Original Article

Spinopelvic Parameters Do Not Influence Outcomes Following Primary Hip Arthroscopy for the Treatment of Femoroacetabular Impingement Syndrome

Derrick M. Knapik, M.D., Ian M. Clapp, M.D., M.S., Daniel M. Wichman, B.S., and Shane J. Nho, M.D., M.S.

Purpose: To evaluate the influence of spinopelvic parameters on short-term postoperative patient-reported outcomes (PROs) following primary hip arthroscopy for the treatment of femoroacetabular impingement syndrome (FAIS). **Methods:** Patients undergoing primary hip arthroscopy between January 2012 and December 2015 were retrospectively reviewed. Hip Outcome Score − Activities of Daily Living, Hip Outcome Score − Sports-Specific Subscale, modified Harris Hip Score, International Hip Outcome Tool-12, and visual analog scale pain were recorded preoperatively and at final follow-up. Lumbar lordosis (LL), pelvic tilt (PT), sacral slope, and pelvic incidence (PI) were measured on lateral radiographs in standing position. Patients were split into subgroups for individual analyses based on previous literature cutoffs: |PI-LL|> or <10°, PT> or <20°, and PI <40°, 40° < PI < 65°, and PI >65°. PROs and rate of achievement of patient acceptable symptom state (PASS) were compared between subgroups at final follow-up. **Results:** Sixty-one patients who underwent unilateral hip arthroscopy were included in the analysis, and 66% of patients were female. Mean patient age was 37.6 ± 11.3 years, whereas mean body mass index was 25.0 ± 5.7. Mean follow-up time was 27.6 ± 9.0 months. No significant difference in preoperative nor postoperative PROs were appreciated in patients with spinopelvic mismatch (|PI-LL| >10°) versus those without, whereas patients with mismatch achieved PASS according to the modified Harris Hip Score ($P = .037$) and International Hip Outcome Tool-12 ($P = .030$) at greater rates. When we compared patients with a PT ≥20° versus PT <20°, no significant differences in postoperative PROs were present. When we compared patients in the following pelvic incidence groups: PI <40°, 40° < PI <65°, and PI >65°, no significant differences in 2-year PROs or rates of PASS achievement for any PRO were appreciated ($P > .05$ for all). **Conclusions:** In this study, spinopelvic parameters and traditional measures of sagittal imbalance did not influence PROs in patients undergoing primary hip arthroscopy for FAIS. Patients with sagittal imbalance (|PI-LL|> 10° or PT >20°) achieved a greater rate of PASS. **Level of Evidence:** IV; Prognostic case series.

Femoroacetabular impingement syndrome (FAIS) is a dynamic process that has gained increasing recognition as a common cause of nonarthritic hip pain[1,2] and functional impairment,[3] predisposing patients to progressive chondrolabral damage and premature osteoarthritis.[4-6] The position of the hip joints in the bony pelvis on the bicoxofemoral axis dictates that functional sagittal motion requires both hip and pelvic range of motion,[7,8] resulting in variable degrees of dynamic pelvic tilt in different functional situations.[9] Although the role of lumbosacral anatomy and mechanics in maintaining overall sagittal balance has been well established,[10,11] the contribution of spinopelvic anatomy to the severity and management outcomes of hip disorders has been a source of increasing interest.[9,12-14] Namely, recent investigations have demonstrated spinopelvic anatomy and motion to influence outcomes in patients undergoing total hip arthroplasty

From the Section of Young Adult Hip Surgery, Division of Sports Medicine, Department of Orthopedic Surgery, Rush University Medical Center, Chicago, Illinois, USA.

The authors report the following potential conflicts of interest or sources of funding: S.J.N. reports IP royalties from Ossur and Stryker; publishing royalties from Stryker; paid consultant from Stryker; participation on a Data Safety Monitoring Boards or Advisory Boards for the American Orthopedic Association, American Orthopaedic Society for Sports Medicine, and Arthroscopy Association of North America; research support from AlloSource, Arthrex, Athletico, DJ Orthopaedics, Linvatec, Miomed, Smith & Nephew, and Stryker; and financial or material support from Springer. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received April 30, 2021; accepted November 6, 2022.

Address correspondence to Ian M. Clapp, Department of Orthopedic Surgery, Rush University Medical Center, 1611 W Harrison St, Suite 300, Chicago, IL 60612. E-mail: Nho.research@rushortho.com

2666-061X/21648
https://doi.org/10.1016/j.asmr.2022.11.003

(THA),[15] with patients with pre-existing lumbosacral pathology with abnormal anatomy reporting inferior outcomes following THA.[16,17] As such, the extra-articular contribution of spinopelvic mechanics on both arthritic and nonarthritic hip pain further warrants consideration.[8,18,19]

Spinopelvic parameters have been introduced to describe and assess pelvic alignment, lumbar lordosis (LL), and sagittal balance.[8,20-22] The orientation of the pelvis relative to the sagittal plane is described by the pelvic tilt (PT) and sacral slope (SS), 2 position-dependent parameters that change in response to postural alterations to maintain sagittal lumbopelvic balance.[8,19] PT and SS compose the pelvic incidence (PI), a fixed anatomic angle independent of the sagittal orientation of the pelvis.[23] PI is regarded as the primary axis of sagittal balance[8,23] with a strong influence on LL.[23] Although abnormalities in PI have been reported in patients with various spinal disorders, recent investigations have suggested variations in PI to be associated with FAIS.[19,24,25]

However, reports describing the association between PI and FAIS have been largely contradictory. Multiple investigations have reported decreased PI to be associated with increased rates of patients possessing FAIS morphology,[8,24] whereas other investigations have cited increased PI to be associated with FAIS.[7,8,18,24] Meanwhile, the influence of spinopelvic parameters on outcomes in patients undergoing operative management for FAIS remain largely unknown. The purpose of the current investigation was to evaluate the influence of spinopelvic parameters on short-term postoperative patient-reported outcomes (PROs) following primary hip arthroscopy for the treatment of FAIS. The authors hypothesized no clinically significant differences would be appreciated in any PRO measure based on differences in spinopelvic parameters.

