Trauma Monthly 2026; 31(5): 2116-2129

10.30491/tm.2026.589182.1954

Trauma Monthly

Research Article

Early Postoperative Changes in Spinopelvic Parameters After Total Hip Arthroplasty: A Registry-Based Analysis with Subgroup Comparison by Trauma History

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Received 2025-07-05 ; **Accepted** 2026-04-25; **Online Published** 2026-10-29

Abstract

Introduction: Total hip arthroplasty (THA) is highly effective for advanced hip pathology, but postoperative instability remains a concern. The relationship among the spine, pelvis, and hip—the spinopelvic complex—influences acetabular orientation and implant stability. This registry-based study evaluated changes in spinopelvic alignment parameters before and after primary THA using standing and sitting radiographs.

Method: A consecutive series of 60 patients (32 males, 28 females; mean age 61±12 years; mean BMI 26.9±3.6 kg/m²) undergoing primary THA for osteoarthritis, avascular necrosis, developmental dysplasia, or trauma were included. We obtained standardized standing and sitting lateral spinopelvic radiographs preoperatively and postoperatively (2 months). Parameters measured included lumbar lordosis (LL), sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), sacro-acetabular angle (SAA), acetabular index (AI), proximal femoral angle (PFA), and combined sagittal index (CSI). Statistical comparisons used paired t-test or Wilcoxon signed-rank test.

Result: In the standing position, significant postoperative increases were observed for PT (12.3°±10.0° to 15.0°±9.5°; p=0.014), SAA (43.8°±24.0° to 70.8°±18.4°; p<0.001), AI (17.4°±13.9° to 39.2°±10.8°; p<0.001), and CSI (185.9°±17.9° to 207.7°±14.5°; p<0.001). In the sitting position, significant increases were found for SAA (69.5°±17.8° to 75.2°±11.1°; p<0.001) and AI (50.6°±17.9° to 62.2°±15.9°; p=0.001). Classical spinopelvic parameters, including LL, SS, and PI, did not change between positions. Subgroup analysis revealed that patients with a history of minor trauma (n=19) demonstrated significantly greater increases in acetabular index in the sitting position compared to those without trauma (25.7° vs. 5.0°; p=0.004).

Conclusion : THA induces significant postoperative changes in acetabular-related sagittal parameters (SAA, AI, CSI) rather than global spinopelvic morphology. The presence of minor trauma history appears to influence postoperative acetabular adaptation, particularly in the sitting position. These findings emphasize the importance of functional, posture-specific spinopelvic assessment in preoperative planning to enable personalized component positioning and reduce instability risk. These early postoperative adaptations suggest that THA induces rapid acetabular reorientation, though the long-term trajectory of these changes remains to be determined.

Keywords: Total hip arthroplasty; Spinopelvic balance; Sagittal alignment; Acetabular orientation; Pelvic tilt, traumatic hip osteoarthritis.

Introduction

Total hip arthroplasty (THA) is one of the most successful orthopedic procedures, providing substantial pain relief, functional restoration, and improved quality of life for patients with advanced hip pathology [1]. Despite excellent implant survivorship, postoperative instability and dislocation remain clinically important complications that may compromise outcomes and require revision surgery [2, 3]. Growing evidence suggests these complications are influenced not only by implant positioning but also by the dynamic relationship among

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the spine, pelvis, and hip, commonly referred to as the spinopelvic complex [4-6]. The pelvis serves as the biomechanical link between the lumbar spine and lower extremities. Duval-Beaupère introduced the concept of the "pelvic vertebra," emphasizing the fundamental role of pelvic orientation in determining global sagittal balance and spinal alignment [7, 8]. Several radiographic parameters have been developed to characterize spinopelvic alignment, including lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS). These parameters are closely interrelated and influence both spinal posture and acetabular orientation.

