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Research article

Limited lumbopelvic mobility does not influence short-term outcomes after primary hip arthroscopy: a propensity-matched controlled study

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This study was performed in accordance with the ethical standards in the 1964 Declaration of Helsinki. This study was carried out in accordance with relevant regulations of the U.S. Health Insurance Portability and Accountability Act. Details that might disclose the identity of the subjects under study have been omitted. This study was approved by the institutional review board (ID: 5276).
This study was performed at the American Hip Institute Research Foundation.
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ABSTRACT

There is a paucity of literature investigating the effect of lumbopelvic mobility on patient-reported outcome scores (PROs) after primary hip arthroscopy. The purpose of this study was (i) to report minimum 1-year PROs in patients with limited lumbopelvic mobility (LM) who underwent primary hip arthroscopy for femoroacetabular impingement syndrome (FAIS) and (ii) to compare clinical results with a propensity-matched control group of patients with normal lumbopelvic mobility (NM). Data were reviewed for surgeries performed between November 2019 and March 2020. Patients were considered eligible if they received a primary hip arthroscopy for FAIS in the setting of LM (seated to standing change in sacral slope $\leq 10^\circ$). LM patients were propensity-matched to a control group of patients with normal lumbopelvic motion (seated to standing change in sacral slope > 10°) for comparison. A total of 17 LM and 34 propensity-matched NM patients were included in the study. LM patients showed significant improvement in all outcome measures and achieved the minimum clinically important difference (MCID) and patient acceptable symptomatic state (PASS) at high rates for modified Harris Hip Score (MCID: 94% and PASS: 82%) and International Hip Outcome Tool-12 (iHOT-12; MCID: 94% and iHOT-12: 76%). When LM patients were compared to a propensity-matched control group of NM patients, they demonstrated similar postoperative PROs and rates of achieving MCID/PASS. LM patients who undergo primary hip arthroscopy may expect favorable short-term PROs at minimum 1-year follow-up. These results were comparable to a control group of NM patients.

INTRODUCTION

The concept of hip-spine syndrome was introduced in 1983 by Offierski and MacNab and was used to describe patients with coexisting hip arthrosis and lumbar spine disorders [1]. Pathology of the lumbar spine and hip can often have overlapping symptoms which can present a diagnostic and therapeutic dilemma for clinicians [2]. A majority of the literature on hip-spine syndrome is described in the setting of hip arthroplasty [3–5], but there has been a recent interest in its influence on hip arthroscopy [6–9].

It has been established that spinopelvic motion can influence acetabular position, and stiffness in the lumbar spine forces the hip to make up for that lack of motion to allow for daily activities such as sitting [10–13]. The literature on the influence of hip-spine syndrome on hip arthroscopy outcomes has mainly evaluated patients with low back pain, radicular symptoms or prior lumbar surgery [6–8, 14, 15]. More recently, Heaps *et al.* [16] reported that patients with lumbosacral transitional vertebrae (LSTV) had less benefit after hip arthroscopy as demonstrated by lower patient-reported outcome scores (PROs) 24–35 months postoperative compared to patients without LSTV. In their paper they proposed the importance of lumbosacral motion loss on outcomes in hip arthroscopy due to the possibility of residual FAI even after surgical correction. Conversely, Luo *et al.* [17] performed a large retrospective cohort study which was unable to establish inferior outcomes in patients with LSTV compared to controls. Given the evidence that spine pathology causing decreased lumbar mobility can potentially compromise outcomes after hip

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arthroscopy, normal anatomic variants that limit spinopelvic motion may have similar effects.

The purpose of this study was (i) to report minimum 1-year PROs in patients with limited lumbopelvic mobility (LM) who underwent primary hip arthroscopy for femoroacetabular impingement syndrome (FAIS) and (ii) to compare clinical results with a propensity-matched control group of patients with normal lumbopelvic mobility (NM). It was hypothesized that (i) patients with LM would demonstrate favorable PROs at minimum 1-year follow-up and (ii) clinical results would be inferior to those of a propensity-matched control group of NM patients.