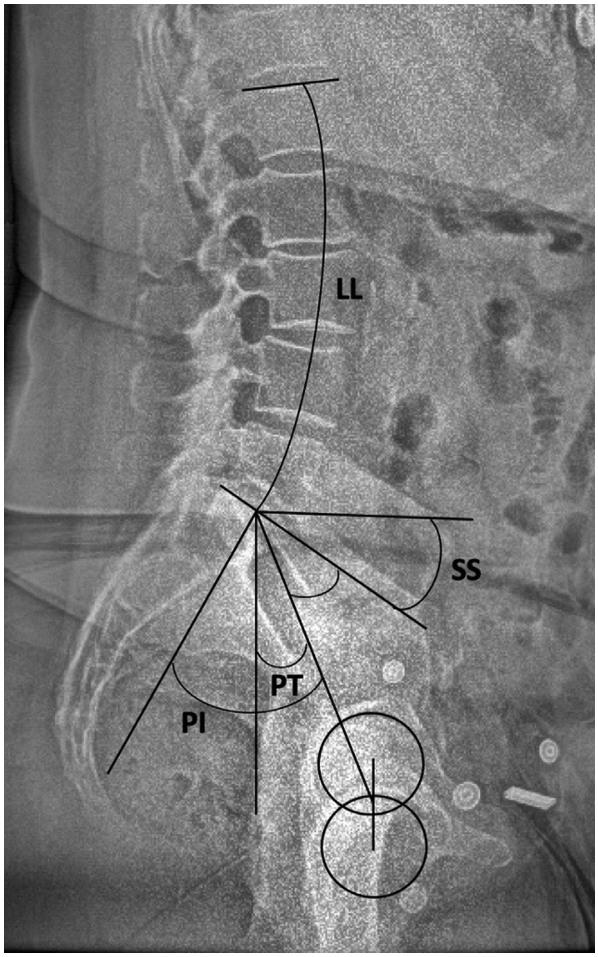

Fig 1. Measurements of spinopelvic parameters and lumbar lordosis on a standing lumbar radiograph. (LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope.)

Methods

Patient Selection

Following institutional review board approval, patients who underwent primary hip arthroscopy for the treatment of FAIS by a single fellowship-trained orthopaedic surgeon (S.J.N.) between July 2012 and December 2015 with preoperative standing lateral lumbar radiographs were retrospectively identified from a prospectively collected and maintained surgical repository. Inclusion criteria consisted of patients with clinical and radiographic diagnosis (alpha angle >55°) of symptomatic FAIS[26] undergoing primary hip arthroscopy following failure of minimum 3 months of conservative management (i.e., physical therapy, activity modification, oral anti-inflammatories, intra-articular cortisone injection). Exclusion criteria consisted of revision hip arthroscopy, hip arthroscopy performed on the contralateral hip during the study period, evidence of osteoarthritis within the hip joint (Tönnis grade >1), hip dysplasia[13] (lateral center edge angle <20° or Tönnis angle >10°), a history of congenital hip disorders (slipped capital femoral epiphysis, developmental hip dysplasia, etc.), those without radiographs of the lumbar spine allowing for appropriate measurements, or patients with a history of spine surgery radicular symptoms or spinal pathology appreciated on radiographs (i.e., spondylolysis, anterolisthesis).

Radiographic Analysis

Radiographs were obtained before and following surgery at final follow up.[27] Radiographs consisted of standing anteroposterior (AP) pelvis, AP hip, false-profile, and Dunn lateral hip radiographs. Alpha angle and Tönnis grade were assessed on AP and Dunn lateral radiographs, whereas[28] acetabular inclination (Tönnis angle), and the lateral center-edge angle of Wiberg (lateral center edge angle) were measured on AP hip radiographs.[28]

Table 1. Patient-Reported Outcomes

	Preoperative	2-Year Postoperative	*P* Value
HOS-ADL	59.4 ± 19.3	84.9 ± 14.6	**<.001**
HOS-SS	35.1 ± 25.2	68.3 ± 27.7	**<.001**
mHHS	53.9 ± 13.2	82.1 ± 12.2	**<.001**
iHOT-12	30.3 ± 18.4	69.4 ± 26.8	**<.001**
VAS pain	63.7 ± 20.1	24.8 ± 24.6	**<.001**

HOS-ADL, Hip Outcome Score — Activities of Daily Living; HOS-SS, Hip Outcome Score — Sports-Specific Subscale; iHOT-12, International Hip Outcome Tool 12; mHHS, Modified Harris Hip Score; VAS, visual analog scale.

Bold values indicate statistical significance at $P < .05$.

Table 2. Spinopelvic Parameters

LL	52.2 ± 12.3
PI	52.0 ± 13.8
Pelvic tilt	12.8 ± 9.5
Sacral slope	39.2 ± 10.2
PI-LL	−0.17 ± 16.1

LL, lumbar lordosis; PI, pelvic incidence.

