The Journal of Arthroplasty xxx (2026) 1–6

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Proceedings of the Hip Society 2025

Comparative Analysis of Relaxed- and Flexed-Seated Radiographs for Assessing Spino-Pelvic Mobility in Total Hip Arthroplasty

Andreas Fontalis, MD, MSc, PhD [a, b, *], Humza T. Osmani, MD, MPhil (Cantab) [a], Maël Guerra-Perron, MD [c], Fabio Mancino, MD [d], Warran Wignadasan, MBBS [a], Pierre Putzeys, MD [c], Fares S. Haddad, MD (Res), MCh (Orth) [a, b]

[a] Department of Trauma and Orthopaedic Surgery, University College Hospital, London, UK
[b] Division of Surgery and Interventional Science, University College London, London, UK
[c] Department of Orthopaedic Surgery, Hôpitaux Robert Schuman, Luxembourg City, Luxembourg
[d] Department of Orthopaedic Surgery, Fiona Stanley Hospital, WA, Perth, Australia

ARTICLE INFO

Article history:
Received 26 November 2025
Received in revised form
23 April 2026
Accepted 23 April 2026
Available online xxx

Keywords:
total hip arthroplasty
spino-pelvic mobility
flexed-seated radiographs
relaxed-seated radiographs
sagittal imbalance
flatback deformity

https://www.hipsoc.org/

ABSTRACT

Background: This study evaluated the comparative value of relaxed- and flexed-seated lateral radiographs in assessing spino-pelvic mobility in patients undergoing total hip arthroplasty.
Methods: A prospective cohort of 200 consecutive patients undergoing primary total hip arthroplasty for osteoarthritis underwent preoperative standing, relaxed-seated, and flexed-seated lateral radiographs using a standardized protocol. There were 10 patients who were excluded for incomplete imaging, leaving 190 for analysis. The mean age was 66 years (range, 35 to 90), and the mean body mass index was 28.0 (range, 20.1 to 41.0). Measurements included sacral slope, lumbar lordosis, pelvic incidence (PI), and pelvic tilt. Patients were also classified according to the hip-spine-classification.
Results: The mean PI was 52.7° ± 12°. The mean standing sacral slope was 36.4°, decreasing to 15.1° in the relaxed-seated and increasing to 29.1° in the flexed-seated position. Based on standing-to-relaxed-seated change, 14.2% were classified as stiff (types 1B/2B). Using standing-to-flexed-seated views, stiffness increased to 52.6%. Reclassification between seated postures occurred in 39.5% of patients, predominantly from mobile (1A/2A) to stiff (1B/2B) phenotypes. Flatback deformity (PI−lumbar lordosis greater than 10°) was present in 28.4% and associated with a higher stiffness rate on flexed-seated imaging (63 versus 27.8%). The SS correlation between relaxed and flexed postures was moderate ($r = 0.48$).
Conclusions: Flexed-seated radiographs classify a greater proportion of patients as having reduced spino-pelvic mobility compared with relaxed-seated imaging, with reclassification observed in a substantial proportion of cases. The two postures show only moderate correlation, indicating that relaxed-seated imaging does not reliably predict flexed-seated behavior. These findings highlight that spino-pelvic assessment is posture-dependent and suggest a role for flexed-seated imaging in selected patients, although the impact on component positioning and clinical outcomes requires further study.

Total hip arthroplasty (THA) is one of the most successful and widely performed procedures in orthopaedics. Its use continues to rise worldwide, with the UK National Joint Registry reporting a 10% increase in primary THA procedures between 2019 and 2023 [1]. Despite technological and surgical advancements, instability remains a leading cause of early revision, accounting for up to 5% of cases [2]. In a cohort of 16,186 THAs, Fleischman et al. [3] reported an adjusted risk of instability ranging from 0.17 to 1.74%, highlighting that this complication persists even in contemporary practice [4]. Importantly, many dislocations occur within the traditional coronal "safe zones" [5], emphasizing the importance of spino-pelvic mechanics in achieving functional component positioning.

Pelvic motion between standing and sitting changes functional cup orientation and alters impingement risk. This has driven the

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to https://doi.org/10.1016/j.arth.2026.04.101.

* Address correspondence to: Andreas Fontalis, MD, MSc, PhD, Department of Trauma and Orthopaedic Surgery, University College Hospital, 235 Euston Road, London NW1 2BU, UK.

https://doi.org/10.1016/j.arth.2026.04.101

growing use of preoperative spino-pelvic imaging to guide component positioning and personalize implant alignment.