The relationship between the hip and spine becomes particularly important in patients with advanced hip disease. Hip osteoarthritis, avascular necrosis, developmental dysplasia, and post-traumatic deformities may alter normal spinopelvic mechanics through compensatory mechanisms such as restricted hip extension, increased pelvic tilt, and changes in lumbar lordosis [9, 10]. These adaptations may result in abnormal sagittal alignment and altered functional acetabular orientation.[11]

Recent investigations have demonstrated that spinopelvic alignment is dynamic rather than static. Changes in posture from standing to sitting involve coordinated movements of the pelvis and lumbar spine, resulting in substantial alterations in acetabular anteversion and inclination [12, 13]. Consequently, acetabular component positioning based solely on static radiographs may not accurately reflect functional orientation during daily activities .[14]

Previous studies have shown that THA can induce measurable changes in spinopelvic alignment, particularly in the early postoperative period [15-17]. Short‐term improvements in hip range of motion (ROM) and pain relief may promote partial normalization of compensatory pelvic and spinal postures. Still, long‐term adaptations appear more complex and heterogeneous, being influenced by spinal pathology, spinopelvic stiffness, and prior spine surgery [10].

Furthermore, the growing recognition of hip–spine syndrome has highlighted the importance of evaluating spinopelvic mobility in THA candidates. Patients with degenerative lumbar spine disease, spinal stiffness, or previous lumbar fusion demonstrate altered spinopelvic mechanics and may be at increased risk of impingement, instability, and dislocation following THA [18-20]. Understanding postoperative changes in spinopelvic alignment may therefore improve surgical planning and optimize implant positioning.

Although several studies have evaluated spinopelvic parameters following THA, most have focused on patients with primary osteoarthritis. At the same time, limited information is available regarding patients undergoing THA for traumatic hip disorders and mixed etiologies. Moreover, the extent to which THA modifies spinopelvic alignment in standing and sitting positions remains incompletely understood. Therefore, this registry-based study evaluated changes in spinopelvic alignment parameters before and after two months of THA using standing and sitting radiographs. We hypothesized that restoring hip function after THA would produce measurable changes in acetabular orientation and selected spinopelvic parameters while preserving fundamental morphologic parameters such as pelvic incidence.

Methods

This registry-based data analysis includes a consecutive series of 60 hips in 60 patients who underwent primary THA between March 2025 and March 2026. The local institutional board approved the study (IR.BMSU.REC.1404.191).

Patients of all sexes aged more than 18 years, and meeting the surgical indication for primary total hip arthroplasty (because of hip osteoarthritis, avascular necrosis of the hip, trauma, and Developmental Dysplasia of the Hip (DDH)) were included in this study. Among the patients, one (2%) patient had a major trauma and 19 (32%) reported minor trauma, most of which were ground-level falls.

We excluded patients with pregnancy, pelvic septic arthritis, bacteremia or active infection, severe peripheral vascular disorders, missing hospital data, missing standard radiographs, or prior ipsilateral total knee arthroplasty (TKA).

Patients were required to have undergone pre- and postoperative spino-pelvic X-rays after two months. All spino-pelvic radiographs were obtained preoperatively using a standardized institutional protocol. We obtained two lateral

radiographs for each patient (standing and sitting) using the same radiographic system and a fixed source-to-image distance.

No formal a priori sample size calculation was performed, as this study was based on a consecutive series of all eligible patients with complete pre- and postoperative radiographic data in the registry during the study period. The sample size of 60 patients is comparable to previous longitudinal studies evaluating spinopelvic changes following THA, which have reported cohorts ranging from 30 to 81 patients [22, 23]. Post-hoc power analysis indicated that the study had approximately 80% power to detect moderate-to-large effect sizes (Cohen's $d \geq 0.50$) for the primary comparisons at $\alpha = 0.05$. However, the sample size was too small for robust subgroup analyses (particularly the trauma subgroup, n=19), so these findings should be considered exploratory. The consecutive enrollment approach was intentionally chosen to reflect real-world clinical practice and enhance generalizability, despite the inherent heterogeneity of the study population.