Spinopelvic Parameters

Standing lateral lumbar radiographs were used to evaluate spinopelvic parameters and lumbar lordosis.[29] A fellowship-trained orthopaedic surgeon (D.M.K.) performed the following radiographic measurements: LL,[30] segmental lordosis (SL), PT,[25] SS,[7] and PI.[23] LL was measured using a traditional Cobb angle from the sacral endplate to the upper endplate of the first lumbar vertebra. SL was measured for L4-L5 as a Cobb angle from the L4 superior endplate to the L5 inferior endplate. For L5-S1 SL, a Cobb angle was measured from the superior endplate of L5 to the superior endplate of the sacrum. For PT and PI, the femoral heads were used to identify the bicoxofemoral axis.[31] PT was measured as the angle between midpoint of the sacral endplate to the bicoxofemoral axis and the vertical plane. PI was then measured as a perpendicular line to the midpoint of the sacral endplate to the bicoxofemoral axis. PI is a morphologic parameter that does not change with movement of the pelvic. Lastly, SS was measured as the angle between the sacral plate and the horizontal plane (Fig 1). These morphologic measurements are related via the formula: $PI = PT + SS$.[32]

The cohort was split into 2 groups using 2 different cutoffs for sagittal imbalance. Patients with a $|\text{PI-LL}| > 10°$ have a pelvic incidence—lumbar lordosis (PI-LL) mismatch and were compared with those without a PI-LL mismatch, $|\text{PI-LL}| \leq 10°$.[32] PT $\geq 20°$ also signifies sagittal imbalance. Patients with a PT $\geq 20°$ or $<20°$ were compared.[33] In addition, the lumbopelvic complex has been classified into 2 main groups based on sagittal range of motion. Within these 2 groups, pelvises have been categorized into 3 groups based on PI values. The first group has a low PI ($<40°$) and tends to have a low LL. The second group has a high PI ($>40°$) and tends to have greater LL, whereas the third group has higher PI ($>65°$). Therefore, the cohort was split into the following groups based on their PI values: PI $<40°$, $40° <$ PI $< 65°$, PI $>65°$.[8,9]

Surgical Technique and Postoperative Rehabilitation

All hip arthroscopies were performed in the same manner using a previously described technique.[34,35] To summarize, standard anterolateral and mid-anterior portals were established under traction with the aid of fluoroscopic guidance. An interportal capsulotomy was created and pathology was addressed in the central compartment. Procedures included acetabular rim trimming and labral repair using anchors with sutures. Traction was then released, and a T-capsulotomy was performed for access to the peripheral compartment. Cam morphology was meticulously resected until an adequate femoral head—neck offset was achieved as verified under subjective fluoroscopic assessment comparing to preresection radiographs. Dynamic examination of the operative leg was performed to confirm an appropriate resolution of impingement. In all cases, the capsule repaired using a suture shuttling system and plication was performed depending on degree of capsular laxity. All patients underwent a standard 4-phased postoperative rehabilitation protocol.[36] The rehabilitation approach included special focus on mobility, muscle performance and stability, and neuromuscular control while each patient's specific demands were taken into account.

PRO Measures

Patients completed preoperative and postoperative hip-specific PRO instruments, including the Hip Outcome Score — Activities of Daily Living Subscale (HOS-ADL),[37] Hip Outcome Score — Sports-Specific Subscale (HOS-SS), modified Harris Hip Score (mHHS),[38] and the international Hip Outcome Tool-12 (iHOT-12).[39] Pain was assessed using visual analog scale (VAS) for pain.

Statistical Analysis

Statistical analysis was performed using SPSS statistical software (SPSS Statistics for Windows, Version 26.0; IBM Corp., Armonk, NY). Patient clinical variables were presented as means ± standard deviations, or percentages. Spinopelvic measurement variables were reported as means ± standard deviation. Intraclass correlation coefficient was used to determine intrarater reliability for these measurements. A paired samples *t*-test was used to compare preoperative and 2-year postoperative PROs. An independent *t*-test was used to compare PROs between patients with a $|\text{PI-LL}| >$ or $\leq 10°$ or PT $\geq$ or $<20°$. PROs between patients with a PI $<40°$, $40° <$ PI $< 65°$, and PI $>65°$ were compared

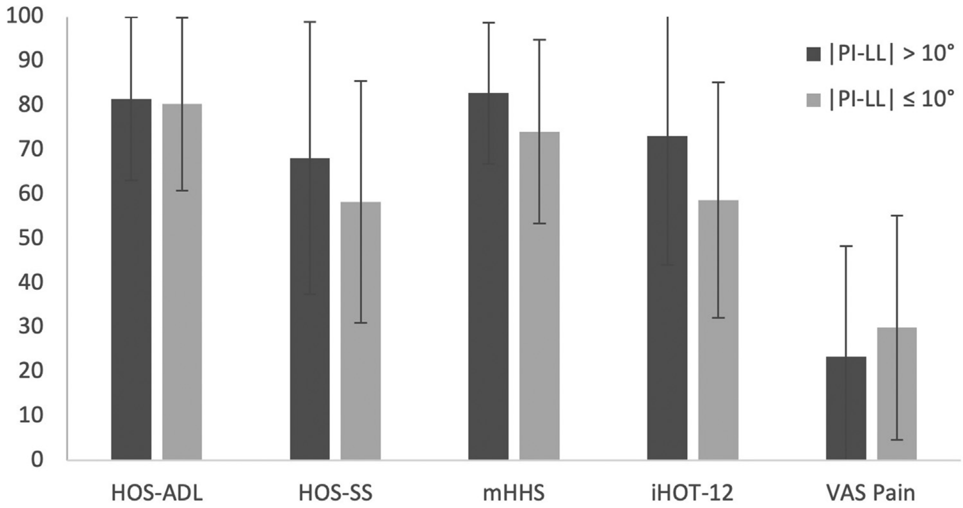

Fig 2. Comparison of 2-year postoperative patient-reported outcomes between patients with and without a pelvic incidence lumbar lordosis (PI-LL) mismatch. (HOS-ADL, Hip Outcome Score – Activities of Daily Living; HOS-SS, Hip Outcome Score – Sports-Specific Subscale; iHOT-12, International Hip Outcome Tool 12; mHHS, Modified Harris Hip Score; VAS, visual analog scale.)

using a one-way analysis of variance test with a Bonferroni correction. To assess whether patients in each subgroup achieved clinically significant outcomes, the principles of the patient acceptable symptom state (PASS) was applied. Patients achieved PASS if they exceeded literature defined PASS threshold.[40] The PASS thresholds at 2-year follow-up for the HOS-ADL, HOS-SS, iHOT-12, and mHHS were 88.2 and 76.4, 83.3, and 72.2, respectively. A χ^2 analysis was performed to compare the rates of PASS achievement between the subgroups.