Spino-pelvic assessment typically involves lateral standing and relaxed-seated radiographs. The optimal seated posture, however, remains debated. Relaxed-seated imaging may not reproduce the functional extremes encountered during everyday flexion and can miss key compensatory mechanisms such as restricted posterior pelvic tilt or paradoxical anterior tilt. Flexed-seated radiographs have, therefore, been proposed as a more functional posture that may better reveal these patterns, particularly in patients who have altered sagittal balance [6].

Yet most published studies still rely on relaxed-seated imaging. A recent review reported that only 29% of studies used flexed or extreme seated positions [7]. Marked variability in stiffness detection has also been reported depending on posture. Sharma et al. [8] showed that change in sacral slope (SS) from standing to relaxed-seated imaging overestimated stiffness in up to 28% of patients, whereas only 6% had true lumbar stiffness when assessed by lumbar flexion. Conversely, Innmann et al. [9 found that relaxed-seated imaging misclassified over half of patients when compared with flexed-seated radiographs. These discrepancies likely reflect differences in stiffness definitions, methodological parameters, and reference postures and highlight the lack of consensus on which seated position best reflects functional pelvic behavior in THA planning.

The concepts of “spine users” and “hip users” have been proposed to characterize how patients compensate during positional changes. Patients who show an excessive anterior pelvic tilt in a flexed-seated position often have a stiff spine and rely on the hip to accommodate flexion—termed “hip users.” On the contrary, excessive posterior pelvic tilt in a relaxed-seated posture may suggest hip stiffness with compensatory lumbar motion, classifying the patient as a “spine user.” These patterns are not binary; in practice, most patients lie on a continuum between these two extremes [6,7].

Therefore, the aims of this study were (1) to directly compare relaxed- and flexed-seated lateral radiographs in detecting spino-pelvic stiffness in patients who underwent primary THA; (2) to evaluate whether flexed-seated imaging provides additional diagnostic value in high-risk groups, such as patients who have flatback deformity; and (3) to explore the relationship between relaxed- and flexed-seated postures and determine whether standard radiographs reflect functional posture.

Material and Methods

This was a prospective, single-center cohort study including 200 consecutive patients who underwent primary THA. Institutional approval was obtained (IRB number EPZ-06651). Eligible patients were those who had symptomatic primary osteoarthritis and were able to complete standardized spino-pelvic imaging. Exclusion criteria were previous spinal fusion, neuromuscular conditions affecting posture, fixed flexion deformity preventing seated positioning, or incomplete visualization of the lumbosacral junction. Ten patients were excluded for inadequate visualization or suboptimal image quality, leaving 190 for analysis. The mean age was 66 years (range, 35 to 90) and the mean body mass index was 28.0 (range, 20.1 to 41.0).

Radiographic Protocol

All spino-pelvic radiographs were obtained preoperatively using a standardized institutional protocol. Three lateral radiographs were taken for each patient—standing, relaxed-seated, and flexed-seated—using the same radiographic system, fixed source-to-image distance and identical beam centering at the S1 endplate.

For the standing view, patients stood upright with feet shoulder-width apart, knees fully extended, and arms folded across the chest. The pelvis was maintained in a neutral position without anterior or posterior lean.

For the relaxed-seated view, patients sat on a flat radiolucent stool with hips and knees flexed to approximately 90°, feet flat on the floor, and the trunk upright. They were instructed not to lean forward, and the arms were folded across the chest to minimize compensatory motion.

For the flexed-seated radiograph, from the same relaxed-seated position, patients were instructed to lean forward from the hips to a comfortable maximum while maintaining a neutral lumbar spine. Arms remained folded across the chest to prevent use of the upper limbs for support or to influence pelvic motion. This posture was used to replicate functional forward flexion encountered during activities such as rising from a chair and to elicit maximal pelvic motion (Figure 1). The degree of forward flexion was not formally quantified; patients were instructed to lean forward to a comfortable maximum to reproduce a functional posture.

Spino-Pelvic Measurements

Measurements were performed by a single trained observer and reviewed by a senior orthopaedic surgeon for consistency using the institutional Picture Archiving and Communication System software. Measurements included SS, pelvic tilt (PT), pelvic incidence (PI), and lumbar lordosis (LL). SS was defined as the angle between a line parallel to the superior endplate of S1 and the horizontal reference line. The PT was measured as the angle formed by a line connecting the center of the femoral head to the midpoint of the S1 superior endplate and a vertical reference line. The PI was calculated as the angle between a line perpendicular to the S1 superior endplate at its midpoint and a line connecting this point to the center of the femoral head (Figure 2).

