A Pre-Operative Exercise Intervention Can Be Safely Delivered to People with Femoroacetabular Impingement and Improve Clinical and Biomechanical Outcomes

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ABSTRACT

Purpose: This study aimed to investigate the effects of a pre-hip arthroscopy exercise intervention on hip strength, pain, and function in individuals with femoroacetabular impingement (FAI). **Methods:** A total of 20 individuals with FAI completed a 10-week, partially supervised exercise programme; this included three phases of increasing resistance and functionality, consisting of four to six exercises per phase. Hip strength in all six directions; hip pain; function, as measured by the Hip disability and Osteoarthritis Outcome Score (HOOS); and objective physical function, as measured by the Timed Stair Climb test, were determined before and after the intervention. **Results:** Maximum isometric hip strength significantly increased in abduction ($p = 0.008$), adduction ($p = 0.021$), and internal rotation ($p = 0.006$) at follow-up. Increases in flexion, extension, and external rotation strength did not reach statistical significance. Self-reported HOOS pain ($p < 0.01$) and activities of daily living sub-scale scores ($p < 0.01$) significantly improved at follow-up. Timed Stair Climb times ($p < 0.001$) also significantly decreased at follow-up. **Conclusion:** A 10-week exercise programme can be safely completed by adults with FAI before surgery, and statistically significant changes in strength, function, and self-reported clinical outcomes can be achieved.

Key Words: exercise; femoroacetabular impingement; function; hip.

RÉSUMÉ

Objectif : examiner les effets d'un programme d'intervention préopératoire sur la force, la douleur et la fonction des hanches chez les personnes souffrant d'un conflit fémoro-acétabulaire (CFA). **Méthodologie :** vingt personnes atteintes d'un CFA ont participé à un programme d'exercice de 10 semaines partiellement supervisé, composé de trois phases de quatre à six exercices de résistance et de fonctionnalité croissantes. La force des hanches dans les six directions, la douleur et la fonction ont été mesurées à l'aide du *Hip Disability and Osteoarthritis Outcome Score (score du pronostic d'incapacité et d'arthrose de la hanche) (HOOS)* et la fonction physique objective a été mesurée par le test de l'escalier, avant et après l'intervention. **Résultats :** au suivi, une augmentation statistiquement significative de la force isométrique maximale a été observée pour l'abduction ($p = 0,008$), l'adduction ($p = 0,021$) et la rotation interne ($p = 0,006$). En revanche, l'augmentation de la flexion, de l'extension et de la force de rotation externe n'était pas significative. Les scores des sous-échelles du HOOS pour la douleur autodéclarée ($p < 0,01$) et les activités quotidiennes ($p < 0,01$) ont aussi augmenté de façon significative. Quant aux temps au test de l'escalier ($p < 0,001$) ils ont diminué de façon significative. **Conclusion :** l'étude démontre qu'un programme d'exercice de 10 semaines peut être suivi de façon sécuritaire par des adultes atteints d'un CFA avant la chirurgie et qu'il peut permettre d'améliorer de façon significative la force, la fonction et les résultats cliniques autodéclarés.

Femoroacetabular impingement (FAI) refers to hip pain associated with abnormal contact between the acetabulum and femoral head-neck junction¹ and is typically found in active young and middle-aged adults.² More important, FAI is thought to be a precursor to the development of hip osteoarthritis (OA) as a result of the abnormal loading within the hip joint caused by repetitive impingement.^{1,3} Surgery is increasingly used for people with FAI; it is intended to relieve any mechanical impingement and treat any residual injuries that may be

present, thus improving the pain-free range of motion.⁴ Despite finding some positive results,⁴⁻⁷ a systematic review of 23 studies showed that surgical treatment failure, requiring hip replacement surgery, occurred in about 4% of patients within 1 year,⁶ in 11% after 5 years,⁸ and in 30% overall at various time points.⁹ This review highlights the need to identify additional treatment strategies for these patients that may either negate the need for surgery or improve the outcomes after surgery.