Results

Patient Demographics and Preoperative Characteristics

Seventy-five patients undergoing primary hip arthroscopy with preoperative lateral lumbar plain radiographs who met the inclusion criteria were identified. Follow-up data were available in 81% (n = 61) of patients, of whom 66% (n = 40/61) were female. Average follow-up time was 27.6 ± 9.0 months following surgery. Mean patient age was 37.6 ± 11.3 years, whereas mean body mass index (BMI) was 25.0 ± 5.7. All patients underwent acetabular rim trimming, femoral osteochondroplasty, and capsular repair. The mean preoperative AP alpha angle was 65.8 ± 16.4, Dunn lateral alpha angle was 63.0 ± 12.5, false-profile alpha angle was 58.3 ± 10.0, and lateral center edge angle was 31.4 ± 6.2. In total, 95.1% of patients were Tönnis grade 0. Postoperative AP alpha angle was 44.6 ± 6, Dunn lateral alpha angle was 37.5 ± 4.5, false-profile alpha angle was 42.8 ± 5.6, and lateral center edge angle was 28.5 ± 6.1. There were no complications or revision surgeries within the follow-up period.

PROs and Spinopelvic Parameters

Significant improvements in HOS-SS, HOS-ADL, mHHS, iHOT-12, and VAS pain at an average 2-year follow-up ($P < .001$ for all) (Table 1). The means and standard deviations of LL, L4-L5 segmental lordosis, L5-S1 segmental lordosis, PI, PT, SS, and PI-LL can be found in Table 2. Intraclass correlation coefficient was 0.99, 0.99, 0.91, 0.98 for LL, PT, SS, and PI, respectively.

Patients with a spinopelvic mismatch (n = 34) |PI-LL| >10° did not have significantly worse PROs at mean 2-year follow-up when compared with patients (n = 27) with a |PI-LL| ≤10° ($P > .05$ for all) (Fig 2). Patients without a spinopelvic mismatch did not differ significantly in age (40.1 ± 11.5 years vs 35.7 ± 11.0 years, $P = .129$), BMI (24.6 ± 5.4 vs 25.2 ± 6.1, $P = .717$), or

Table 3. Comparison of PASS Achievement Between Patients With a |PI-LL| > or ≤10°

	|PI-LL| >10° (n = 34)	|PI-LL| ≤10° (n = 27)	*P* Value
HOS-ADL	46.9%	42.3%	.728
HOS-SS	46.9%	32.0%	.256
mHHS	51.7%	24.0%	**.037**
iHOT-12	65.2%	31.6%	**.030**
Any PASS	63.6%	48.1%	.228

HOS-ADL, Hip Outcome Score – Activities of Daily Living; HOS-SS, Hip Outcome Score – Sports-Specific Subscale; iHOT-12, International Hip Outcome Tool 12; mHHS, Modified Harris Hip Score; PASS, patient acceptable symptom state.

Bold values indicate statistical significance at $P < .05$.

Table 4. Comparison of PASS Achievement Between Patients With a PT ≥ or <20°

	PT <20° (n = 47)	PT ≥20° (n = 14)	*P* Value
HOS-ADL	37.8%	69.2%	**.045**
HOS-SS	31.8%	69.2%	**.016**
mHHS	34.1%	53.8%	.204
iHOT-12	48.5%	55.6%	.707
Any PASS	53.2%	69.2%	.302

HOS-ADL, Hip Outcome Score − Activities of Daily Living; HOS-SS, Hip Outcome Score − Sports-Specific Subscale; iHOT-12, International Hip Outcome Tool 12; mHHS, Modified Harris Hip Score; PASS, patient acceptable symptom state.

Bold values indicate statistical significance at *P* < .05.

sex (% female 59.3% vs 70.6%, *P* = .355) than those with one. Patients with a spinopelvic mismatch achieved PASS according to the mHHS at a rate of 51.7% compared with 24% for the nonspinopelvic mismatch group (*P* = .037). Patients with spinopelvic mismatch achieved PASS according to the iHOT-12 at a rate of 65.2% compared with 31.6% (*P* = .030) (Table 3).

When we compared patients with a PT ≥ or <20°, patients with a PT ≥20° (n = 14) had significantly greater HOS-SS (78.6 ± 29.5 vs 59.6 ± 28.3, *P* = .039) at mean 2-year follow-up than those with a PT <20° (n = 47) (Fig 3). Preoperative symptoms >2 years was significant (*P* = .026) in linear regression for HOS-SS when controlling for age, sex, BMI, preoperative AP alpha angle, and PT ≥ or <20°. Patients with a PT ≥20° did not significantly differ from those with a PT <20° in age (41.1 ± 10.2 years vs 36.6 ± 11.5 years, *P* = −0.198), BMI (26.1 ± 5.0 vs 24.6 ± 5.9, *P* = .421), or sex (% female, 64.2% vs 66.0%, *P* = .908). A greater percentage of patients with a PT ≥20° achieved PASS according to the HOS-ADL (*P* = .045) and HOS-SS (*P* = .016) than those with a PT <20° (Table 4).

When we compared patients with a PI <40° (n = 9), 40° < PI < 65° (n = 41), and PI >65° (n = 11), there were no significant differences in 2-year PROs or rates of PASS achievement for any PRO (*P* > .05 for all) (Fig 4, Table 5). Patients with a PI < 40° were significantly younger than those with a PI >65° (29.9 ± 11.1 vs 42.0 ± 6.9, *P* = .48) and there were no significant differences in age (38.2 ± 11.7) in patients with a PI 40° < PI < 65° compared with the other 2 subgroups. There were no significant differences in BMI (22.9 ± 4.1 vs 25.1 ± 5.9 vs 26.2 ± 6.4, *P* = .432) or sex (% female, 66.7% vs 58.5% vs 90.9%, *P* = .133) between the 3 subgroups.