The LL was defined as the Cobb angle between the superior endplate of L1 and the inferior endplate of L5. Change in sacral slope (delta SS) and change in lumbar lordosis (delta LL) were calculated; spino-pelvic stiffness was defined as delta SS less than 10° from standing to seated positions, and sagittal imbalance (flatback deformity) was identified when PI−LL was greater than 10°. Patients were also classified according to the hip-spine classification described by Vigdorchik et al. [9].

Data Analyses

Data were analyzed using the Statistical Package for Social Sciences (version 29; IBM Corp., Armonk, New York). Continuous variables were assessed for normality (skewness, kurtosis, boxplots, Shapiro-Wilk, and Kolmogorov-Smirnov tests). Normally distributed data are reported as means ± standard deviations (SD) and compared using paired *t*-tests; nonparametric data were analyzed with Wilcoxon signed-rank tests. Categorical variables were compared using *Chi*-square tests. Pearson correlation coefficients were used to assess associations across postures. Statistical significance was defined as $P < 0.05$.

Results

The mean PI was 52.7° (standard deviation 12.0; range, 11.0 to 89.0); mean standing SS was 36.4°, decreasing to 15.1° in the relaxed-seated position and increasing to 29.1° in the flexed-

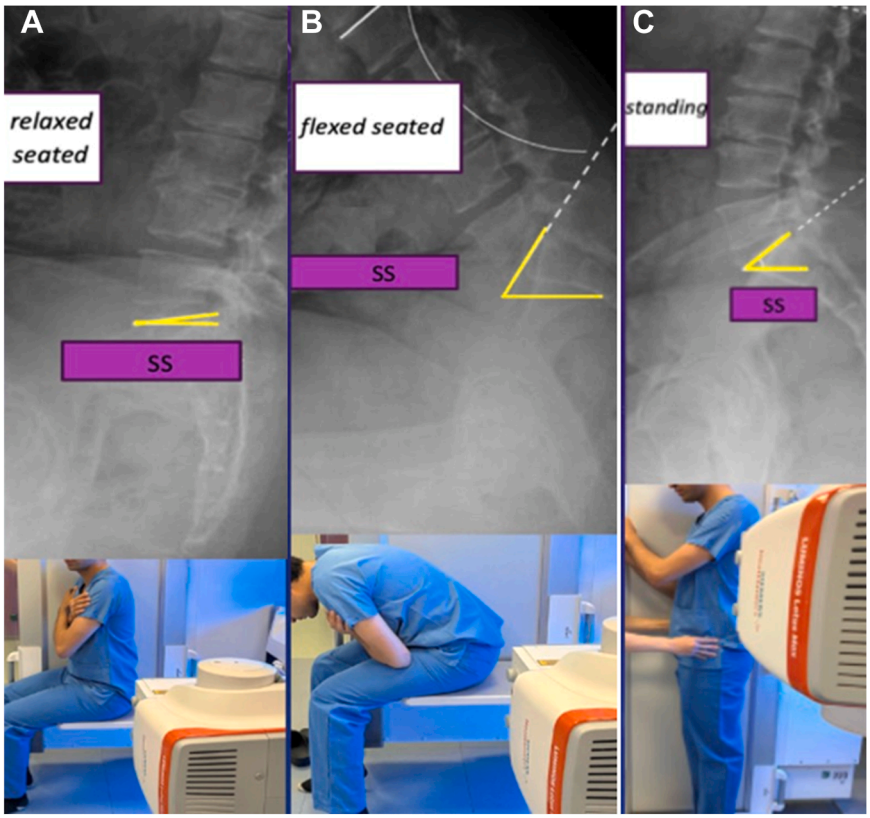

Figure 1. Standardized spino-pelvic radiographic protocol demonstrating the following three imaging positions: (A) relaxed-seated, with the patient sitting upright and hips and knees flexed to approximately 90°; (B) flexed-seated, with forward flexion from the hips to a comfortable maximum; and (C) standing, with the patient upright. All images were obtained using the same radiographic setup with consistent beam centring at the S1 endplate.

seated posture, reflecting expected pelvic retroversion on sitting and anterior pelvic rotation with forward flexion. The pelvic tilt increased from a mean of 17.1° in standing to 37.5° in relaxed-seated and 24.6° in flexed-seated. Lumbar lordosis decreased across postures, with mean values of 47.8° in standing, 31.9° in relaxed-seated, and 15.7° in flexed-seated (Table 1).

