip joint as well as movement into hip internal and external rotation. The test is considered positive if there is a reproduction in hip pain and/or intra-articular joint clicking.

The scour test consists of the examiner passively moving the patient's lower extremity through an arc of motion from hip flexion and adduction to hip extension and abduction. A compressive force, as well as movement into hip internal and external rotation, is added throughout the range of motion (**FIGURE 1**). Reproduction of the patient's pain and/or eliciting an intra-articular clicking or popping sensation are considered positive findings. Furthermore, pain and clicking in a position of maximum hip flexion, adduction, and internal rotation is indicative of anterior-superior pathology, while pain and clicking in a position of hip extension, abduction, and external rotation is indicative of posterior-inferior pathology.[17] The patient in this resident's case problem presented with positive findings in the position of maximum hip flexion, adduction, and internal rotation, which was suggestive of anterior-superior labral pathology.

The log roll test is used to assess for acetabular labral pathology and general hip joint laxity, which may predispose an individual to injury. This test has been shown to demonstrate moderate inter-rater reliability (ICC = 0.63) and is performed with the patient supine with both lower extremities in neutral hip flexion/extension and adduction/abduction.[17-18] The examiner maximally internally and

FIGURE 2. The log roll test. The examiner passively moves the patient's lower extremity through the maximal available range of hip external (A) and internal rotation (B). Eliciting a clicking or popping sensation may indicate an acetabular labral tear, while increased total range of motion when compared to the opposite side may indicate ligament or capsular laxity.

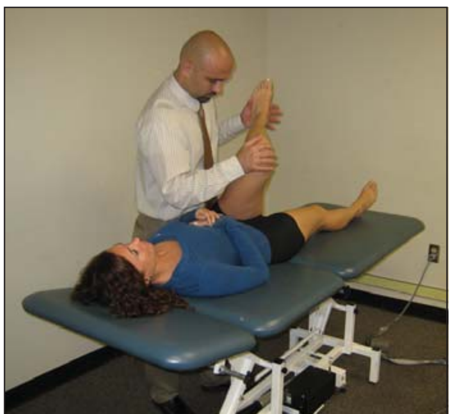

FIGURE 3. The impingement test. The examiner passively moves the patient's lower extremity into a position of hip flexion, adduction, and internal rotation. A positive test is reflected by increased hip or groin pain.

FIGURE 4. The FABER test. The examiner passively positions the testing limb in a position of hip flexion, abduction, and external rotation. The examiner assesses the perpendicular distance from the knee on the tested lower extremity to the table. A decrease in this distance or pain, when compared to the uninvolved side, is suggestive of intra-articular hip pathology.

externally rotates the femur, comparing range of motion bilaterally (**FIGURE 2**). The presence of clicking may indicate a labral tear.[17] In this particular patient, the log roll test was found to be positive, reproducing pain and eliciting clicking when moving into a position of femoral internal rotation. This finding was compelling in that it revealed the provocative nature of isolated hip internal rotation even when the hip was in neutral flexion/extension and abduction/adduction.

The impingement test is used to identify the presence of FAI. For this procedure, the patient lies supine while the examiner passively brings the involved hip into flexion, adduction, and internal rotation (**FIGURE 3**). Positive findings include a painful or pinching sensation in the hip and/or groin.[17] Although the impingement test also was found to be positive for this patient, previous literature has highlighted the limited usefulness with this procedure. For example, Narvani et al[24] reported that the sensitivity and specificity of this test in identifying individuals with labral tears was 75% and 43%, respectively. Moreover, Martin et al[18] has determined that the interrater reliability of this test is moderate (ICC = 0.58).

The FABER test is performed with the patient supine. The examiner passively positions the involved lower extremity into hip flexion, abduction, and external rotation. The involved knee is flexed and the ankle on the involved side rests on the anterior aspect of the contralateral lower extremity proximal to the knee. The examiner allows the involved knee to lower toward the table and evaluates for the presence of pain, as well as range-of-motion differences when compared to the uninvolved side (**FIGURE 4**). Side-to-side differences in the measured distance from the patient's knee to the table as well as a reproduction of groin and anterior-medial hip pain are considered positive findings.[17] For this patient, the FABER test revealed a greater perpendicular distance from her knee to the table and an increase in her groin pain. Mitchell et al[22] reported that the presence of hip pain during the FABER test was 88% sensitive for intra-articular hip pathology. Furthermore, Martin et al[18] determined the FABER test to have moderate interrater reliability (ICC = 0.61).