Discussion

The main findings from this investigation were that no significant difference in postoperative PRO were appreciated following primary hip arthroscopy for the treatment of symptomatic FAIS based on the presence of spinopelvic mismatch or sagittal imbalance. Patients with spinopelvic mismatch [PI-LL] ≥10° achieved PASS at a greater rate when compared with those without mismatch based on mHHS and iHOT-12. Meanwhile, patients with PT ≥20° achieved a greater rate of PASS according to HOS-ADL and HOS-SS versus patients with PT <20°.

Differences in spinopelvic parameters were not found to significantly influence PROs following hip arthroscopy for FAIS. Although previous studies have evaluated outcomes following hip surgery based on measurements of spinopelvic parameters, no current study has focused exclusively on patients following hip arthroscopy. When we examined spinopelvic parameters (PT, SS, PI, LL, PI-LL, T9-spinopelvic inclination, sagittal vertical axis [SVA], T1-pelvic angle) in 107 patients with evidence of sagittal spinal deformity

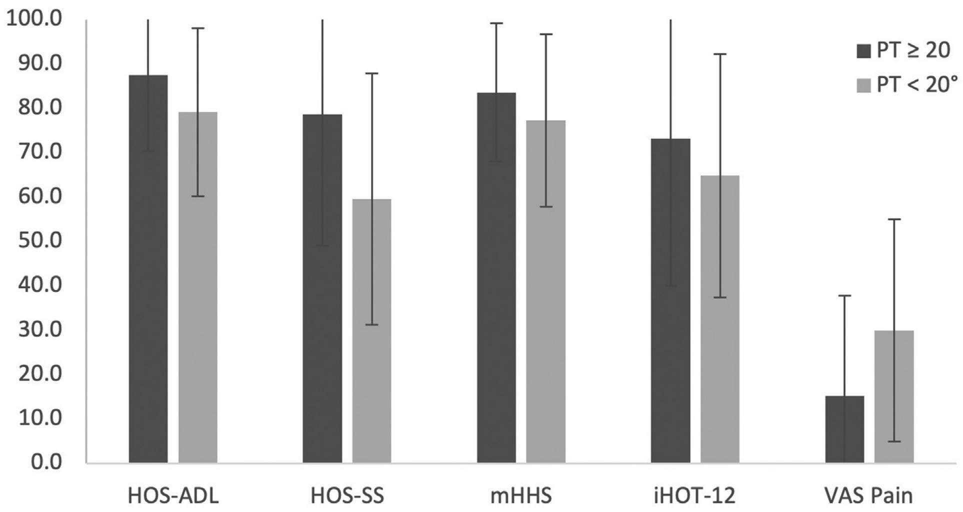

Fig 3. Comparison of 2-year postoperative patient-reported outcomes between patients with and without a pelvic tilt (PT) ≥20°. (HOS-ADL, Hip Outcome Score − Activities of Daily Living; HOS-SS, Hip Outcome Score − Sports-Specific Subscale; iHOT-12, International Hip Outcome Tool 12; mHHS, Modified Harris Hip Score; VAS, visual analog scale.)

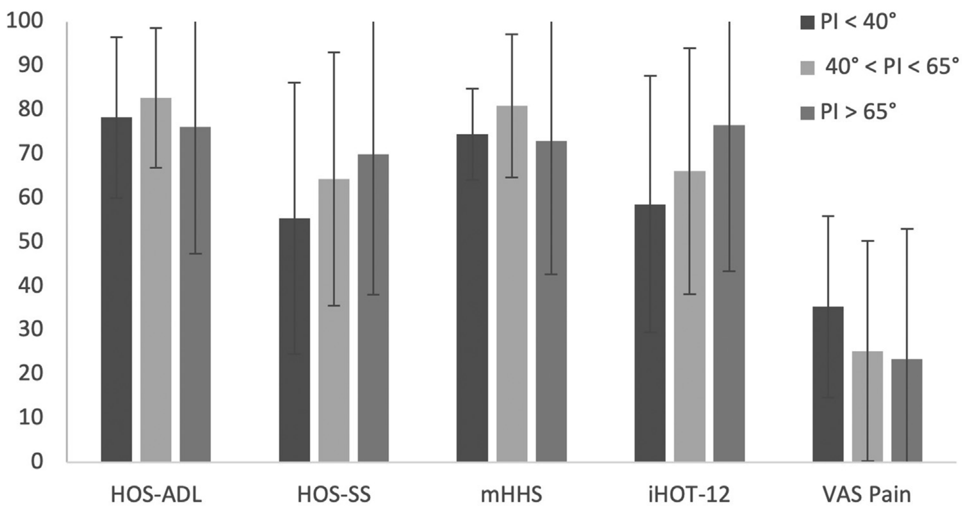

Fig 4. Comparison of 2-year postoperative patient-reported outcomes between patients with a pelvic incidence (PI) <40°, 40° < pelvic incidence < 65°, and pelvic incidence >65°. (HOS-ADL, Hip Outcome Score − Activities of Daily Living; HOS-SS, Hip Outcome Score − Sports-Specific Subscale; iHOT-12, International Hip Outcome Tool 12; mHHS, Modified Harris Hip Score; VAS, visual analog scale.)

following THA using stereoradiographic EOS, DelSole et al.[16] reported a high dislocation rate (8%), with patients suffering dislocation possessing significantly greater spinopelvic tilt and PI-LL mismatch. Meanwhile, when evaluating spinopelvic parameters on outcomes in 38 patients at a minimum of 22 months following gluteus medius/minimus repair, Saltzman et al.[41] reported that patients with a positive sagittal vertical axis (SVA > 0 cm) reported significantly worse HOS-ADL ($P = .026$) and HOS-SS ($P = .011$) when compared with patients with a SVA <0 cm. As such, although the relationship between the spine and the hip in patients undergoing various hip procedures has been established, further investigations are warranted to better understand the influence of spinopelvic mechanics and anatomy using additional spinopelvic parameters and advanced imaging modalities (i.e., computed tomography [CT], magnetic resonance imaging [MRI]) on outcomes following hip arthroscopy for FAIS.