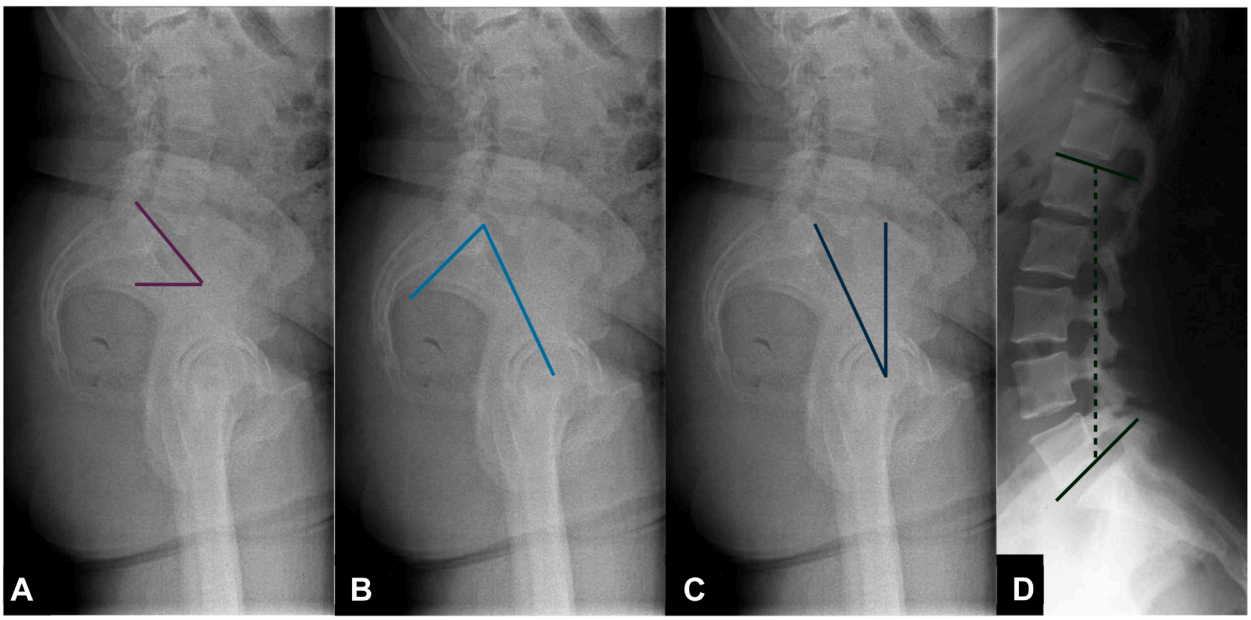

Figure 2. Measurements taken on lumbar lateral radiographs. (A) Sacral slope: angle subtended by a line tangent to the S1 superior endplate and a horizontal line. (B) Pelvic incidence: the angle between a line perpendicular to the S1 superior endplate midpoint and a line connecting the midpoint to the center of the femoral head. (C) Pelvic tilt: the angle between a line connecting the center of the femoral head to the midpoint of the S1 superior endplate and a vertical line from the center of the femoral head; also equal to 'pelvic incidence - sacral slope.' (D) Lumbar Lordosis: The angle between a line parallel to the superior endplate of L1 and the inferior endplate of L5.

Table 1
Baseline Spino-Pelvic Characteristics.

Variable	Mean	SD	Min	Max
PI	52.7	12	11	89
SS standing	36.4	11	6	73
SS relaxed-seated	15.1	11	-17	49
SS flexed-seated	29.1	14	-3	70
PT standing	17.1	11	-2	76
PT relaxed-seated	37.5	12	5	71
PT flexed-seated	24.6	14	-15	52
LL standing	47.8	14	-53	88
LL relaxed-seated	31.9	12	-5	73
LL flexed-seated	15.7	13	-16	64

PI, pelvic incidence; SS, sacral slope; LL, lumbar lordosis; PT, pelvic tilt.

Spino-Pelvic Classification (Standing to Relaxed Versus Standing to Flexed)

Using the standing-to-relaxed-seated delta SS criterion, the distribution was 1A 65.3%, 2A 20.5%, 1B 6.3%, and 2B 7.9%, corresponding to a stiffness prevalence of 14.2% (types 1B/2B).