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 (Figure 1). For the sitting 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 to fold their arms across their chests to minimize compensatory motion (Figure 2).

An orthopedic surgeon manually measured each anonymized radiograph independently at 1-month intervals. Angles were defined and measured as follows (see Figures 3 and 4):

Lumbar Lordosis (LL): The Cobb angle between the superior endplate of L1 and the superior endplate of S1

Sacral Slope (SS): Angle between the horizontal line and the superior endplate of the sacrum (S1).

Pelvic Tilt (PT): Angle between the vertical axis and a line from the center of the femoral head to the midpoint of the superior endplate of S1.

Pelvic Incidence (PI): Angle between a line perpendicular to the sacral slope and a line connecting the midpoint of the superior endplate of S1 to the center of the femoral heads.

Sacro-Acetabular angle (SAA): The angle between the line between the two edges of the acetabulum and the surface of the sacrum.

Acetabular Index (AI): Angle between a line from the anterior to the posterior wall of the acetabulum and a horizontal line.

Proximal Femoral Angle (PFA): Angle between a line drawn from the center of the femoral head to the midpoint of the superior endplate of S1 and the anatomical axis of the femur.

Combined Sagittal Index (CSI): The angle of the acetabular cup in the sagittal plane, which is the sum of AI and PFA.

All radiographic parameters—including Lumbar Lordosis (LL), Sacral Slope (SS), Pelvic Tilt (PT), Pelvic Incidence (PI), Sacro-Acetabular angle (SAA), Proximal Femoral Angle (PFA), and Acetabular Index (AI)—were analyzed as continuous variables. Data are presented as mean ± standard deviation (SD) and median for all. Variables were assessed for normality using the Shapiro–Wilk test. We compared preoperative and postoperative measurements within each position (standing and sitting separately) using the paired t-test for normally distributed variables or the Wilcoxon signed-rank test for non-normally distributed variables. To assess the influence of trauma history on postoperative changes, patients were stratified based on the presence or absence of minor trauma (minor_trauma=1 vs. 0). Differences in demographic characteristics between groups were assessed using independent t-tests for continuous variables (age, BMI) and chi-square or Fisher's exact tests for categorical variables (gender, diagnosis). Differences in preoperative-to-postoperative changes (Δ values) between the two groups were compared using the Mann-Whitney U test for non-normally distributed data. All subgroup analyses were considered exploratory, and a p-value <0.05 was considered statistically significant. No adjustment for multiple comparisons was performed given the exploratory nature of these analyses. A p-value less than 0.05 was considered statistically significant.