The relationship between the incidence of FAI morphology and spinopelvic parameters, namely PI, remain largely uncertain, with multiple contradictory investigations. In the setting of a low PI, patients have been shown to insufficiently increase their PT when flexing the leg, resulting in increased flexion of the hip when compared with patients with a normal PI.[19] Moreover, increasing PT has been shown to result in dynamic anteversion of the acetabulum, providing a functional advantage for hip internal rotation when going from standing to sitting.[42-44] As such, patients with a decreased PI are unable to compensate for their hip pathoanatomy due to the inability to alter PT, effectively decreasing dynamic acetabular anteversion, limiting hip internal rotation, and leading to hip impingement with flexion.[19,43,45,45] Such findings have been corroborated in clinically studies. Specifically, Hellman et al.[19] performed a retrospective analysis of consecutive male (n = 30) and female (n = 30) patients undergoing hip arthroscopy for FAIS using CT. When compared with 300 historic controls, patients with FAIS were found to possess a significantly smaller mean PI (49.3° ± 12.3°) when compared with controls (55° ± 10.6°) ($P < .001$) When reviewing CT scans from 65 patients with symptomatic hip pain with radiographic evidence of FAIS against 27 control patients, Weinberg et al.[46] similarly reported that patients with FAIS had significantly lower PI values (46.7° ± 3.7° compared with control patients (56.1° ± 4.4° ($P = .01$).

In contrast, studies reporting an association between FAIS morphology and a high PI have cited a high PI to represent an increased risk for abnormal spinopelvic

Table 5. Comparison of PASS Achievement Between Patients With a PI <40°, 40° < PI < 65°, and PI >65°

	PI <40° (n = 9)	40° < PI < 65° (n = 41)	PI >65° (n = 11)	*P* Value
HOS-ADL	37.5%	47.5%	40.0%	.826
HOS-SS	22.2%	42.1%	50.0%	.435
mHHS	14.3%	44.7%	33.3%	.294
iHOT-12	50.0%	46.7%	66.7%	.670
Any PASS	55.6%	58.5%	50.0%	.885

HOS-ADL, Hip Outcome Score − Activities of Daily Living; HOS-SS, Hip Outcome Score − Sports-Specific Subscale; iHOT-12, International Hip Outcome Tool 12; mHHS, Modified Harris Hip Score; PASS, patient acceptable symptom state.

movement.[31] The presence of abnormal spinopelvic motion has been identified in patients with FAIS, with multiple investigations reporting patients to possess a greater degree of anterior PT during static and dynamic assessments.[45,47] As such, this increased motion has been speculated to lead to increased femoral head coverage anteriorly, increasing the risk for impingement during functional motion.[18] When evaluating difference in spinopelvic parameters using CT between patients with symptomatic cam lesions (n = 26), asymptomatic CAM lesions (n = 23), and controls without cam lesions (n = 18), Grammatopoulos et al.[18] reported that hips with cam morphology possessed significantly greater PI when compared with controls (54° vs 48°, respectively; *P* = .027). Meanwhile, patients with symptomatic cam deformity possessed greater PI when compared with asymptomatic cam lesions (58° vs 51°, respectively) and controls (58° versus 48°, respectively) (*P* = .003). Patients with symptomatic cam deformities also were noted to have significantly greater acetabular version (*P* < .01), indicating a greater degree of coverage superior-posteriorly, corresponding to the area of contact between the acetabulum and anterosuperior cam lesion during hip flexion. When using 3-dimensional MRI to evaluate spinopelvic parameters in participants with either symptomatic FAIS (n = 176) versus asymptomatic volunteers (n = 372), Mascarenhas et al.[3] reported symptomatic patients to possess significantly larger mean PI values (51.4° ± 8°) compared with controls (40.8° ± 6.6°) (*P* = .004) Similarly, when examining patients with symptomatic cam lesions (n = 19), asymptomatic cam lesions (n = 19) or controls (n = 19), Ng et al.[7] reported symptomatic patients to possess a larger PI (58° ± 11°) compared with asymptomatic patients (50° ± 10°) and controls (47° ± 7°). The authors concluded that identification of patients with cam deformity and a larger PI may help predict patients at risk for early symptoms as a result of constrained sagittal hip mobility. Despite the standardization of spinopelvic measurements, the presence of multiple contradictory studies necessitates further clinical investigations, as well as biomechanical studies to determine the association between FAIS morphology as a maladaptive response versus cause of sagittal imbalance based on spinopelvic parameters. Future prospective investigations are necessary to provide a better understanding of the clinical significance of spinopelvic abnormalities on the risk for treatment failure and development of ipsilateral osteoarthritis or contralateral hip pain following hip arthroscopy.[20,41]

Limitations

This investigation was not without limitations. The study is inherently limited by its retrospective design and the absence of a control group of asymptomatic patients. Due to the inclusion of only patients with dedicated standing lumbar spine radiographs, the sample size of patients analyzed was relatively small. Also, a large number of patients underwent hip arthroscopy during the study period who were ineligible for inclusion due to lack of dedicated lumbar radiographs. All measurements were performed using conventional radiographs, with previous studies reporting poor reliability when measuring hip pathomorphologic features, with CT and MRI possessing superior accuracy.[46,48,49] Moreover, not all radiographs were obtained at the same preoperative time points, while the degree of pelvic rotation was not standardized for each patient. However, all radiographs were reviewed by the senior author (S.J.N.) and determined to be of sufficient quality to allow for reliable spinopelvic measurements. All measured variables were static and not reflective of the dynamic nature of FAIS, warranting further studies incorporating in vivo dynamic analysis.[18] Based on the design of the study, the causal relationship between FAIS morphology and spinopelvic parameters cannot be inferred. While all patients possessed hip pain attributed to FAIS, not all patient possessed the same degree of intra-articular pathology (i.e., chondral damage, labral damage, capsular laxity necessitating variable degrees of plication), as such a small degree of variability is expected to exist between cases. Direct comparisons between PT >20 and PT <20 as well as spinopelvic mismatch groups were underpowered. Lastly, all procedures were performed by a single, sports-fellowship trained surgeon with a practice dedicated predominately to hip arthroscopy, as such the results from this investigation cannot be generalized to other surgeons or institution using different techniques, with variable levels of technical expertise.