When the standing-to-flexed-seated delta SS was applied, stiff phenotypes increased to 52.6% overall, with the distribution shifting to 1A 36.9%, 2A 10.5%, 1B 34.7%, and 2B 17.9%. (Table 2)

Using the lumbar-based definition (delta LL $\leq 20^\circ$ standing → flexed), 16.0% of patients were classified as stiff. Among these delta LL-defined stiff patients, stiffness was detected in 27.0% using relaxed-seated delta SS and 80.0% using flexed-seated delta SS.

Reclassification Between Seated Postures

Switching from relaxed- to flexed-seated classification reclassified 75 of 190 patients (39.5%). Most changes were from mobile to stiff phenotypes: 1A → 1B: 55 patients (44.3% of all 1A) and 2A → 2B: 19 patients (48.7% of all 2A). Reverse transitions were uncommon. These findings indicate that the principal value of flexed-seated radiographs is in revealing functional stiffness in patients who have underlying sagittal malalignment, rather than in those who have normal spino-pelvic alignment (Table 3).

Correlations Between the Two Postures

The SS showed moderate correlations between standing and relaxed ($r = 0.34$) and relaxed and flexed ($r = 0.48$), with a moderate association between standing SS and delta SS (standing → flexed) ($r = 0.41$).

Lumbar lordosis correlated moderately between standing and relaxed ($r = 0.41$) and strongly between relaxed and flexed ($r = 0.64$), with a weaker correlation between standing and flexed ($r = 0.32$). LL (flexed) correlated strongly with SS (flexed; $r = 0.71$) (Table 4).

Across seated postures, the mean difference in SS (relaxed versus flexed) was $-14.0^\circ \pm 12.8$ (range, -54.0 to 16.0). An absolute seated-to-seated SS difference greater than 20° was observed in 26.8% of patients, indicating substantial variability in pelvic rotation between the postures. Paradoxical anterior pelvic tilt relative to standing (i.e., an increase in SS suggesting anterior tilt when patients flex forward rather than posterior rollback) was seen in 27.9% and exceeded 10° in 12.1% of patients.

Table 2
Hip-Spine Classification Based on Standing-to-Relaxed Versus Standing-to-Flexed Seated Radiographs.

Hip Spine Classification (Standing → Relaxed)			Hip Spine Classification (Flexed → Relaxed)	
Class	N	%	N	%
1A	124	65.3	70	36.9
2A	39	20.5	20	10.5
1B	12	6.3	66	34.7
2B	15	7.9	34	17.9

Hip-spine classification as proposed by Vigdorchik et al.—types 1 and 2A indicate mobile phenotypes (delta SS $\geq 10^\circ$), types 1 and 2B indicate stiff phenotypes (delta SS $< 10^\circ$); sagittal balance defined by PI–LL $\leq 10^\circ$ (type 1) or $>10^\circ$ (type 2).
PI, pelvic incidence; SS, sacral slope; LL, lumbar lordosis.

Table 3
Spino-Pelvic Reclassification[a] From Relaxed-Seated (Rows) to Flexed-Seated Positions (Columns).

Class	1A	2A	1B	2B
1A	69	0	55	0
2A	0	20	0	19
1B	1	0	11	0
2B	0	0	0	15

[a] Hip-spine classification as proposed by Vigdorchik et al.

Flatback Deformity Subgroup

Flatback deformity (defined as PI-LL greater than 10° in standing) was present in 28.4% of the cohort. These patients demonstrated a smaller standing SS compared with those who have normal sagittal alignment (33.1° versus 37.7) and reduced capacity for posterior pelvic rotation.

The prevalence of spino-pelvic stiffness was substantially higher in flatback patients. Using relaxed-seated delta SS (less than 10°): 27.8% of flatback patients were stiff versus 8.8% in the normal group. Using flexed-seated delta SS (less than 10°), stiffness was identified in 63.0 versus 48.5%, respectively.

Although the absolute seated-to-seated SS change (relaxed to flexed) was similar in both alignment groups (Table 5), a much greater proportion of flatback patients met the stiffness threshold when the flexed-seated view was used (Table 6). This suggests flexed-seated radiographs better capture pelvic-driven compensation in sagittal imbalance, which may remain hidden on relaxed-seated imaging.

Discussion

In this prospective cohort of 190 patients undergoing primary THA, the type of seated radiograph obtained had a substantial effect on detecting spino-pelvic stiffness and sagittal imbalance. We found that reliance on relaxed-seated lateral radiographs underestimated the prevalence of functional stiffness by more than three-fold compared with flexed-seated imaging (14.2 versus 52.6%). Importantly, nearly 40.0% of patients were reclassified into a stiffer phenotype when flexed-seated radiographs were used, with the greatest diagnostic yield in those who have underlying sagittal malalignment (type 2A), where over half of patients were reclassified to type 2B. These findings suggest that relaxed-seated radiographs may not adequately reproduce functional postures encountered during flexion-dependent activities such as rising from a chair, tying shoes, or getting into a car—positions where instability risk may be higher [6].