Figure 1 : patient position during standing X-ray



Figure 2 : patient position during sitting X-ray

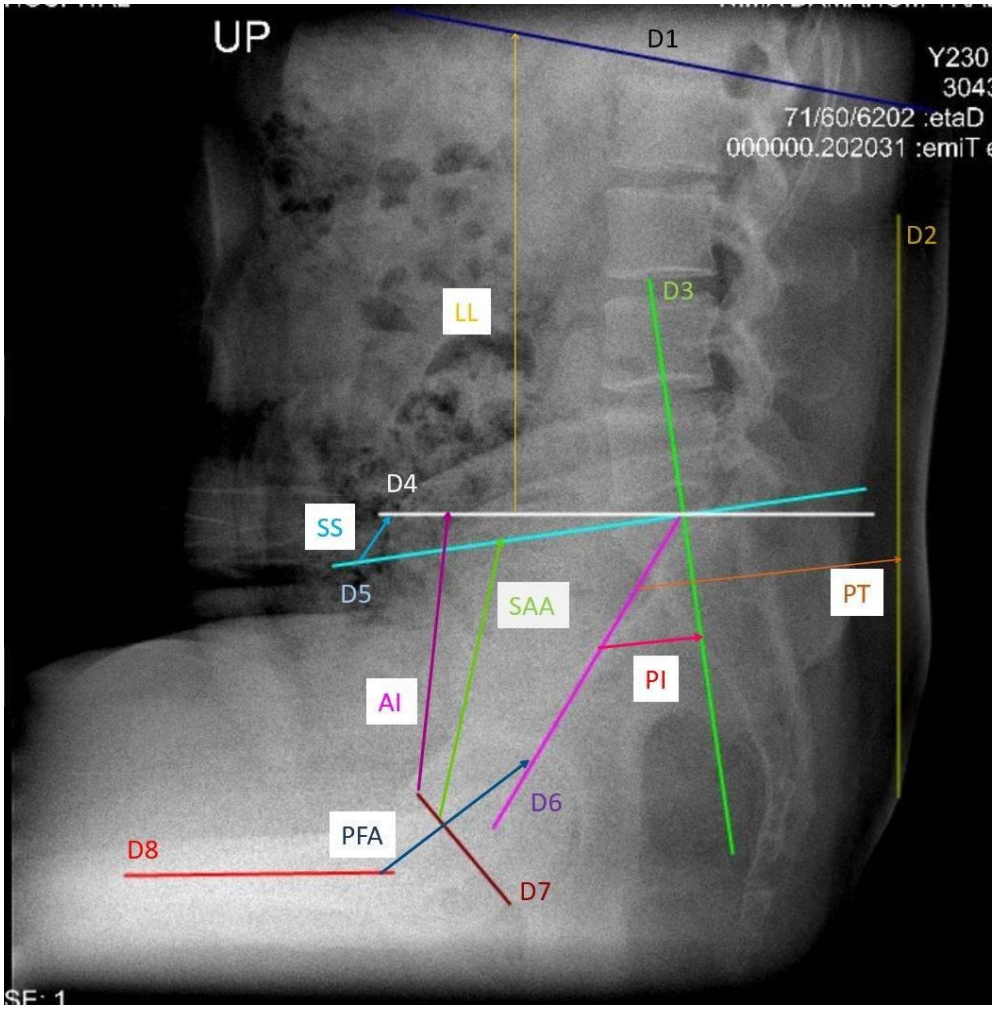


Figure 3 : measured Angles on sitting X-ray. d1: Parallel line to L5 end plate, d2: vertical line plate, d3: vertical line perpendicular to S1 end plate, d4: horizontal line of page, d5: parallel line to S1 end plate, d6: line from the center of the S1 endplate to the center of the femoral head, d7: line between the two edges of the acetabulum, d8: line parallel to the femoral shaft. LL: Angle between d1 and d5, SS: Angle between d4 and d5, PT: Angle between d2 and d6, PI: Angle between d3 and d6, SAA: Angle between d5 and d7, AI: Angle between d4 and d7, PFA: Angle between d6 and d8, CSI: summary of AI and PFA.