Given the positive findings on all 4 clinical tests described above, an acetabular labral tear was suspected. While the diagnostic accuracy of these tests may not be optimal, the collection of positive findings provided strong suspicion for our initial hypothesis of labral pathology as a possible diagnosis. Accordingly, the patient was referred to an orthopaedic surgeon for further evaluation and diagnostic imaging was performed.

Diagnostic Imaging

MRI and radiographic findings are often used in diagnosing acetabular labral pathology. While multiple radiographic views, such as anterior-posterior (AP) of the pelvis, frog leg lateral, and cross-table lateral, are typically utilized to identify bony morphological abnor-

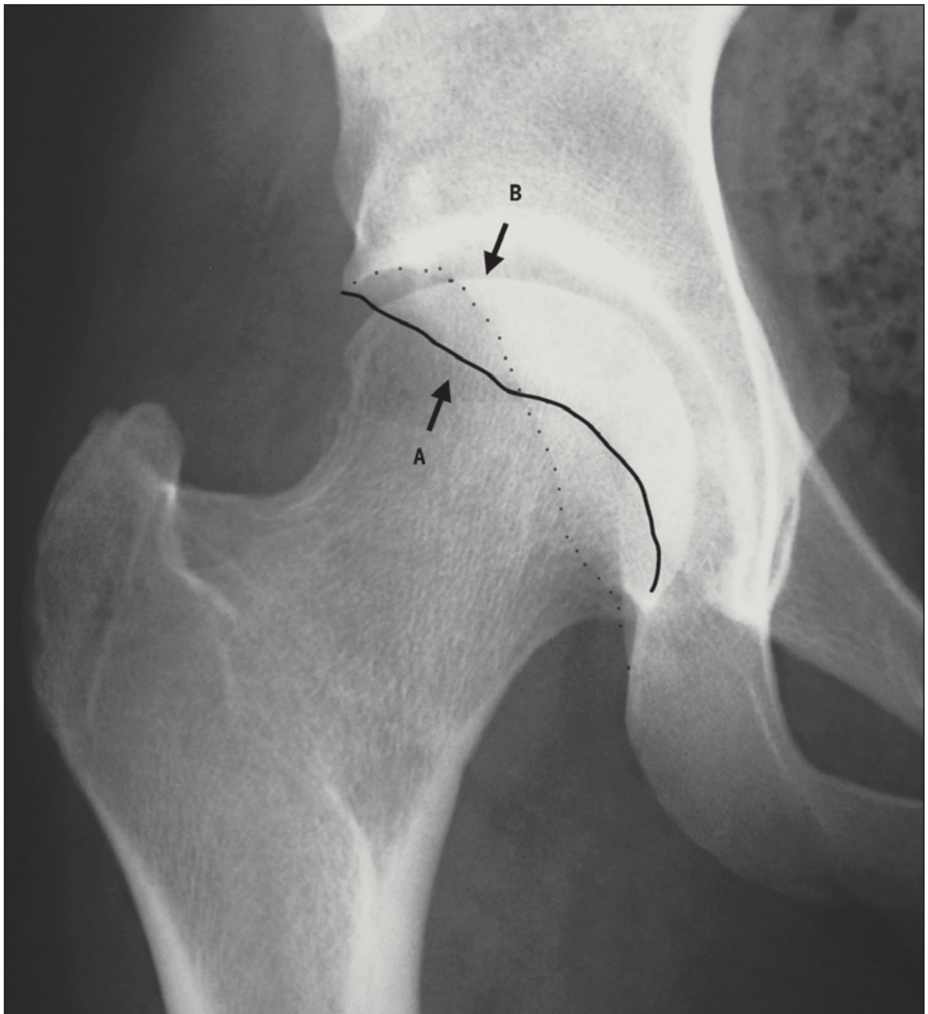

FIGURE 5. Acetabular retroversion is described qualitatively on an anterior-posterior radiograph by identifying the crossover sign, in which the anterior border of the acetabular rim (A) extends laterally compared to the posterior border (B).