Our results align with Innmann et al. [10], who also showed that flexed or deep-seated radiographs detect stiffness more accurately, with relaxed-seated views missing over half of stiff spines. Gilbertson et al. also reported wide variability in flexed-seated SS relative to standing or relaxed postures [11], emphasizing that functional pelvic behavior cannot be reliably inferred

Table 4
Correlational Analysis Between the Two Postures.

Pair	*r*	*P*-value
SS standing versus SS relaxed	0.34	<0.001
SS relaxed versus SS flexed	0.48	<0.001
SS standing versus delta SS (stand → flex)	0.41	<0.001
LL standing versus LL relaxed	0.41	<0.001
LL relaxed versus LL flexed	0.64	<0.001
LL standing versus LL flexed	0.32	<0.001
LL flexed versus SS flexed	0.71	<0.001

PI, pelvic incidence; SS, sacral slope; LL, lumbar lordosis.

from static or semiupright seated positions. In the present study, we extend this concept by demonstrating that this variability is not random but phenotype driven: patients who have flatback deformity showed limited posterior pelvic tilt in flexed postures, resulting in a higher stiffness prevalence (63.0 versus 48.0%). Buckland et al. [12] suggested that posterior pelvic tilt often represents compensatory pelvic motion secondary to lumbar restriction rather than true hypermobility. Accordingly, flexed-seated radiographs may better capture pelvic-driven compensation, while relaxed-seated views may primarily reflect lumbar mechanics. This distinction may help explain inconsistent stiffness detection across studies [13,14].

A key mechanistic observation was the frequency of paradoxical anterior pelvic tilt during flexed-seated positioning—27.9% overall, with greater than 10° anterior tilt in 12.0%. These patients appeared mobile on relaxed-seated films (delta SS greater than 10°), but stiff when asked to flex forward, consistent with the "hip user" pattern [12,15]. This reflects limited lumbar flexion compensated by anterior pelvic rotation, which increases functional cup anteversion and may predispose to posterior impingement or dislocation. Importantly, these patterns would not have been recognized using relaxed-seated imaging alone. Recent work [16] further supports this concept, showing that stiff spines drive greater pelvic motion during deep flexion, altering functional cup orientation and increasing instability risk.

The substantial reclassification observed between postures likely reflects a combination of true biomechanical stiffness and posture-dependent factors, including patient effort, pain, and age-related limitations in lumbar flexion. As such, flexed-seated radiographs should be interpreted as reflecting functional behavior rather than isolated spinal stiffness. Nevertheless, this remains clinically relevant, as it represents the motion achieved during forward flexion. Patients classified as stiff on flexed-seated imaging (especially type 2B) may not be identified using relaxed-seated radiographs alone [17]. Given that contemporary planning is often guided by spino-pelvic parameters, such reclassification would be expected to alter input parameters and potentially target component orientation. This was not formally evaluated in the present study and warrants further investigation.

Table 5
Comparison of SS and LL Between Flatback Deformity and Normal Sagittal Alignment Groups.

Variable	Normal (PI−LL ≤ 10°)	Flatback (PI−LL > 10°)
SS standing (°)	37.7 ± 10.2	33.1 ± 10.6
SS relaxed (°)	14.4 ± 10.3	16.7 ± 11.9
SS flexed (°)	29.0 ± 14.3	29.2 ± 12.8
Delta SS stand → relaxed (°)	23.3 ± 10.6	16.4 ± 14.6
Delta SS stand → flexed (°)	8.7 ± 14.8	3.8 ± 12.5
LL standing (°)	50.9 ± 11.0	40.4 ± 17.8
LL relaxed (°)	31.6 ± 11.6	32.8 ± 13.6
LL flexed (°)	14.6 ± 12.2	18.4 ± 13.4
Delta LL stand → relaxed (°)	19.3 ± 11.8	7.6 ± 16.6
Delta LL stand → flexed (°)	36.2 ± 12.7	21.9 ± 17.6

PI, pelvic incidence; SS, sacral slope; LL, lumbar lordosis.

Table 6
Prevalence of Spino-Pelvic Stiffness by Alignment Group Using Relaxed-Seated Versus Flexed-Seated Delta SS Criteria.