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Hip muscle weakness is prevalent in those with FAI, and it can lead to abnormal joint loading, causing pain and dysfunction during dynamic weight-bearing activities such as walking. The limited available evidence has supported the notion of widespread muscle weakness in people with FAI, with strength values ranging from 11% to 28% lower than healthy controls.^{10,11} Although muscle strengthening is a key component of exercise treatment for many musculoskeletal pathologies, no published studies have examined changes in strength, function, and self-reported clinical outcomes after hip muscle-strengthening programmes in people with FAI. However, after 6 weeks of strengthening exercises people awaiting total hip and knee arthroplasty achieved improvements in strength and function compared with a control group.¹² Thus, if people with FAI who are awaiting hip arthroscopic surgery can achieve similar results, they may be able to reduce pain and dysfunction and improve overall clinical outcomes. Accordingly, the feasibility of delivering muscle strength training to people with FAI needs to be ascertained. Furthermore, knowledge of expected strength, function, and self-reported clinical outcomes is important to guide clinical practice and inform future controlled research studies.

The primary objectives of this feasibility study were to (1) examine the immediate post-intervention changes of a pre-surgical exercise intervention (focusing on hip strength) on hip strength, pain, and function in individuals with FAI and (2) examine the adherence to, and safety of, delivering an exercise intervention to people with FAI. We hypothesized that strength would be improved in all hip movements, pain and function would be improved after the intervention, and the intervention could be delivered safely and effectively.

METHODS

Participants

Consecutive participants on a surgical wait-list for arthroscopic hip debridement surgery, under the care of a single orthopaedic surgeon, were screened for eligibility. Eligible participants exhibited definitive signs of FAI on magnetic resonance arthrogram, a positive hip impingement test determined by the orthopaedic surgeon, and reports of anterior groin pain consistent with the pathology of FAI. A further inclusion criterion was the ability to attend five supervised exercise sessions over 10 weeks. Exclusion criteria were (1) evidence of hip OA on imaging, (2) a recent (<1 mo) cortisone injection to relieve hip pain, (3) previous hip surgery, (4) a history of significant lower body injuries or conditions other than FAI that would impair the measurement of hip function or hip strength, (5) a history of osteonecrosis of the hip, and (6) planned commencement of a lower body strengthening programme during the intervention, or current enrolment in an exercise programme focused on strengthening the hip muscles.

This study was approved by the institution's Clinical Research Ethics Board, and all participants provided written informed consent. The study conforms to the human and animal rights requirements of the February 2006 International Committee of Medical Journal Editors' Uniform Requirements for Manuscripts Submitted to Biomedical Journals.

Sample size was calculated on the basis of similar studies in the literature. To our knowledge, no previous studies specifically on exercise interventions for FAI have been published; therefore, a similar resistance training intervention in hip OA (a related pathology) was used to calculate sample size. Steinhilber and colleagues¹³ reported effect sizes (mean difference divided by the SD of difference) ranging from 0.13 to 1.01 for isometric hip strength across four movements for an 8-week hip muscle-strengthening intervention. On the basis of a one-tailed $\alpha = 0.05$, power = 0.9, and effect size = 1.0, a sample size of 18 participants was needed to best examine differences in hip strength and pain. To conservatively account for 10% attrition, the sample size was increased to 20 participants. Sample size was calculated from reference Table C.2 (a sample-size calculation table for paired *t*-tests) in the Portney and Watkins textbook.¹⁴

Study design

Baseline testing consisted of measures to assess participants' hip muscle strength and physical function as well as self-report questionnaires to assess pain and physical function. All participants then completed the 10-week exercise intervention and returned to the laboratory for follow-up testing.

Intervention

Participants enrolled in a 10-week, home-based exercise intervention, supplemented with five kinesiology-supervised sessions. During this 10-week programme, participants progressed through three phases of increasing exercise intensity and functionality of movement, receiving a bilateral intervention of four to six exercises per phase. They were instructed to perform these exercises at home four times per week (three sets of 10–12 repetitions per exercise per session); this instruction meets the American College of Sports Medicine's guidelines for achieving significant strength increases.¹⁵ Each participant consulted with the study kinesiology five times (once per week in weeks 1, 2, 4, 6, and 8) to ensure that he or she was performing the exercises properly and resistance had been increased safely. Exercise intensity was modified by increasing the number of repetitions from 10 to 12 as necessary and introducing the use of resistance bands and weight cuffs. Participants completed a weekly exercise diary to track adherence, changes in treatment or medication, and adverse effects, if any.