MATERIALS AND METHODS

Patient selection

Data were prospectively collected and retrospectively reviewed on consecutive patients who underwent primary hip arthroscopy between November 2019 and March 2020 in the setting of FAIS. Patients were included in the analysis if they had preoperative and minimum 1-year follow-up PROs for the modified Harris Hip Score (mHHS) [18], the Nonarthritic Hip Score (NAHS) [19], the International Hip Outcome Tool-12 (iHOT-12) [20] and the Visual Analog Scale (VAS) for pain [21]. Patients were excluded from analysis if they had a previous diagnosed ipsilateral hip or lumbar spine condition (e.g. avascular necrosis, slipped capital femoral epiphysis or Legg–Calvé–Perthes disease) or were not diagnosed with FAIS. As per established literature, patients were defined as having limited lumbopelvic motion if they had a seated to standing change in sacral slope $\leq 10°$ [22].

Participation in the (X.X.X.) registry

Some data may have been reported in other studies from this institution; however, this study provides a unique analysis. An institutional review board has approved all data collection.

Radiographic evaluation

Radiographic imaging, including the standing and supine anteroposterior pelvis, modified 45° Dunn and false-profile view, was acquired and reviewed before surgery [23–26]. These images were evaluated using the General Electric Healthcare's Picture Archiving and Communication System. The anteroposterior supine view was used to assess the level of osteoarthritis as graded with the Tönnis system [27] and the lateral center-edge angle of Wiberg [28] as modified by Ogata *et al.* [29]. The standing and seated lateral spinal views were used to measure the sacral slope. Sacral slope was defined as the angle subtended by a line parallel to the superior endplate of S1 relative to the horizontal plane (Fig. 1). Limited spinal mobility was defined by less than a 10° change in sacral slope from the standing to seated positions [22, 30–32]. In addition, proximal femoral angle was measured in both the standing and seated positions according to previously described methods [33]. The proximal femoral angle was measured between a vertical line and the line defined by the anterior cortex of the most visible femur. Flexion of the hip joint was calculated by adding the change in position of the proximal femur to the change in position of the pelvis (using the sacral slope angle) by subtracting the sitting position values from standing position values [13]. The institution's radiographic measurements have demonstrated good interobserver reliability in previously published studies [34–36]. A magnetic resonance arthrography was also obtained from each patient to evaluate for a labral tear and to diagnose other intra-articular and extra-articular pathologies.

Surgical indications and procedures

Surgery was recommended by the senior author (Y.Y.Y.) for patients with diagnosis of FAIS. These patients also presented with hip pain for at least 3 months with no relief from conservative treatment including physical therapy, injections, nonsteroidal anti-inflammatory drugs and activity modification [37].

All arthroscopies were performed by one orthopedic surgeon (Y.Y.Y.). In the operating room, patients received general

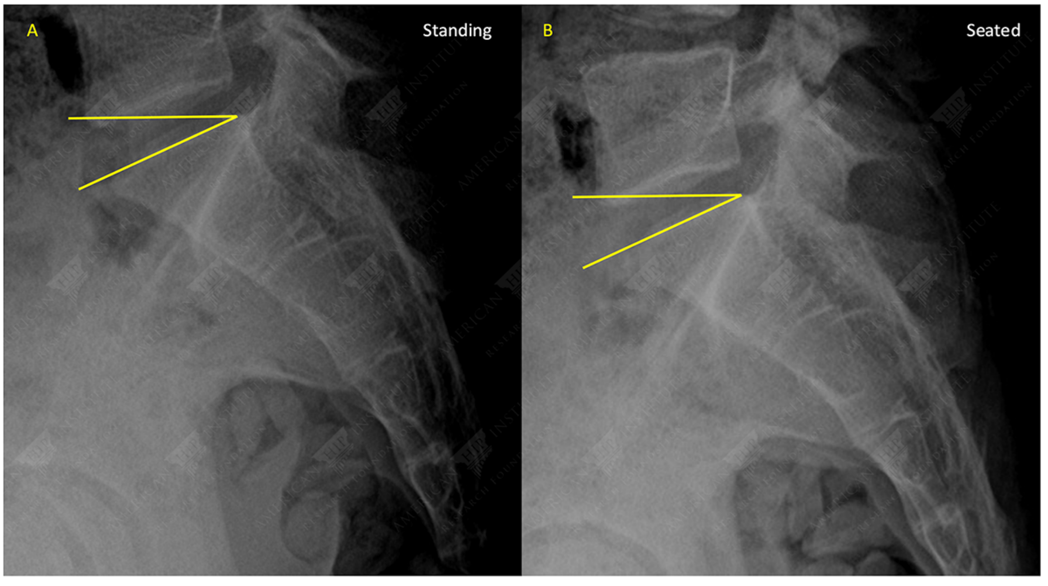

Fig. 1. Sacral slope measurements (yellow lines) on standing (A) and seated (B) *x*-rays.

anesthesia and were placed in a modified supine position on a traction table [38]. The surgeon accessed the joint through the anterolateral, mid-anterior and distal anterolateral portals [39]. An interportal capsulotomy was then performed and a diagnostic arthroscopy was carried out to assess the hip pathology. The Domb and Villar systems were used to classify the ligamentum teres [40, 41]. The Seldes system was used to grade the labral pathology [41]. Cartilage damage on the acetabulum and femoral head were classified by the Outerbridge system [43]. The acetabular labrum articular disruption (ALAD) was used to grade the chondrolabral junction [44].