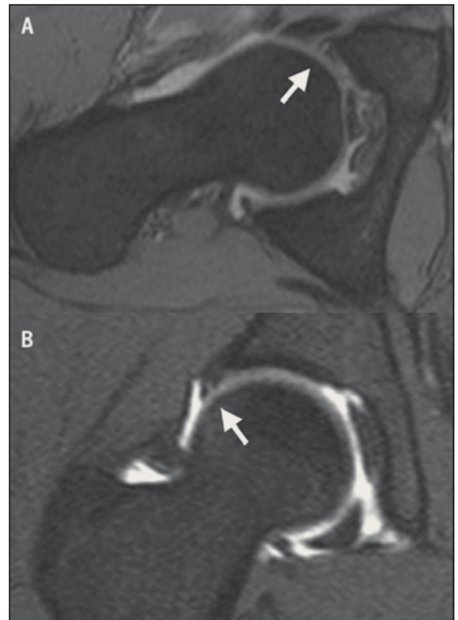

FIGURE 6. T2 axial oblique (A) and T1 coronal fat-saturated (B) magnetic resonance images demonstrating the presence of an anterior superior labral tear (arrow).

malities or osteophyte formation associated with FAI,[6,17,42] only an AP pelvis and frog leg lateral views were obtained on this patient. Femoral head-neck offset, a nonspherical shape of the femoral head, chondral defects, and osteophyte formation are some of the abnormalities that may be revealed on standard AP and frog leg lateral views. A standard AP radiograph also is utilized to visualize acetabular retroversion, which is described qualitatively by identifying the crossover sign. A crossover sign occurs when the anterior-superior border of the acetabular rim extends laterally compared to the posterior-superior border (**FIGURE 5**).[3,8,29,33,41,42] The patient's AP pelvis images revealed the presence of a crossover sign, indicating acetabular retroversion as well as the presence of borderline acetabular dysplasia. Both AP pelvis and frog leg lateral views revealed a nonspherical shape of the femoral head.

To visualize the intracapsular and extracapsular structures of the hip joint, MRI with gadolinium contrast was performed. Current literature indicates that MRI using gadolinium contrast is more effective in identifying acetabular labral pathology than MRI in the absence of a contrast agent.[7,8,17,22] This patient's MRI revealed an anterior-superior labral tear (**FIGURE 6**) and a nonspherical femoral head (**FIGURE 7**).

A nonspherical femoral head is quantified on MR images using the alpha angle. The alpha angle was measured using the method described by Nötzli et al.[26] Briefly, the alpha angle is defined by the intersection of 2 lines. The first line extends from the center of the femoral head to the point on the anterior aspect of the femoral head-neck junction where the radius of the femoral head exceeds that of a best-fit sphere drawn around the femoral head (**FIGURE 7**). The second line extends from the center of the femoral head through the femoral neck axis.[26] Previous studies have reported alpha angles greater than 50° as being diagnostic for cam impingement.[1,2] The alpha angle of this particular patient was 84° (**FIGURE 7**).

Movement Analysis

After receiving the diagnosis of an anterior-superior acetabular labral tear, the patient returned to a physical therapist in an attempt to utilize conservative measures to alleviate symptoms. Given the patient's imaging revealed bony abnormalities, a decision was made to further evaluate for movement dysfunction that may be contributing to dynamic impingement. Observational movement analysis during a