The distribution of exercises per phase throughout the intervention can be found in Table 1. The aim of phase 1 was to facilitate optimal, pain-free activation of

Table 1 Exercises Given to Participants

Phase 1	Phase 2	Phase 3
Bridging	Clamshells with weight cuff	Squats and lunges
Transverse abdominus heel drops	Standing hip extension with resistance band	Sidesteps with resistance band
Clamshells	Sidesteps with resistance band	Step-ups
Four-point-kneel hip abduction	Standing hip abduction with weight cuff	Single-leg dead lift
Single-leg balance		Single-leg hops

key muscle groups, improve neuromuscular control, and develop some muscular endurance. These aspects were necessary to provide a solid foundation on which to later improve muscle strength in this patient population. The aim of phase 2 was to build on the participants' foundation of muscle strength and increase the intensity of the exercises. The aim of phase 3 was to have the participants further increase hip muscle strength but during movements that were more functional, some of which may not have been properly executed free of pain before the intervention began. Specific information regarding the exercises for this study, including instructions and photographs, can be found in the online Appendix.

Outcome measures

At baseline and follow-up, maximum isometric hip muscle strength in all six hip movement directions was assessed using a handheld dynamometer, the microFET2 (Hoggan Scientific, Salt Lake City, UT). A trained tester, who had no involvement in the intervention, performed all assessments. Flexion strength was assessed in supine, with the hip and knee flexed at 90 degrees and the dynamometer placed 5 centimetres proximal to the patella. Abduction and adduction strength were assessed in supine with the hip and knee straight, with the dynamometer placed on the lateral and medial femoral epicondyle, respectively. Extension strength was assessed in prone with the hip and knee straight, with the dynamometer placed 5 centimetres proximal to the centre of the knee joint. Internal and external hip rotation strength was assessed in high sitting, with the hip and knee flexed 90 degrees and the dynamometer placed 5 centimetres proximal to the lateral and medial malleolus. Participants were asked to push as hard as possible for 5 seconds. This was repeated three times for each movement, and the largest force produced for each movement was converted to a torque by multiplying by the lever arm distance (distance along the body segment between the joint axis of rotation and placement of the dynamometer), then normalizing to body mass (Newton metre per kilogram, or N-m/kg).

Test-retest reliability showed good to excellent reliability; this was determined from a sub-sample of the first 12 study participants, who were tested 1 week apart before commencing the intervention. Intra-class correlation (ICC) coefficients (ICC_{2,1}) in our sub-sample were 0.89 (95% CI: 0.53, 0.97) for flexion, 0.84 (95% CI: 0.43,

0.95) for extension, 0.86 (95% CI: 0.54, 0.96) for abduction, 0.94 (95% CI: 0.79, 0.98) for adduction, 0.90 (95% CI: 0.66, 0.97) for internal rotation, and 0.69 (95% CI: 0.65, 0.91) for external rotation.

Self-reported hip pain and function were assessed using the Hip disability and Osteoarthritis Outcome Score (HOOS). The HOOS is a valid and reliable,¹⁶ 40-item Likert-response questionnaire developed to assess symptoms, pain, function with activities of daily living (ADLs), sports and recreation function, and quality of life in middle-aged to older adults with and without hip OA. A score was calculated for each of the five sub-scales, on which 100 = *no symptoms* and 0 = *extreme symptoms*. For the purpose of this study, all 5 sub-scales were scored, with the primary focus placed on HOOS pain and HOOS ADLs.

Objective physical function was assessed using the Timed Stair Climb test, which is the time (in seconds) taken to ascend 12 stairs as quickly as possible while contacting every stair. This test is an objective test that quantifies physical function in people with hip pathology.¹⁷ Reliability coefficients of 0.90 (95% CI: 0.79, 0.96) for the stair climb were reported in a previous study, which evaluated performance outcomes after total hip arthroscopy.¹⁸

Participants reported global rating of change during their follow-up visit. On a 15-point scale that ranged from -7 (*a very great deal worse*) to 7 (*a very great deal better*), participants reported how their hip pain compared with baseline. Scores were then grouped in clusters of five to produce three distinct categories (scores of -3 or lower were scored as "worse," scores of -2 to 2 were scored as "no change," and scores of 3 or greater were scored as "improved").