Procedures varied based on each patient's hip pathology. Labral tears were either repaired, selectively debrided or reconstructed [45, 46]. Fluoroscopic guidance and a 5.5-mm burr were used to perform a femoroplasty, acetabuloplasty or subspine decompression to treat cam morphology, pincer morphology or subspine impingement, respectively [47]. Repair or plication of the capsule was performed based on the patient's range of motion, ligamentous laxity and acetabular coverage [48, 49].

Surgical outcome tools

Patients were assessed preoperatively, 3 months postoperatively and annually thereafter. Outcome scores were computed from questionnaires completed during clinic visits, over the telephone or over encrypted email. Questionnaires included the mHHS [18], the NAHS [19], the International Hip Outcome Tool-12 (iHOT-12) [50] and the VAS for pain [21]. mHHS, NAHS and iHOT-12 were measured on a scale of 0 to 100. VAS was measured on a scale of 0 to 10. The threshold for achievement of the minimal clinically important difference was calculated for mHHS, NAHS and iHOT-12 [51]. The patient acceptable symptomatic state (PASS) thresholds were calculated for mHHS and iHOT-12 based on previously published literature [52]. The rates of achievement of the maximum outcome improvement satisfaction thresholds were also recorded based on thresholds set by previously published literature [53].

Propensity score matching and statistical analysis

To allow for adequate sample size for analysis, patients were divided into two groups: patients with change in seated to sanding sacral slopes $\leq 10°$ (LM) and those with changes $> 10°$ (NM). Patients were then matched according to age, sex and body mass index (BMI). The propensity score matching was done in a 2:1 ratio without replacement and to the nearest Euclidean distance. The matched cohorts excluded any patients who fell outside a caliper of 0.2 times the standard deviation of the logit propensity scores. Data were summarized using mean and standard deviation or proportion where appropriate. Normality and equality of variance were measured with the Shapiro–Wilk test and the *F*-test, respectively. The two-tailed *t*-test of its nonparametric equivalent was used for continuous data, while the Fisher exact test or chi-square test was used to compare categorical data. A threshold *P* value of 0.05 was used to determine statistical significance. Based on the assumption that a mean difference of nine points in follow-up mHHS between groups is clinically important, an *a priori* power analysis was used to determine that in a 1:2 matching ratio, 16 study cases and 31 control cases were necessary to achieve at least 80% power [54]. All analyses were conducted in Microsoft Excel with the Real Statistics Add-in package (Microsoft Corporation; Redmond, WA).

RESULTS

Demographic data for all patients are provided in Table I. Sixty-six patients (66 hips) were eligible, of which 54 patients had adequate follow-up (81.8%). Of the 54 patients with adequate follow-up data, 51 were matched into two groups based on spinal mobility: 34 (66.7%) patients were classified as normal spinal mobility and 17 (33.3%) patients had limited spinal mobility. Three patients in the study group (limited mobility) were male (17.6%) and 14 were female (82.4%), while 12 patients in the control group (normal mobility) were male (35.3%) and 22 were female (64.7%).

There were significant differences for several radiographic measurements between the two groups. The sitting sacral slope for the study group was significantly higher than the control group ($P < 0.001$). The sacral slope deltas were also statistically significant ($P < 0.001$). Additionally, the standing proximal femoral angles were significantly lower in the study group ($P = 0.033$). The femoroacetabular flexion angle was significantly higher in the study group ($P < 0.001$). Complete radiographic data can be found in Table II.