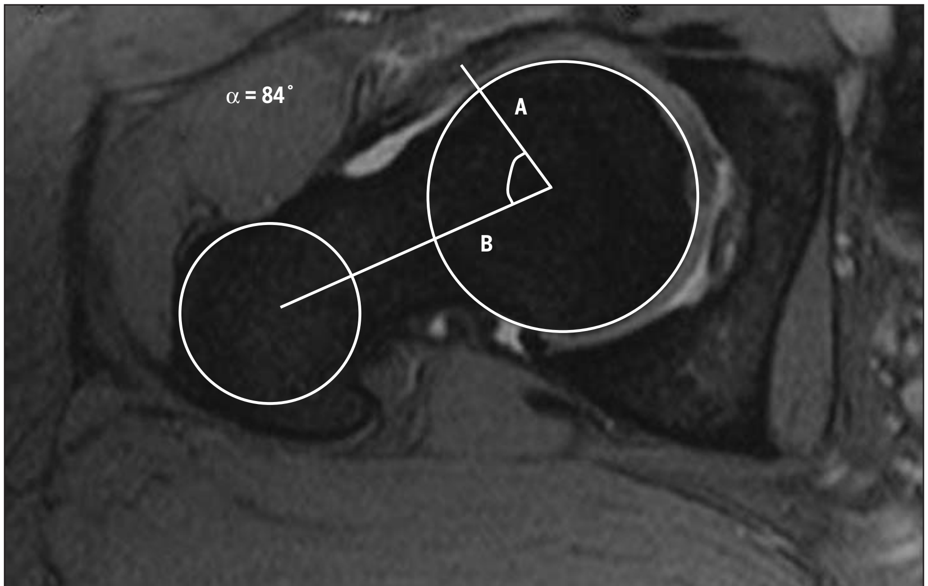

FIGURE 7. T2 axial oblique magnetic resonance image of the hip joint using gadolinium contrast. The image demonstrates an alpha angle of 84°, indicating the presence of cam impingement. The alpha angle is defined by the intersection of 2 lines. The first line extends from the center of the femoral head to the point on the anterior aspect of the femoral head-neck junction where the radius of the femoral head (A) exceeds that of a best-fit sphere drawn around the femoral head. The second line extends from the center of the femoral head through the femoral neck axis (B).

FIGURE 8. The S.E.R.F. Strap consists of thin, elastic material that is secured to the proximal tibia, wraps around the distal thigh, and is anchored around the pelvis as shown here. The line of action of the S.E.R.F strap pulls the hip into external rotation.

single-leg step-down task (slowly lowering the body from a 20-cm step) revealed excessive hip adduction and internal rotation. The excessive motion at the hip resulted in the knee joint center moving medial to the great toe at peak knee flexion and reproduced her anterior-medial hip and groin pain. Therefore, it was hypothesized that excessive hip adduction and internal rotation during functional activities may have contributed to FAI.

To quantify the hip movement impairments contributing to her hip symptoms, the patient was referred to the Musculoskeletal Biomechanics Research Laboratory at the University of Southern California. A 3-dimensional motion analysis system was used to obtain lower extremity kinematics, based on methods described in previous publications.[30,32,35] Kinematic data were collected during 3 functional tasks: running, a single-leg step-down task, and a drop jump maneuver.

Given the belief that abnormal hip motion in the frontal and transverse planes were contributing to FAI in this patient, we repeated the kinematic analysis while the patient utilized a hip-strapping device (S.E.R.F. Strap, Don Joy Orthopaedics, Inc, Vista, CA) to assist with hip control during the same functional tasks. The S.E.R.F. Strap consists of thin, elastic material that is secured to the proximal tibia, wraps around the distal thigh, and is anchored around the pelvis (**FIGURE 8**). The line of action of the S.E.R.F. Strap pulls the hip into external rotation, with the intent of improving lower extremity kinematics during dynamic activities.[38] We believed that the combination of improved hip kinematics, coupled with decreased pain, could be interpreted as a diagnostic indicator that abnormal movement patterns at the hip were a contributing factor to FAI.

Prior to initiating each task, the patient received a verbal explanation, visual demonstration, and was allowed 1 practice trial. The patient was instructed to rate her pain using a 10-cm visual analogue scale after the completion of each task (0 representing no pain and 10 the worst pain imaginable). The running task was completed along a 10-m path at a speed of 180 m/min. For the drop jump task, the patient began by standing on a 46-cm-high platform. She was instructed to drop onto the floor landing on both feet, then immediately jump upward as high as possible. Finally, the single-leg step-down maneuver was performed on a 17-cm step (equal to 10% of the patient's height). During the step-down task test, the patient was instructed to lower herself slowly over the course of 2 seconds, gently tap the ground with her heel, and return to the starting position over 2 seconds.

The patient completed 3 trials of each task with and without the S.E.R.F Strap. The S.E.R.F Strap was applied to the patient according to manufacturer instructions. Prior to testing, the patient was allowed to ambulate with the strap for 3 to 5 minutes to acclimate to its line of pull. No specific instructions were given to the patient during the kinematic testing.

Movement Analysis Results

Frontal and transverse plane kinematics at the hip for all 3 tasks, as well as the results of the patient's self-reported pain responses, are shown in **FIGURES 9 AND 10**,