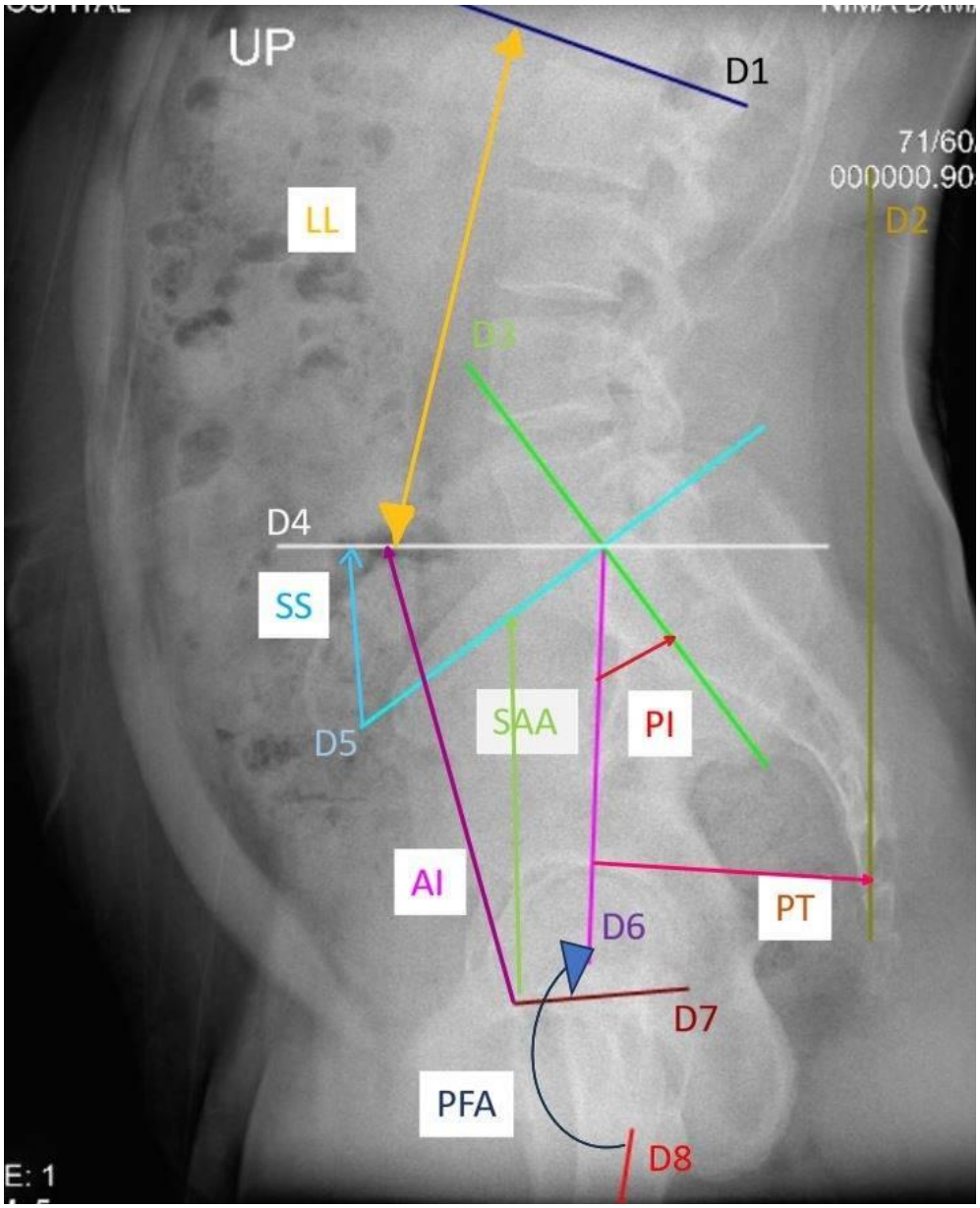


Figure 4 : measured Angles on standing X-ray. From sitting to standing, SS has increased, PT has decreased, AI and SAA have also decreased, and PFA has increased.

Results

A total of 60 patients (32 males, 53%; 28 females, 47%) with a mean age of 61 years (±12) and a mean body mass index (BMI) of 26.9 kg/m² (±3.6) were included. Preoperative and postoperative spinopelvic parameters in the sitting and standing positions are presented in Table 1.

Sitting position

There were no significant differences between preoperative and postoperative measurements for lumbar lordosis (24.3° ± 12.8° vs. 25.7° ± 12.9°; p = 0.302), sacral slope (14.6° ± 12.4° vs. 16.2° ± 11.8°; p = 0.387), pelvic tilt (34.8° ± 13.6° vs. 34.1° ± 14.8°; p = 0.736), pelvic incidence (49.4° ± 12.4° vs. 50.3° ± 12.0°; p = 0.411), proximal femoral angle (134.6° ± 20.0° vs. 131.3° ± 23.1°; p = 0.254), or combined sagittal index (185.3° ± 28.4° vs. 193.5° ± 28.9°; p =

0.059). However, the sacro-acetabular angle increased significantly from 69.5° ± 17.8° preoperatively to 75.2° ± 11.1° postoperatively ($p < 0.001$), and the acetabular index also increased significantly from 50.6° ± 17.9° to 62.2° ± 15.9° ($p = 0.001$).