Intraoperative findings are presented in Table III. The distribution of Seldes-defined labral tear types was not significantly different between groups ($P = 0.684$), nor was the distribution of ALAD ($P = 0.898$). There was no significant difference in acetabular ($P = 0.898$) or femoral head ($P = 0.204$) Outerbridge lesions between the study and control groups. There

Table I. Patient characteristics and demographic factors[a]

	Spinal mobility		
	Limited	*Normal*	*P value*
Number of hips	17	34	
Sex			0.192
Male	3 (18)	12 (35)	
Female	14 (82)	22 (65)	
Follow-up time, months	12.54 ± 0.68 (12.00–14.40)	12.25 ± 0.37 (12.00–13.19)	0.167
Age at surgery, years	39.85 ± 17.22 (12.72–76.41)	31.98 ± 13.82 (14.75–70.92)	0.127
BMI, kg/m^2	25.50 ± 4.45 (20.44–33.89)	25.63 ± 5.41 (18.79–38.07)	0.976

[a]Data reported as *n* (%) or mean ± standard deviation (range), unless otherwise indicated. Bold indicates statistical significance ($P < 0.05$).

Table II. Radiographic measurements[a]

	Spinal mobility		
	Limited	Normal	P value
Sacral slope			
Sitting	30.62 ± 8.94	19.35 ± 9.70	**<0.001**
Standing	36.25 ± 9.40	41.80 ± 11.54	0.093
Delta	5.64 ± 2.19	22.46 ± 9.58	**<0.001**
Proximal femoral angle			
Sitting	88.43 ± 2.82	88.84 ± 3.70	0.792
Standing	4.29 ± 2.19	6.34 ± 4.48	**0.033**
Femoroacetabular flexion angle	78.5 ± 5.84	60.05 ± 11.51	**<0.001**

[a]Data reported in degrees as mean ± standard deviation. Bold indicates statistical significance ($P < 0.05$).

Table III. Intraoperative findings[a]

	Spinal mobility		
	Limited	Normal	P value
Seldes type (labral tear)			0.684
I	7 (41)	17 (50)	
II	2 (12)	2 (6)	
I and II	8 (47)	14 (41)	
ALAD			0.898
0	0	1 (3)	
1	9 (53)	14 (41)	
2	5 (29)	11 (32)	
3	1 (6)	3 (9)	
4	2 (12)	5 (15)	
Outerbridge: acetabulum			0.898
0	0	1 (3)	
1	9 (53)	14 (41)	
2	5 (29)	11 (32)	
3	1 (6)	3 (9)	
4	2 (12)	5 (15)	
Outerbridge: femoral head			0.204
0	15 (88)	33 (97)	
1	0	0	
2	1 (6)	0	
3	1 (6)	0	
4	0	1 (3)	
Ligamentum teres tear percentile			0.227
0	5 (29)	16 (47)	
1	5 (29)	11 (32)	
2	5 (29)	5 (15)	
3	2 (12)	2 (6)	

[a]Values are presented as number of hips (n), unless otherwise stated. Bold indicates statistical significance ($P < 0.05$).

was no significant difference between groups with respect to the distribution of ligamentum teres tear ($P = 0.227$).

Surgical procedures

Between the two groups, there were no significant differences in labral treatment ($P = 0.392$) or capsular treatment ($P = 0.250$). There were also no significant differences in treatments for FAI morphology or cartilage damage, including acetabuloplasty ($P = 0.610$), femoroplasty ($P = 0.475$) and acetabular microfracture ($P = 0.207$). Data for surgical procedures can be found in Table IV.

Table IV. Surgical procedures[a]

	Spinal mobility		
	Limited	Normal	P value
Labral treatment			0.392
Repair	15 (88)	30 (88)	
Selective debridement	1 (6)	0	
Reconstruction	1 (6)	2 (6)	
Capsular treatment			0.250
Repair	17 (100)	29 (85)	
Unrepaired capsulotomy	0	5 (15)	
Acetabuloplasty	16 (94)	33 (97)	0.610
Femoroplasty	17 (100)	33 (97)	0.475
Microfracture acetabulum	0	3 (9)	0.207

[a]Data reported as n (%), unless otherwise indicated. Bold indicates statistical significance ($P < 0.05$).

Patient-reported outcomes and clinical outcome thresholds

For all PROs, both groups improved significantly in preoperative scores to 1-year postoperative scores. There were no significant differences between groups in any preoperative or postoperative score or delta value. Complete PRO data can be found in Table V. Clinical outcome thresholds were also assessed, in which there were also no significant differences between groups in rates of achievement of these thresholds. These rates can be found in Table VI.