Self-reported adherence to the exercise programme, changes in treatment, and adverse events were obtained from open-ended questions in the weekly diary that was completed by each participant. These questions included "Did you suffer any adverse effects (including back pain) from the exercises this week?" "Did your hip joint symptoms change this week (better or worse)?" "Did you have any new treatments for your hip this week?" and "Did you change your medications at all this week?" If participants answered "yes" to any of these questions, they were requested to provide written details. Participants' attendance at the supervised sessions was also recorded.

Figure 1 Flowchart of participant inclusion and retention.
OA = osteoarthritis.

Statistical analysis

To investigate the effect that the exercise intervention had on the outcomes, within-subjects paired *t*-tests were used. Baseline and follow-up primary outcomes included hip muscle strength, pain, and physical function. Given the exploratory nature of this study, no statistical adjustment was used; instead, differences were considered significant if $p < 0.05$. All statistical analyses were conducted using IBM SPSS Statistics, version 21.0 (IBM Corporation, Armonk, NY).

RESULTS

Between March 2013 and April 2014, 46 individuals underwent clinical and radiographic screening for the study (see Figure 1). Of these, 20 individuals (18 men, 2 women; mean age 29.8 [SD 6.8] years; BMI = 24.1 [SD 2.9] kg/m²) underwent baseline testing. Participants reported hip pain for a mean of 53.6 (SD 40.2) months (range = 12–132). One individual was unable to attend any exercise sessions after week 5 as a result of an acute neck injury sustained in a car accident, unrelated to the inter-

vention. Therefore, 19 participants were included in the follow-up analyses, with a mean follow-up time of 11.3 (SD 0.6) weeks (range = 10.4–12.5 wk).

Seven participants demonstrated bilateral FAI, and 13 participants demonstrated unilateral FAI. In cases of bilateral FAI, the hip reported to be more painful and dysfunctional, and scheduled for surgery, was considered to be the affected (study) hip.

Mean values for primary outcomes at baseline and follow-up are displayed in Table 2. Isometric hip muscle strength for abduction, adduction, and internal rotation increased significantly at follow-up, whereas isometric hip muscle strength during flexion, extension, and external rotation did not show statistically significant changes after the intervention ($p > 0.05$).

HOOS scores are also summarized in Table 2. Scores on all five HOOS sub-scales significantly increased at follow-up ($p < 0.05$). Finally, the amount of time it took participants to perform the Timed Stair Climb test significantly decreased at follow-up ($p < 0.001$). Using global ratings of change scores during the follow-up assessment,

Table 2 Outcome Measures

Outcome	Baseline: week 0, mean (SD)	Follow-up: week 11, mean (SD)	Mean difference (95% CI)	<i>p</i> -value
Hip muscle strength (N-m/kg)				
Flexion	1.89 (0.45)	2.04 (0.43)	0.15 (−0.03, 0.34)	0.10
Extension	1.81 (0.46)	1.93 (0.50)	0.11 (−0.1, 0.33)	0.29
Abduction	1.53 (0.35)	1.67 (0.34)	0.14 (0.05, 0.24)	0.008
Adduction	1.40 (0.38)	1.53 (0.39)	0.13 (0.02, 0.24)	0.021
Internal rotation	0.76 (0.36)	0.89 (0.36)	0.13 (0.04, 0.22)	0.006
External rotation	0.75 (0.23)	0.77 (0.18)	0.03 (−0.05, 0.10)	0.49
HOOS sub-scale (0–100)*				
Pain	64.1 (12.3)	72.5 (12.3)	8.5 (3.3, 13.6)	0.003
Symptoms	56.1 (13.2)	63.9 (14.6)	7.9 (1.3, 14.5)	0.022
ADLs	73.0 (14.4)	83.4 (11.0)	10.4 (4.1, 16.7)	0.003
Sports	51.7 (12.2)	63.4 (14.0)	11.7 (4.7, 18.6)	0.003
QOL	35.3 (17.2)	42.8 (22.0)	7.6 (1.1, 14.1)	0.025
Timed Stair Climb test (sec)	2.96 (0.66)	2.61 (0.46)	−0.36 (−0.49, −0.22)	<0.001

*Higher HOOS scores represent less impairment.

N-m/kg = Newton metres per kilogram of body mass; HOOS = Hip disability Osteoarthritis Outcome Score; ADLs = activities of daily living; QOL = quality of life.