Criterion	Normal, n/N (%)	Flatback, n/N (%)
Stiff by delta SS (stand → relaxed)	12/136 (8.8)	15/54 (27.8)
Stiff by delta SS (stand → flexed)	66/136 (48.5)	34/54 (63.0)

Delta SS, changes in sacral slope.

Our correlation analysis showed that relaxed-seated radiographs cannot be used to predict the pelvic or lumbar motion in the flexed-seated posture. Sacral slope measured in relaxed and flexed postures showed only a moderate association ($r = 0.48$) and was insufficient to allow reliable prediction. The discordance was even more pronounced for LL, with only a weak correlation ($r = 0.32$), reflecting that lumbar compensation during forward flexion is highly variable and patient-specific.

Flatback deformity was present in 28.0% of the cohort and further highlighted the limitations of relaxed-seated imaging. In this subgroup, stiffness was detected in only 27.8% using relaxed-seated views, compared with 63.0% using flexed-seated radiographs. This threefold increase reflects that reduced LL limits pelvic compensation, and this restriction only becomes evident when the patient flexes forward. Although the highest diagnostic yield was observed in patients who have sagittal imbalance, a substantial proportion of patients who have normal alignment were also classified as stiff. In these cases, findings should be interpreted with caution, as they may reflect posture-dependent variation rather than fixed stiffness alone.

Taken together, these findings suggest that flexed-seated radiographs provide additional information in the assessment of spino-pelvic mobility, particularly in patients who have sagittal malalignment or borderline stiffness on relaxed-seated films [14].

Strengths of this study include its prospective design, standardized imaging protocol, and a large consecutive cohort representative of current THA practice. Measurements were performed using validated digital techniques and verified by a senior surgeon. Potential limitations include the single-center setting and the use of a single observer without formal interobserver reliability assessment. In addition, spino-pelvic mechanics are inherently three-dimensional, and the use of two-dimensional lateral radiographs represents a simplification of a complex, multiplanar process. As this was a radiographic study, the impact on component positioning and clinical outcomes was not formally assessed. Furthermore, the degree of forward flexion was not quantified and may have varied between patients, potentially influencing measurements.

Further work should correlate these radiographic patterns with those who have clinical outcomes, particularly instability and revision. Given the low event rates and the multifactorial nature of instability, this will require larger, adequately powered cohorts with longitudinal follow-up. Integration with planning algorithms or simulation platforms may also help quantify how these radiographic differences translate into component orientation.

Conclusions

Flexed-seated radiographs identify substantially more patients as having reduced spino-pelvic mobility compared with relaxed-

seated imaging, with reclassification occurring in a large proportion of cases. Relaxed-seated radiographs show only moderate correlation with flexed-seated behavior and do not reliably reflect functional motion. These findings highlight that spino-pelvic assessment is posture-dependent and that flexed-seated imaging may provide additional information, particularly in patients who have sagittal malalignment or equivocal findings. The clinical impact of these differences on component positioning and outcomes requires further study.

CRediT authorship contribution statement

Andreas Fontalis: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Humza Osmani:** Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation. **Maël Guerra-Perron:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Data curation. **Fabio Mancino:** Writing – review & editing, Resources, Methodology, Investigation, Formal analysis, Data curation. **Warran Wignadasan:** Writing – review & editing, Project administration, Methodology, Investigation, Data curation. **Pierre Putzeys:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Fares S. Haddad:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization.

Acknowledgments

The authors would like to acknowledge Dr Thomas Vanspauwen for his valuable help with data collection for this study.