Conclusions

In this study, spinopelvic parameters and traditional measures of sagittal imbalance did not influence PROs in patients undergoing primary hip arthroscopy for FAIS. Patients with sagittal imbalance (|PI-LL|> 10° or PT> 20°) achieved a greater rate of PASS.

References

1. Nepple JJ, Prather H, Trousdale RT, et al. Clinical diagnosis of femoroacetabular impingement. *J Am Acad Orthop Surg* 2013;21:S16-S19 (suppl 1).
2. Bedi A, Kelly BT. Femoroacetabular impingement. *J Bone Joint Surg Am* 2013;95:82-92.
3. Mascarenhas VV, Rego P, Dantas P, et al. Can we discriminate symptomatic hip patients from asymptomatic volunteers based on anatomic predictors? A 3-dimensional magnetic resonance study on cam, pincer, and spinopelvic parameters. *Am J Sports Med* 2018;46:3097-3110.

4. Tanzer M, Noiseux N. Osseous abnormalities and early osteoarthritis: The role of hip impingement. *Clin Orthop Relat Res* 2004:170-177.
5. Agricola R, Heijboer MP, Bierma-Zeinstra SM, Verhaar JA, Weinans H, Waarsing JH. Cam impingement causes osteoarthritis of the hip: A nationwide prospective cohort study (CHECK). *Ann Rheum Dis* 2013;72:918-923.
6. Ganz R, Leunig M, Leunig-Ganz K, Harris WH. The etiology of osteoarthritis of the hip: An integrated mechanical concept. *Clin Orthop Relat Res* 2008;466:264-272.
7. Ng KCG, Lamontagne M, Jeffers JRT, Grammatopoulos G, Beaulé PE. Anatomic predictors of sagittal hip and pelvic motions in patients with a cam deformity. *Am J Sports Med* 2018;46:1331-1342.
8. Rivière C, Hardijzer A, Lazennec JY, Beaulé P, Muirhead-Allwood S, Cobb J. Spine—hip relations add understandings to the pathophysiology of femoro-acetabular impingement: A systematic review. *Orthop Traumatol Surg Res* 2017;103:549-557.
9. Lazennec JY, Brusson A, Rousseau MA. Hip—spine relations and sagittal balance clinical consequences. *Eur Spine J* 2011;20:686-698 (suppl 5).
10. Glassman SD, Berven S, Bridwell K, Horton W, Dimar JR. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. *Spine (Phila Pa 1976)* 2005;30:682-688.
11. Glassman SD, Bridwell K, Dimar JR, Horton W, Berven S, Schwab F. The impact of positive sagittal balance in adult spinal deformity. *Spine (Phila Pa 1976)* 2005;30:2024-2029.
12. An VVG, Phan K, Sivakumar BS, Mobbs RJ, Bruce WJ. Prior lumbar spinal fusion is associated with an increased risk of dislocation and revision in total hip arthroplasty: A meta-analysis. *J Arthroplasty* 2018;33:297-300.
13. Beck EC, Nwachukwu BU, Chapman R, Gowd AK, Waterman BR, Nho SJ. The influence of lumbosacral spine pathology on minimum 2-year outcome after hip arthroscopy: A nested case-control analysis. *Am J Sports Med* 2020;48:403-408.
14. Leong NL, Clapp IM, Neal WH, Beck E, Bush-Joseph CA, Nho SJ. The influence of pain in other major joints and the spine on 2-year outcomes after hip arthroscopy. *Arthroscopy* 2018;34:3196-3201.
15. McCrum CL. Editorial Commentary: Lumbosacral anatomy and mechanics influence femoroacetabular impingement syndrome and surgical outcomes: The hip bone is connected to the back bone. *Arthroscopy* 2021;37:156-158.
16. DelSole EM, Vigdorchik JM, Schwarzkopf R, Errico TJ, Buckland AJ. Total hip arthroplasty in the spinal deformity population: does degree of sagittal deformity affect rates of safe zone placement, instability, or revision? *J Arthroplasty* 2017;32:1910-1917.
17. Eneqvist T, Nemes S, Brisby H, Fritzell P, Garellick G, Rolfson O. Lumbar surgery prior to total hip arthroplasty is associated with worse patient-reported outcomes. *Bone Joint J* 2017;99-b:759-765.
18. Grammatopoulos G, Speirs AD, Ng KCG, et al. Acetabular and spino-pelvic morphologies are different in subjects with symptomatic cam femoro-acetabular impingement. *J Orthop Res* 2018;36:1840-1848.
19. Hellman MD, Haughom BD, Brown NM, Fillingham YA, Philippon MJ, Nho SJ. Femoroacetabular impingement and pelvic incidence: Radiographic comparison to an asymptomatic control. *Arthroscopy* 2017;33:545-550.
20. Lawton CD, Butler BA, Selley RS, et al. Pelvic incidence in a femoroacetabular impingement population. *J Orthop* 2020;22:90-94.
21. Boulay C, Bollini G, Legaye J, et al. Pelvic incidence: A predictive factor for three-dimensional acetabular orientation—a preliminary study. *Anat Res Int* 2014;2014:594650.
22. Sengupta DK. Spinopelvic balance. *J Bone Joint Surg Rev* 2014;2.
23. Legaye J, Duval-Beaupère G, Hecquet J, Marty C. Pelvic incidence: A fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. *Eur Spine J* 1998;7:99-103.
24. Gebhart JJ, Streit JJ, Bedi A, Bush-Joseph CA, Nho SJ, Salata MJ. Correlation of pelvic incidence with cam and pincer lesions. *Am J Sports Med* 2014;42:2649-2653.
25. Patel RV, Han S, Lenherr C, Harris JD, Noble PC. Pelvic tilt and range of motion in hips with femoroacetabular impingement syndrome. *J Am Acad Orthop Surg* 2020;28:e427-e432.
26. Griffin DR, Dickenson EJ, O'Donnell J, et al. The Warwick Agreement on femoroacetabular impingement syndrome (FAI syndrome): An international consensus statement. *Br J Sports Med* 2016;50:1169-1176.
27. Weber AE, Jacobson JA, Bedi A. A review of imaging modalities for the hip. *Curr Rev Musculoskelet Med* 2013;6:226-234.
28. Clohisy JC, Carlisle JC, Beaulé PE, et al. A systematic approach to the plain radiographic evaluation of the young adult hip. *J Bone Joint Surg* 2008;90:47-66 (suppl 4).
29. Chung NS, Jeon CH, Lee HD, Won SH. Measurement of spinopelvic parameters on standing lateral lumbar radiographs: Validity and reliability. *Clin Spine Surg* 2017;30:E119-E123.
30. Tyrakowski M, Yu H, Siemionow K. Pelvic incidence and pelvic tilt measurements using femoral heads or acetabular domes to identify centers of the hips: Comparison of two methods. *Eur Spine J* 2015;24:1259-1264.
31. Barrey C, Jund J, Noseda O, Roussouly P. Sagittal balance of the pelvis—spine complex and lumbar degenerative diseases. A comparative study about 85 cases. *Eur Spine J* 2007;16:1459-1467.
32. Merrill RK, Kim JS, Leven DM, Kim JH, Cho SK. Beyond pelvic incidence-lumbar lordosis mismatch: The importance of assessing the entire spine to achieve global sagittal alignment. *Global Spine J* 2017;7:536-542.
33. Divi SN, Goyal DKC, Bowles DR, et al. How do spinopelvic parameters influence patient-reported outcome measurements after lumbar decompression? *Spine J* 2020;20:1610-1617.
34. Frank RM, Lee S, Bush-Joseph CA, Kelly BT, Salata MJ, Nho SJ. Improved outcomes after hip arthroscopic surgery in patients undergoing T-capsulotomy with complete repair versus partial repair for femoroacetabular impingement: A comparative matched-pair analysis. *Am J Sports Med* 2014;42:2634-2642.