Standing position

In the standing position, lumbar lordosis (40.4° ± 12.4° vs. 42.4° ± 14.8°; $p = 0.231$), sacral slope (36.6° ± 13.0° vs. 36.0° ± 11.3°; $p = 0.663$), pelvic incidence (48.8° ± 11.8° vs. 50.9° ± 11.6°; $p = 0.116$), and proximal femoral angle (168.5° ± 10.1° vs. 168.4° ± 9.2°; $p = 0.959$) remained statistically unchanged. In contrast, significant postoperative increases were observed for pelvic tilt (12.3° ± 10.0° vs. 15.0° ± 9.5°; $p = 0.014$), sacro-acetabular angle (43.8° ± 24.0° vs. 70.8° ± 18.4°; $p < 0.001$), acetabular index (17.4° ± 13.9° vs. 39.2° ± 10.8°; $p < 0.001$), and combined sagittal index (185.9° ± 17.9° vs. 207.7° ± 14.5°; $p < 0.001$).

Subgroup Analysis Based on Trauma History

To explore whether the presence of minor trauma influenced postoperative spinopelvic changes, patients were stratified into two groups: those without minor trauma (n=41, 68.3%) and those with a history of minor trauma (n=19, 31.7%). Baseline characteristics and postoperative changes were compared between groups. Patients with minor trauma were slightly older (63.2±9.4 years vs. 59.5±13.0 years) and had a marginally lower BMI (25.9±3.3 kg/m² vs. 27.4±3.6 kg/m²) compared to those without trauma. However, these differences were not statistically significant. Gender distribution was comparable between groups, with no significant association between gender and trauma history (Pearson Chi-Square=0.397, p=0.528). The majority of patients in both groups had degenerative joint disease (DJD) as the underlying diagnosis, comprising 68.3% (28/41) of the non-trauma group and 100% (19/19) of the trauma group. All patients with avascular necrosis (n=7), developmental dysplasia of the hip (n=4), Perthes disease (n=1), and major trauma (n=1) were in the non-trauma group (p=0.060, Fisher's Exact Test).

Postoperative Changes by Trauma History

Sitting Position:

In the sitting position, the changes in spinopelvic parameters following THA varied between the two groups. Patients without minor trauma demonstrated a mean increase in sacro-acetabular angle (SAA) of 8.2°±19.2°. In contrast, those with minor trauma showed a larger increase of 16.2°±23.4°, though this difference did not reach statistical significance (Mann-Whitney U=325.0, p=0.305). A more pronounced difference was observed in the acetabular index (AI), with patients without trauma showing a mean increase of 5.0°±23.8° compared with 25.7°±19.8° in patients with minor trauma (Mann-Whitney U=210.0, p=0.004). This difference was statistically significant, suggesting that patients with a history of minor trauma experience greater postoperative acetabular reorientation in the sitting position.

Notably, lumbar lordosis (LL) changes differed between groups in the sitting position: patients without minor trauma showed a mean increase of 2.9°±10.4°, whereas those with minor trauma demonstrated a mean decrease of -1.8°±9.6° (Mann-Whitney U=298.5, p=0.148). Similarly, sacral slope (SS) increased by 3.6°±14.4° in the non-trauma group but decreased by -3.0°±10.8° in the trauma group (Mann-Whitney U=277.5, p=0.075), approaching but not reaching statistical significance. The combined sagittal index (CSI) increased more in the trauma group (17.1°±35.9°) compared to the non-trauma group (4.1°±31.4°), though this difference was not statistically significant (p=0.080).

Pelvic tilt (PT) changes also differed: the non-trauma group demonstrated a mean decrease of -2.5°±16.7° in sitting PT, while the trauma group showed a mean increase of 3.3°±12.9° (p=0.131). Pelvic incidence (PI) and proximal femoral angle (PFA) changes did not differ significantly between groups (p=0.975 and p=0.849, respectively).