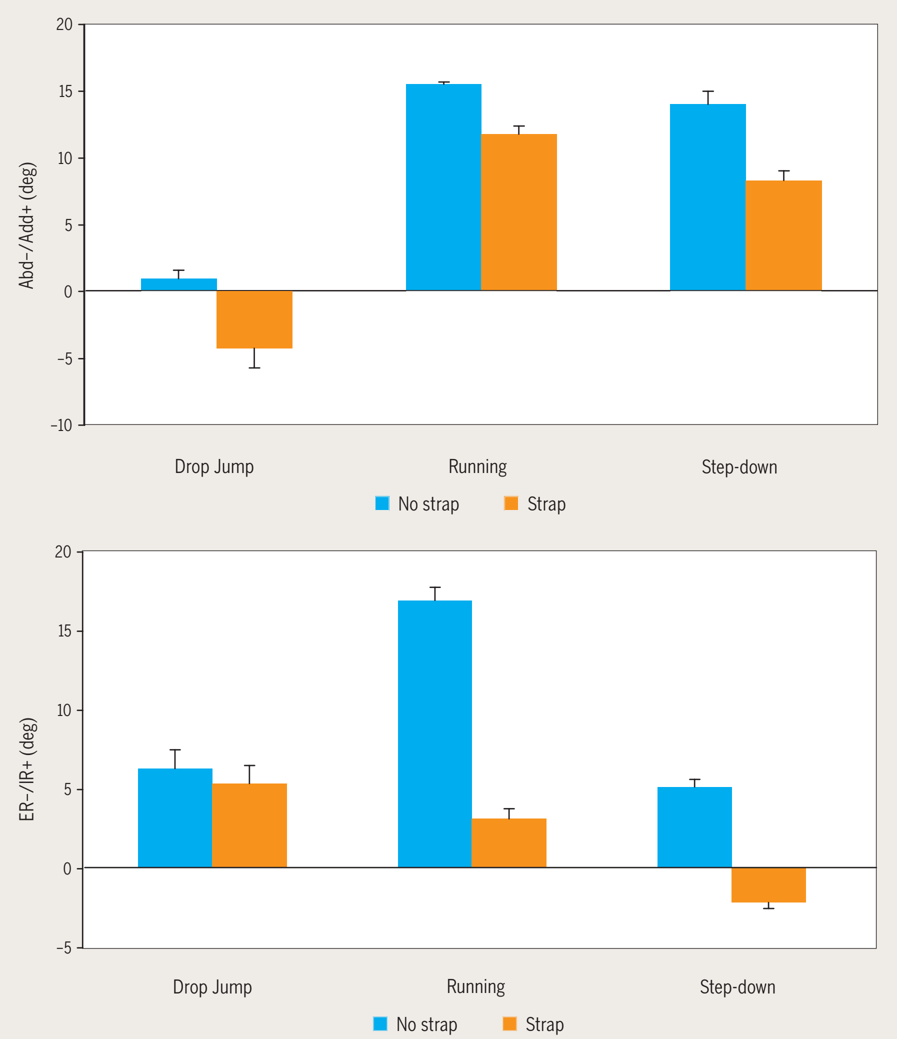

FIGURE 9. Peak hip abduction/adduction (top) and internal/external rotation (bottom) angles during the drop jump, running, and step-down tasks. Error bars represent 1 standard error.

respectively. In general, the addition of the S.E.R.F. Strap resulted in kinematic changes at the hip, as well as decreased pain scores. For the step-down task, peak hip adduction decreased by 5.7°, peak hip internal rotation decreased by 7.3°, and pain decreased by 2 points on the VAS. During the drop jump maneuver, peak hip adduction decreased by 5.2°, peak hip internal rotation decreased by 1°, and pain decreased by 4 points. Finally, application of the S.E.R.F. Strap during running resulted in a 3.7° decrease in hip adduction, a 13.8° decrease in hip internal rotation, and a 2.5-point decrease in pain.

DISCUSSION

Previous investigations have established the prevalence of abnormal femoral and acetabular morphology in individuals who develop acetabular labral pathology. Wenger et al[42] found that 87% (27 of 31) of individuals with acetabular labral pathology had at least 1 bony abnormality present on conventional radiographs. The most common bony abnormalities included acetabular retroversion, decreased femoral head-neck offset, and coxa valga.[42] Similarly, Kassarjian et al[13] reported that 93% of individuals with clinically suspected cam impingement had abnormally high alpha angles. There is consensus in the literature that bony morphological abnormalities cause a decrease in the amount of available joint space between the femoral head-neck junction and both the acetabular labrum and acetabular rim.[8,13,42] However, previous investigations have not examined why some individuals with structural abnormalities develop labral pathology while others with the same abnormalities do not.