DISCUSSION

The main finding of this study was that patients with LM undergoing primary hip arthroscopy demonstrate significant improvements in PROs from baseline to minimum 1-year follow-up ($P < 0.001$ for mHHS, NAHS and iHOT-12). Furthermore, patients with LM demonstrated favorable rates of achieving PASS/MCID for mHHS and iHOT-12. LM patients were found to have similar postoperative PROs and rates of achieving clinically meaningful improvement when compared to a propensity-matched control group of NM patients.

The role of lumbopelvic mobility has been well studied in the hip arthroplasty literature [22, 55]. In a flexible spine, the pelvis tilts posteriorly when transitioning from standing to sitting, enabling the hips to flex so that the femurs are parallel to the ground. In the setting of a stiff lumbar spine, there is decreased pelvic rollback, which increases relative hip joint flexion in the seated position which increases the risk of anterior acetabular rim impingement [57]. Limited spinal mobility remains a poorly recognized clinical entity in hip preservation. In a critical evaluation of the current literature, the majority of studies drew comparisons between patients with lumbar spine pathology or anatomic variants against a control group of patients without known lumbar spine disease [6, 7, 16]. These studies have demonstrated that preexisting lumbar pathology may adversely affect outcomes after hip arthroscopy. The present study is one of few studies

Table V. Patient-reported outcomes after propensity score matching[a]

	Spinal mobility		
	Limited	*Normal*	*P value*
mHHS			
Preoperative	58.00 ± 11.78 (40–83)	62.39 ± 15.86 (34–100)	0.318
1 year	85.35 ± 16.76 (40–100)	84.03 ± 16.49 (43–100)	0.835
P value	**<0.001**	**<0.001**	
Delta	27.35 ± 17.24 (−14–52)	21.64 ± 15.85 (−22–46)	0.244
NAHS			
Preoperative	59.78 ± 12.63 (40–81.25)	63.36 ± 14.53 (32.5–92.5)	0.391
1 year	87.06 ± 13.12 (52.5–100)	85.15 ± 14.71 (45–100)	0.744
P value	**<0.001**	**<0.001**	
Delta	27.28 ± 13.33 (−7.5–47.5)	21.79 ± 14.42 (−5–61.25)	0.195
VAS			
Preoperative	4.69 ± 3.24 (0–8.52)	5.12 ± 2.19 (0–9.1)	0.622
1 year	1.91 ± 1.87 (0–5)	2.09 ± 2.19 (0–7)	0.961
P value	**0.002**	**<0.001**	
Delta	−2.78 ± 3.04 (−8.41–3.39)	−3.04 ± 3.04 (−9.1–4.23)	0.776
iHOT-12			
Preoperative	30.79 ± 16.12 (7.42–53.58)	35.06 ± 14.45 (12.62–59.73)	0.343
1 year	74.46 ± 23.54 (17.45–100)	74.50 ± 22.91 (17.31–100)	0.929
P value	**<0.001**	**<0.001**	
Delta	43.66 ± 24.83 (0.09–91.60)	39.44 ± 23.05 (−4.84–81.44)	0.550

[a]Values are presented as mean ± standard deviation (range). Bold indicates statistical significance ($P < 0.05$).

Table VI. Clinical outcome thresholds after propensity score matching[a]

	Spinal mobility		
	Limited	*Normal*	*P value*
MCID			
mHHS	16 (94)	29 (85)	0.650
NAHS	16 (94)	29 (85)	0.650
iHOT-12	16 (94)	29 (85)	0.650
PASS			
mHHS	14 (82)	27 (79)	>0.999
iHOT-12	13 (76)	24 (71)	0.749
MOIST			
mHHS	14 (82)	20 (59)	0.122
NAHS	14 (82)	22 (65)	0.328
iHOT-12	10 (59)	20 (59)	>0.999
VAS	9 (53)	20 (59)	0.689

[a]Values are presented as *n* (%). Bold indicates statistical significance ($P < 0.05$). MOIST, maximum outcome improvement satisfaction threshold.

to quantitatively evaluate lumbopelvic motion and its effect on clinical outcomes.