Table 3 Self-Reported Adverse Events during the 10-Week Intervention

Event	No.	Time point (week no.)	Outcome
Post-exercise soreness	6	1 and 2	Subsided within 3–4 d
Lateral knee pain	2	4 and 5	Subsided within 2 wk
Low back stiffness	1	5	Subsided within 5 d

10 participants reported that their hip pain had improved, 8 participants experienced no change, and 1 participant reported that the pain had gotten worse.

Attendance at the supervised exercise sessions was high (90 of 95 sessions attended; 95%), with individual attendance rates ranging from 3 (60%) to 5 (100%). Adherence to the home exercises was lower (601 of 760 sessions completed; 79%). Participants completed, on average, a mean of 32 of the 40 home-based exercise sessions over the 10 weeks, with individual session completion rates ranging from 18 (45%) to 40 (100%). On average, the participants spent 3.3 weeks in each of phases 1 and 2 and 3.5 weeks in phase 3. All participants progressed to phase 3.

Eight participants noted nine separate self-reported adverse events during the 10-week intervention (see Table 3), although most events were the post-exercise soreness typical of starting any exercise programme. No participants experienced substantial changes in typical medication use. Five participants reported that they had resumed previous sporting activities (e.g., swimming or cycling) during the 10-week intervention. One participant had gone for two massage treatments halfway through the intervention, one participant had started an upper body resistance training programme during the final 5 weeks of the intervention, and one participant reported

one session of hip mobilization with a physiotherapist during week 2 of the intervention. Finally, five participants cancelled their surgical appointment and, at 12 months since the intervention, had not undergone surgery; however, the reasons for the cancellation cannot solely be attributed to the current intervention.

DISCUSSION

The objectives of this study were to examine the effects and feasibility of a pre-hip arthroscopy exercise intervention emphasizing hip muscle strengthening in patients with FAI. Significant improvements in hip muscle strength during hip abduction, adduction, and internal rotation were found post-intervention. Conversely, no significant differences in muscle strength were found in hip flexion, extension, or external rotation post-intervention. Furthermore, we found significant improvements on all five HOOS sub-scales post-intervention. Although many studies have assessed and reported the effects of an exercise intervention on various lower limb impairments, this is the first study to do so in the FAI population. As a result, it will help fill that gap in the literature and provide the preliminary information needed to justify further exploration of exercise as a treatment for affected individuals.

It was hypothesized that participants who completed the 10-week exercise programme would increase their muscle strength because the intervention consisted mainly of muscle strengthening and functional movement exercises. However, not all six movements of the hip significantly increased in strength post-intervention. Although the present study did not have a healthy control group, the strength values in this cohort indicate muscle weakness compared with similar published data in those with and without FAI.^{10,11} One reason this study did not see

significant strength improvements in flexion and extension could be that the exercises did not provide enough challenge or resistance for these muscle groups or that the intervention was not long enough. With a goal of ensuring pain-free activation of muscle around the hip joint, it is possible that exercise intensity may have been lowered, thus resulting in less challenging exercises and smaller gains.

Thorborg and colleagues¹⁹ reported that increases in strength above 10% when using handheld dynamometry can be considered real changes when compared with healthy individuals. The 17% improvement in internal rotation strength found in this study clearly surpasses this cutoff. It is possible, however, that a meaningful cutoff for strength increases would be lower in clinical populations because clinical populations, such as those with FAI, have lower baseline strength values than healthy individuals and thus may experience benefits from smaller improvements. As a result, whether the strength increases seen for flexion, abduction, and adduction of the hip are clinically meaningful or approximate meaningful levels of improvement is not known.

Weak hip muscles are postulated to result in altered hip motion and stability, ultimately causing hip pain;²⁰ this suggests that stronger hip muscles can help counteract that effect. Thus, strengthening the muscles surrounding the hip joint may enhance joint stability.²⁰ The significant increase in muscle strength in certain hip motions may partially account for improvements in pain and function observed after the 10-week strengthening programme. In particular, the strengthened abductor, adductor, and internal rotator muscles can help align the femur in the acetabulum, creating a more stable hip joint, with concomitant improvements in self-reported pain and function. In contrast, increased muscle activation may produce larger joint-contact forces, which may exacerbate symptoms and the progression of altered hip morphology. It is currently unclear whether “normalizing” muscle function has positive or negative implications on joint health. Further research with longitudinal cohort designs is needed.