References

[1] Achakri H, Ben-Shlomo Y, Blom A, Boulton C, Bridgens J, Brittain R, et al. The National Joint Registry 21st Annual Report 2024. London: National Joint Registry; 2023.
[2] Fontalis A, Putzeys P, Plastow R, Giebaly DE, Kayani B, Glod F, et al. Functional component positioning in total hip arthroplasty and the role of robotic-arm assistance in addressing spinopelvic pathology. Orthop Clin North Am 2023. https://doi.org/10.1016/J.OCL.2022.11.003.
[3] Fleischman AN, Tarabichi M, Magner Z, Parvizi J, Rothman RH. Mechanical complications following total hip arthroplasty based on surgical approach: a large, single-institution cohort study. J Arthroplasty 2019;34:1255–60. https://doi.org/10.1016/J.ARTH.2019.02.029.
[4] Scott CEH, Clement ND, Davis ET, Haddad FS. Modern total hip arthroplasty: peak of perfection or room for improvement? Bone Joint J 2022;104-B:189–92. https://doi.org/10.1302/0301-620X.104B2.BJJ-2022-0007.
[5] Abdel M, von Roth P, Jennings M, Hanssen A, Pagnano M. What safe zone? The vast majority of dislocated THAs are within the lewinnek safe zone for acetabular component position. Clin Orthop Relat Res 2016;474:386–91. https://doi.org/10.1007/S11999-015-4432-5.
[6] Fontalis A, Buchalter D, Mancino F, Shen T, Sculco PK, Mayman D, et al. Contemporary insights into spinopelvic mechanics. Bone Joint J 2024;106-B:1206–15. https://doi.org/10.1302/0301-620X.106B11.BJJ-2024-0373.
[7] Buchalter DB, Gall AM, Buckland AJ, Schwarzkopf R, Meftah M, Hepinstall MS. Creating consensus in the definition of spinopelvic mobility. J Am Acad Orthop Surg Glob Res Rev 2023;7:e22.00290. https://doi.org/10.5435/JAAOSGLOBAL-D-22-00290.
[8] Sharma AK, Grammatopoulos G, Pierrepont JW, Madurawe CS, Innmann MM, Vigdorchik JM, et al. Sacral slope change from standing to relaxed-seated grossly overpredicts the presence of a stiff spine. J Arthroplasty 2023;38:713–718.e1. https://doi.org/10.1016/J.ARTH.2022.05.020.
[9] Vigdorchik JM, Sharma AK, Buckland AJ, Elbuluk AM, Eftekhary N, Mayman DJ, et al. 2021 Otto Aufranc Award: a simple hip-spine classification for total hip arthroplasty. Bone Joint J 2021;103-B:17–24. https://doi.org/10.1302/0301-620X.103B7.BJJ-2020-2448.R2.
[10] Innmann MM, Merle C, Phan P, Beaulé PE, Grammatopoulos G. How can patients with Mobile hips and stiff lumbar spines be identified prior to total hip arthroplasty? A prospective, diagnostic cohort study. J Arthroplasty 2020;35:S255–61. https://doi.org/10.1016/J.ARTH.2020.02.029.
[11] Gilbertson B, Babazadeh S, van Bavel D. Variations in pelvic tilt between relaxed-seated and flexed-seated positions affect stability assessment in 3D modelling in total hip replacement. ANZ J Surg 2025;95:175–9. https://doi.org/10.1111/ANS.19317.
[12] Buckland AJ, Fernandez L, Shimmin AJ, Bare JV, McMahon SJ, Vigdorchik JM. Effects of sagittal spinal alignment on postural pelvic mobility in total hip arthroplasty candidates. J Arthroplasty 2019;34:2663–8. https://doi.org/10.1016/J.ARTH.2019.06.036.
[13] Verhaegen JCF, Innmann M, Alves Batista N, Dion CA, Horton I, Pierrepont J, et al. Defining "normal" static and dynamic spinopelvic characteristics: a cross-sectional study. JB JS Open Access 2022;7:e22.00007. https://doi.org/10.2106/JBJS.OA.22.00007.
[14] Behery OA, Vasquez-Montes D, Cizmic Z, Vigdorchik JM, Buckland AJ. Can flexed-seated and single-leg standing radiographs be useful in preoperative evaluation of lumbar mobility in total hip arthroplasty? J Arthroplasty 2020;35:2124–30. https://doi.org/10.1016/J.ARTH.2020.03.035.
[15] Luthringer TA, Vigdorchik JM. A preoperative workup of a "Hip-Spine" total hip arthroplasty patient: a simplified approach to a complex problem. J Arthroplasty 2019;34:S57–70. https://doi.org/10.1016/J.ARTH.2019.01.012.
[16] Verhaegen JCF, Innmann MM, Merle C, Batista NA, Phan P, Grammatopoulos G. Spine stiffness leads to high pelvic mobility: uncoupling native mechanics and explaining why patients with stiff spines have increased dislocation risk. Clin Orthop Relat Res 2025;484:354–67. https://doi.org/10.1097/CORR.0000000000003691.
[17] Karasavvidis T, Pagan CA, Sharma AK, Jerabek SA, Mayman DJ, Vigdorchik JM. Decreased instability in high-risk (Hip-Spine 2B) patients after modifications of surgical planning and technique. J Arthroplasty 2024;39:S138–44. https://doi.org/10.1016/J.ARTH.2024.04.043.