As described above, altering frontal- and transverse-plane hip kinematics in this patient using the S.E.R.F. Strap resulted in a 50% decrease in self-reported pain. In all instances, the change in pain with the S.E.R.F. Strap exceeded the meaningful clinically important difference (MCID).[34] Furthermore, the changes in hip adduction and internal rotation following the application of the S.E.R.F. Strap exceeded the standard error of measurement for the quantification of frontal and transverse plane kinematics (1.0° and 1.3°, respectively), as established through pilot testing in the Musculoskeletal Biomechanics Research Laboratory. Accordingly, it can be inferred that dynamic movement into hip adduction and internal rotation may have been a potential cause of FAI and acetabular labral pathology in this patient. This information was used to educate the patient and develop a conservative treatment plan, which included exercises aimed at improving hip muscle strength and neuromuscular control.

The findings highlighted in this resident's case problem add a new dimension to the limited evidence surrounding the etiology of acetabular labral pathology. However, a single case report limits our ability to conclusively answer the many questions that exist. Further investigations are required to determine if the clinical findings evident in our patient would apply to a larger group of individuals with acetabular labral pathology. Additionally, future analyses are necessary to identify the movement patterns that characterize individuals with this particular injury.

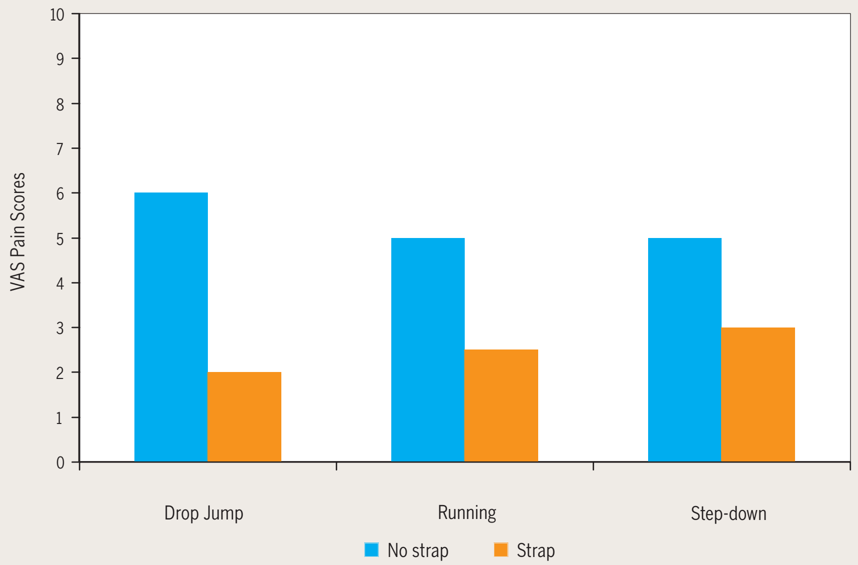

FIGURE 10. Visual analogue scale (VAS) pain ratings following the drop jump, running, and step-down tasks with and without the S.E.R.F. Strap. The VAS scale ranged from 0 to 10, where 0 indicated no pain and 10 indicated the worst pain imaginable.

SUMMARY

External assistance to improve hip control in the form of the S.E.R.F. Strap resulted in a decrease in hip adduction and internal rotation for the patient described in this resident's case problem. Furthermore, improvement in hip motion during functional tasks resulted in an average decrease in symptoms of 50%. The combination of decreased pain and improved hip kinematics suggests that dynamic impingement may have contributed to labral pathology in this patient. Future research is required to determine the extent to which physical therapy interventions aimed at improving hip kinematics would be effective in treating individuals with labral injuries.