Limited lumbopelvic motion was implicated in compromising PROs in a study by Heaps *et al.* [16] where they compared outcomes after hip arthroscopy between patients with and without LSTV. They found that patients with LSTV had significantly lower scores for all measured PROs when compared to a control group of patients without LSTV. They discussed that loss of lumbar spine motion and less sacral tilt are often present in patients with LSTV and theorized that the inferior outcomes in their study group were due to an inability of the lumbar spine to compensate for changes in pelvic sagittal alignment [58–60]. It was proposed that due to these altered mechanics, patients were susceptible to residual FAIS after hip arthroscopy which compromised their outcomes. These findings are supported by the current study where patients with limited lumbar mobility demonstrated significantly greater femoroacetabular flexion angles in the seated position compared to controls. In contrast to the findings of Heaps *et al.*, the findings of the present study did not demonstrate inferior short-term outcomes after hip arthroscopy in patients with limited lumbopelvic motion when compared to a propensity-matched control group with normal lumbopelvic motion; however, the study by Heaps *et al.* was better powered than the current study to detect differences which may account for the discrepancy. On the other hand, Luo *et al.* evaluated the prevalence of LSTV in patients with FAI undergoing hip arthroscopy and associations between LSTV and PROs [17]. Similar to the present study, their study revealed an overall prevalence of 13.9% in a cohort of patients undergoing hip arthroscopy. Of note, 50 patients with LSTV were found to have similar 1-year postoperative PROs (mHHS, HOS-ADL, HOS-SSS and iHOT) when compared to 100 age- and sex-matched control patients. Further study is warranted to determine if patients with LM are more susceptible to residual FAIS after hip arthroscopy and if this negatively influences postoperative PROs and reoperation rates at longer-term follow-up.

This paper has several strengths. It is one of few studies to report PROs in patients with quantitatively evaluated limited lumbopelvic motion. Furthermore, these results were compared with a propensity-matched control group with normal motion to isolate the influence of lumbopelvic mobility on PROs. The use of several PROs designed to detect outcomes in patients with nonarthritic hips limited ceiling effects and adds to the generalizability of the results [61]. Given that statistical significance does not necessarily equate to clinical importance, the proportion of patients who achieved the MCID and/or PASS for mHHS and iHOT-12 was used to provide a clinical application [62].

This study is not without limitations. First, this was a non-randomized study and additional confounding variables may have affected the results. Second, this is a retrospective study which has inherent limitations, despite the data being prospectively collected. Third, the data were collected from patients of a single high-volume surgeon who specializes in hip preservation surgery, which has the potential to limit the generalizability of the results [63]. The present study included minimum 1-year follow-up, but longer follow-up is necessary to determine the durability of results. Lastly, lumbopelvic motion as determined by the change in sacral slope from the standing to seated positions alone may be oversimplistic.

CONCLUSION

LM patients who undergo primary hip arthroscopy may expect favorable short-term PROs at minimum 1-year follow-up. These results were comparable to a control group of NM patients.

DATA AVAILABILITY

The data underlying this article will be shared on reasonable request to the corresponding author.

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None declared.

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CONFLICT OF INTEREST STATEMENT

Dr Domb reports grants and other from American Orthopedic Foundation, during the conduct of the study; personal fees from Amplitude, grants, personal fees and non-financial support from Arthrex, personal fees and non-financial support from DJO Global, grants, personal fees and non-financial support from Medacta, grants, personal fees, non-financial support and other from Stryker, grants from Breg, personal fees from Orthomerica, grants and non-financial support from Medwest Associates, grants from ATI Physical Therapy, personal fees and non-financial support from St. Alexius Medical Center, grants from Ossur, non-financial support from Zimmer Biomet, outside the submitted work; In addition, Dr Domb has a patent 8920497 - Method and instrumentation for acetabular labrum reconstruction with royalties paid to Arthrex, a patent 8708941-Adjustable multi-component hip orthosis with royalties paid to Orthomerica and DJO Global, and a patent 9737292 - Knotless suture anchors and methods of tissue repair with royalties paid to Arthrex and Dr Domb is a board member of American Hip Institute Research Foundation, AANA Learning Center Committee, the Journal of Hip Preservation Surgery, the Journal of Arthroscopy; has had ownership interests in the American Hip Institute, Hinsdale Orthopedic Associates, Hinsdale Orthopedic Imaging, SCD#3, North Shore Surgical Suites, and Munster Specialty Surgery Center.

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AUTHOR CONTRIBUTIONS

A.E.J.—data collection/analysis and writing of the manuscript.
J.D.F.—data collection/analysis and writing of the manuscript.
K.B.M.—data collection/analysis and writing of the manuscript.
D.R.M.—data collection and revision of the manuscript.
B.R.S.—data collection and revision of the manuscript.
H.K.A.—data collection and revision of the manuscript.
P.W.S.—data collection and revision of the manuscript.
A.C.L.—data interpretation and revision of manuscript.
B.G.D.—data interpretation, revision of manuscript and writing of the manuscript.

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