35. Slikker W 3rd, Van Thiel GS, Chahal J, Nho SJ. The use of double-loaded suture anchors for labral repair and capsular repair during hip arthroscopy. *Arthrosc Tech* 2012;1:e213-e217.
36. Malloy P, Gray K, Wolff AB. Rehabilitation after hip arthroscopy: A movement control-based perspective. *Clin Sports Med* 2016;35:503-521.
37. Martin RL, Philippon MJ. Evidence of validity for the hip outcome score in hip arthroscopy. *Arthroscopy* 2007;23:822-826.
38. Byrd JW. Hip arthroscopy: Patient assessment and indications. *Instr Course Lect* 2003;52:711-719.
39. Nwachukwu BU, Chang B, Beck EC, et al. How should we define clinically significant outcome improvement on the iHOT-12? *HSS J* 2019;15:103-108.
40. Nwachukwu BU, Beck EC, Kunze KN, Chahla J, Rasio J, Nho SJ. Defining the clinically meaningful outcomes for arthroscopic treatment of femoroacetabular impingement syndrome at minimum 5-year follow-up. *Am J Sports Med* 2020;48:901-907.
41. Saltzman BM, Louie PK, Clapp IM, et al. Assessment of association between spino-pelvic parameters and outcomes following gluteus medius repair. *Arthroscopy* 2019;35:1092-1098.
42. Ross JR, Nepple JJ, Philippon MJ, Kelly BT, Larson CM, Bedi A. Effect of changes in pelvic tilt on range of motion to impingement and radiographic parameters of acetabular morphologic characteristics. *Am J Sports Med* 2014;42:2402-2409.
43. Zilber S, Lazennec JY, Gorin M, Saillant G. Variations of caudal, central, and cranial acetabular anteversion according to the tilt of the pelvis. *Surg Radiol Anat* 2004;26:462-465.
44. Konyves A. Editorial Commentary: Looking past the hip joint—the role of pelvic incidence in femoroacetabular impingement. *Arthroscopy* 2017;33:551-552.
45. Lamontagne M, Kennedy MJ, Beaulé PE. The effect of cam FAI on hip and pelvic motion during maximum squat. *Clin Orthop Relat Res* 2009;467:645-650.
46. Weinberg DS, Gebhart JJ, Liu RW, Salata MJ. Radiographic signs of femoroacetabular impingement are associated with decreased pelvic incidence. *Arthroscopy* 2016;32:806-813.
47. Rylander J, Shu B, Favre J, Safran M, Andriacchi T. Functional testing provides unique insights into the pathomechanics of femoroacetabular impingement and an objective basis for evaluating treatment outcome. *J Orthop Res* 2013;31:1461-1468.
48. Clohisy JC, Carlisle JC, Trousdale R, et al. Radiographic evaluation of the hip has limited reliability. *Clin Orthop Relat Res* 2009;467:666-675.
49. Zaltz I, Kelly BT, Hetsroni I, Bedi A. The crossover sign overestimates acetabular retroversion. *Clin Orthop Relat Res* 2013;471:2463-2470.