REFERENCES

1. Beall DP, Sweet CF, Martin HD, et al. Imaging findings of femoroacetabular impingement syndrome. *Skeletal Radiol.* 2005;34:691-701. http://dx.doi.org/10.1007/s00256-005-0932-9
2. Beaule PE, Zaragoza E, Motamedi K, Copelan N, Dorey FJ. Three-dimensional computed tomography of the hip in the assessment of femoroacetabular impingement. *J Orthop Res.* 2005;23:1286-1292. http://dx.doi.org/10.1016/j.orthres.2005.03.011.1100230608
3. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. *J Bone Joint Surg Br.* 2005;87:1012-1018. http://dx.doi.org/10.1302/0301-620X.87B7.15203
4. Bharam S. Labral tears, extra-articular injuries, and hip arthroscopy in the athlete. *Clin Sports Med.* 2006;25:279-292, ix. http://dx.doi.org/10.1016/j.csm.2006.01.003
5. Buckwalter JA, Saltzman C, Brown T. The impact of osteoarthritis: implications for research. *Clin Orthop Relat Res.* 2004;S6-15.
6. Burnett RS, Della Rocca GJ, Prather H, Curry M, Maloney WJ, Clohisy JC. Clinical presentation of patients with tears of the acetabular labrum. *J Bone Joint Surg Am.* 2006;88:1448-1457. http://dx.doi.org/10.2106/JBJS.D.02806
7. Chan YS, Lien LC, Hsu HL, et al. Evaluating hip labral tears using magnetic resonance arthrography: a prospective study comparing hip arthroscopy and magnetic resonance arthrography diagnosis. *Arthroscopy*. 2005;21:1250. http://dx.doi.org/10.1016/j.arthro.2005.07.007
8. Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res.* 2003;112-120. http://dx.doi.org/10.1097/01.blo.0000096804.78689.c2
9. Guevara CJ, Pietrobon R, Carothers JT, Olson SA, Vail TP. Comprehensive morphologic evaluation of the hip in patients with symptomatic labral tear. *Clin Orthop Relat Res.* 2006;453:277-285. http://dx.doi.org/10.1097/01.blo.0000246536.90371.12
10. Ito K, Minka MA, 2nd, Leunig M, Werlen S, Ganz R. Femoroacetabular impingement and the cam-effect. A MRI-based quantitative anatomical study of the femoral head-neck offset. *J Bone Joint Surg Br.* 2001;83:171-176.
11. Jager M, Wild A, Westhoff B, Krauspe R. Femoroacetabular impingement caused by a femoral osseous head-neck bump deformity: clinical, radiological, and experimental results. *J Orthop Sci.* 2004;9:256-263. http://dx.doi.org/10.1007/s00776-004-0770-y
12. James SL, Ali K, Malara F, Young D, O'Donnell J, Connell DA. MRI findings of femoroacetabular impingement. *AJR Am J Roentgenol.* 2006;187:1412-1419. http://dx.doi.org/10.2214/AJR.05.1415
13. Kassarjian A, Yoon LS, Belzile E, Connolly SA, Millis MB, Palmer WE. Triad of MR arthrographic findings in patients with cam-type femoroacetabular impingement. *Radiology*. 2005;236:588-592. http://dx.doi.org/10.1148/radiol.2362041987
14. Kim KC, Hwang DS, Lee CH, Kwon ST. Influence of femoroacetabular impingement on results of hip arthroscopy in patients with early osteoarthritis. *Clin Orthop Relat Res.* 2007;456:128-132. http://dx.doi.org/10.1097/01.blo.0000246542.49574.2c
15. Lequesne M, Malghem J, Dion E. The normal hip joint space: variations in width, shape, and architecture on 223 pelvic radiographs. *Ann Rheum Dis.* 2004;63:1145-1151. http://dx.doi.org/10.1136/ard.2003.018424
16. Lewis CL, Sahrmann SA. Acetabular labral tears. *Phys Ther.* 2006;86:110-121.
17. Martin RL, Enseki KR, Draovitch P, Trapuzzano T, Philippon MJ. Acetabular labral tears of the hip: examination and diagnostic challenges. *J Orthop Sports Phys Ther.* 2006;36:503-515. http://dx.doi.org/10.2519/jospt.2006.2135
18. Martin RL, Sekiya JK. The interrater reliability of 4 clinical tests used to assess individuals with musculoskeletal hip pain. *J Orthop Sports Phys Ther.* 2008;38:71-77. http://dx.doi.org/10.2519/jospt.2008.2677
19. Mason JB. Acetabular labral tears in the athlete. *Clin Sports Med.* 2001;20:779-790.
20. McCarthy J, Noble P, Aluisio FV, Schuck M, Wright J, Lee JA. Anatomy, pathologic features, and treatment of acetabular labral tears. *Clin Orthop Relat Res.* 2003;38-47. http://dx.doi.org/10.1097/01.blo.0000043042.84315.17
21. McCarthy JC, Noble PC, Schuck MR, Wright J, Lee J. The Otto E. Aufranc Award: The role of labral lesions to development of early degenerative hip disease. *Clin Orthop Relat Res.* 2001;25-37.
22. Mitchell B, McCrory P, Brukner P, O'Donnell J, Colson E, Howells R. Hip joint pathology: clinical presentation and correlation between magnetic resonance arthrography, ultrasound, and arthroscopic findings in 25 consecutive cases.