We compared our HOOS scores with those of another study that reported minimal important change (MIC) for HOOS scores after hip surgery. Kemp and colleagues²¹ reported that the MICs for HOOS pain and ADL sub-scales were 9 and 6 points, respectively. The mean differences in the current study were 9 and 10 points, respectively, indicating likely meaningful changes. When combined with the global rating-of-change scores (10 of the 19 participants reported improvement in pain), our exercise intervention provided clinically meaningful improvements in symptoms for most participants. However, although potentially clinically meaningful improvements in symptoms were observed with the HOOS, global change scores do not necessarily reflect the individual constructs of a patient-reported outcome such as the HOOS, and an

intervention may need a longer duration or more treatment elements to produce more wide-ranging benefits. Clearly, more research is needed in this emerging area.

Given that this is the first reported study in the literature on strengthening exercises for FAI, it was important to explore the feasibility of delivering such an intervention to this patient population. Participant attendance during supervised exercise sessions was excellent at 95%, and participants completed, on average, 79% of the home sessions (3.2 exercise sessions per week). This is much higher than the average adherence rate for exercise interventions reported in the literature of 66%.²² Overall, attrition was absent, with no participant withdrawing from the study for intervention-related reasons. Thus, it can be concluded that delivering such an intervention to people with FAI on a surgical wait-list is feasible, safe, and effective.

Despite the encouraging results found in this study, it does have several limitations. First, the absence of a control group is considered to be a main limitation because it detracts from the ability to make firm conclusions regarding treatment effects. However, because this was the first study of its kind with this patient population, our initial findings provide the impetus for future studies with larger sample sizes. Indeed, a randomized controlled trial with an exercise group and a control group would be ideal and is now justified on the basis of the current findings. Furthermore, both men and women were recruited to our study to aid in the generalizability of the findings because both genders experience FAI. However, because only two women were recruited, the majority of our data came from male participants. It is unclear whether our findings would have changed if our cohort had consisted of a greater number of women, and generalization of our findings to women with FAI should be made with caution.

A potential limitation is that handheld dynamometry was used to measure hip strength. Although not as reliable as isokinetic dynamometry, handheld dynamometry is commonplace in the clinical setting, and our strength values can therefore be used for comparison purposes by clinicians who assess strength in patients with FAI. That said, handheld dynamometry poses several challenges, including ensuring proper stabilization and the ability to maintain a true isometric test; as a result, our values should be interpreted with caution. Finally, our sample size was relatively small and based on effect sizes from different patient populations. Although we did find several statistically significant differences, future research would benefit from a study that used a larger number of participants. Nevertheless, findings from this study can be used to better guide sample size calculations in future FAI intervention studies.

CONCLUSION

We found that a 10-week exercise programme with a focus on hip strengthening could be safely completed

by adults with FAI and that statistically significant changes in strength, function, and self-reported clinical outcomes were achieved. Although this initial feasibility study had promising findings, it is clear that more research is needed to draw stronger conclusions. More important, an assessment of changes after surgery is needed to better understand the longer term outcomes from an exercise intervention in this patient population and whether pre-surgical exercise can improve post-surgical outcomes. This would be timely given the long surgical wait-lists for people with FAI, thus presenting an obvious treatment opportunity for those who would otherwise simply be waiting for surgery.

KEY MESSAGES

What is already known on this topic

Femoracetabular impingement (FAI) is a common musculoskeletal disorder that presents with hip pain, dysfunction, and muscle weakness. Surgery is the most common treatment approach and involves debridement surgery to improve arthrokinematic movement. However, clinical success post-surgery is not guaranteed, with many patients reporting sub-optimal outcomes, and as many as 30% eventually undergoing hip replacement surgery. The effects of conservative treatment approaches, such as muscle strengthening, in this population are less clear.

What this study adds

We showed, for the first time, that a hip strengthening programme can be safely delivered to people with FAI and that improvements in muscle strength and self-report outcomes can be achieved. After just 10 weeks of exercises focusing on improving hip muscle strength and function, significant improvements were found in hip abduction, adduction, and internal rotation, as well as in self-reported hip pain and physical function. More important, few adverse effects were reported. These findings provide new information related to treatment options for people with FAI who may not want to undergo surgery.

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