Clin J Sport Med. 2003;13:152-156.
23. Murphy S, Tannast M, Kim YJ, Buly R, Millis MB. Debridement of the adult hip for femoroacetabular impingement: indications and preliminary clinical results. *Clin Orthop Relat Res.* 2004;178-181.
24. Narvani AA, Tsiridis E, Kendall S, Chaudhuri R, Thomas P. A preliminary report on prevalence of acetabular labrum tears in sports patients with groin pain. *Knee Surg Sports Traumatol Arthrosc.* 2003;11:403-408. http://dx.doi.org/10.1007/s00167-003-0390-7
25. Narvani AA, Tsiridis E, Tai CC, Thomas P. Acetabular labrum and its tears. *Br J Sports Med.* 2003;37:207-211.
26. Notzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. 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.
27. Peelle MW, Della Rocca GJ, Maloney WJ, Curry MC, Clohisy JC. Acetabular and femoral radiographic abnormalities associated with labral tears. *Clin Orthop Relat Res.* 2005;441:327-333.
28. Pfirrmann CW, Mengiardi B, Dora C, Kalberer F, Zanetti M, Hodler J. Cam and pincer femoroacetabular impingement: characteristic MR arthrographic findings in 50 patients. *Radiology*. 2006;240:778-785. http://dx.doi.org/10.1148/radiol.2403050767
29. Philippon MJ, Schenker ML. Arthroscopy for the treatment of femoroacetabular impingement in the athlete. *Clin Sports Med.* 2006;25:299-308, ix. http://dx.doi.org/10.1016/j.csm.2005.12.006
30. Powers CM, Chen PY, Reischl SF, Perry J. Comparison of foot pronation and lower extremity rotation in persons with and without patellofemoral pain. *Foot Ankle Int.* 2002;23:634-640.
31. Powers CM, Landel R, Perry J. Timing and intensity of vastus muscle activity during functional activities in subjects with and without patellofemoral pain. *Phys Ther.* 1996;76:946-955; discussion 956-967.
32. Powers CM, Ward SR, Chen YJ, Chan LD, Terk MR. The effect of bracing on patellofemoral joint stress during free and fast walking. *Am J Sports Med.* 2004;32:224-231.
33. Reynolds D, Lucas J, Klaue K. Retroversion of the acetabulum. A cause of hip pain. *J Bone Joint Surg Br.* 1999;81:281-288.
34. Salaffi F, Stancati A, Silvestri CA, Ciapetti A, Grassi W. Minimal clinically important changes in chronic musculoskeletal pain intensity measured on a numerical rating scale. *Eur J Pain.* 2004;8:283-291. http://dx.doi.org/10.1016/j.ejpain.2003.09.004
35. Salsich GB, Brechter JH, Farwell D, Powers CM. The effects of patellar taping on knee kinetics, kinematics, and vastus lateralis muscle activity during stair ambulation in individuals with patellofemoral pain. *J Orthop Sports Phys Ther.* 2002;32:3-10.
36. Schmid MR, Notzli HP, Zanetti M, Wyss TF, Hodler J. Cartilage lesions in the hip: diagnostic effectiveness of MR arthrography. *Radiology*. 2003;226:382-386.
37. Siebenrock KA, Schoeniger R, Ganz R. Anterior femoro-acetabular impingement due to acetabular retroversion. Treatment with periacetabular osteotomy. *J Bone Joint Surg Am.* 2003;85-A:278-286.
38. Souza RB, Selkowitz D, Powers CM. The effect of femoral strapping on pain response, hip rotation and gluteus maximus activation in persons with patellofemoral pain. *Physiotherapy*. 2007;93:S198.
39. Tanzer M, Noiseux N. Osseous abnormalities and early osteoarthritis: the role of hip impingement. *Clin Orthop Relat Res.* 2004;170-177.
40. Tonnis D, Heinecke A. Acetabular and femoral anteversion: relationship with osteoarthritis of the hip. *J Bone Joint Surg Am.* 1999;81:1747-1770.
41. Toomayan GA, Holman WR, Major NM, Kozlowicz SM, Vail TP. Sensitivity of MR arthrography in the evaluation of acetabular labral tears. *AJR Am J Roentgenol.* 2006;186:449-453. http://dx.doi.org/10.2214/AJR.04.1809
42. Wenger DE, Kendell KR, Miner MR, Trousdale RT. Acetabular labral tears rarely occur in the absence of bony abnormalities. *Clin Orthop Relat Res.* 2004;145-150.