Standing Position:

In the standing position, the pattern of changes was more consistent between groups. Both groups showed substantial increases in SAA (non-trauma: 27.2°±28.7°; trauma: 26.6°±29.1°; p=0.962) and AI (non-trauma: 20.2°±16.2°; trauma: 25.4°±18.2°; p=0.236), with no significant differences between groups. The CSI increased by 20.3°±21.6° in the non-trauma group and 24.7°±18.5° in the trauma group (p=0.535).

Pelvic tilt in standing increased in both groups, though the change was more modest in the trauma group (0.9°±8.3°) compared to the non-trauma group (3.5°±8.3°), with no significant difference (p=0.204). Lumbar lordosis in standing showed a mean increase of 4.0°±12.5° in the non-trauma group but a mean

decrease of -2.4°±11.5° in the trauma group (p=0.144), mirroring the sitting-position findings. Pelvic incidence, sacral slope, and proximal femoral angle changes showed no significant differences between groups in the standing position (all p>0.05).

Table 1 : Pre and Postoperative Spinopelvic angles Change in sitting and Standing positions Following Total Hip Arthroplasty. (Values are reported as mean ± standard deviation; median is shown in parentheses.)

Sitting	Pre op	Post op	P-value
Lumbar Lordosis	24.3 ± 12.8 (22.8)	25.7 ± 12.9 (25.5)	0.302
Sacral Slope	14.6 ± 12.4 (12.8)	16.2 ± 11.8 (15.7)	0.387
Pelvic Tilt	34.8 ± 13.6 (32.6)	34.1 ± 14.8 (33.3)	0.736
Pelvic Incidence	49.4 ± 12.4 (48.2)	50.3 ± 12.0 (50.0)	0.411
Sacro-Acetabular angle	69.5 ± 17.8 (68.4)	75.2 ± 11.1 (77.3)	< 0.001
Acetabular index	50.6 ± 17.9 (51.8)	62.2 ± 15.9 (66.2)	0.001
Proximal Femoral Angle	134.6 ± 20.0 (129.8)	131.3 ± 23.1 (129.6)	0.254
Combined Sagittal Index	185.3 ± 28.4 (185.5)	193.5 ± 28.9 (195.3)	0.059
Standing			
Lumbar Lordosis	40.4 ± 12.4 (40.4)	42.4 ± 14.8 (42.3)	0.231
Sacral Slope	36.6 ± 13.0 (35.6)	36.0 ± 11.3 (35.6)	0.663
Pelvic Tilt	12.3 ± 10.0 (11.0)	15.0 ± 9.5 (14.2)	0.014
Pelvic Incidence	48.8 ± 11.8 (48.2)	50.9 ± 11.6 (53.1)	0.116
Sacro-Acetabular angle	43.8 ± 24.0 (41.7)	70.8 ± 18.4 (75.4)	< 0.001
Acetabular index	17.4 ± 13.9 (14.1)	39.2 ± 10.8 (38.6)	< 0.001
Proximal Femoral Angle	168.5 ± 10.1 (171.0)	168.4 ± 9.2 (170.9)	0.959
Combined Sagittal Index	185.9 ± 17.9 (182.9)	207.7 ± 14.5 (209.0)	< 0.001

Table 2: Comparison of Postoperative Changes in Spinopelvic Parameters between Patients with and Without Minor Trauma History

Parameter	Non-Trauma (n=41) Mean ± SD	Trauma (n=19) Mean ± SD	p-value
Sitting Position			
Δ Lumbar Lordosis	2.87 ± 10.38	-1.82 ± 9.59	0.148
Δ Sacral Slope	3.62 ± 14.41	-2.98 ± 10.81	0.075
Δ Pelvic Tilt	-2.54 ± 16.72	3.30 ± 12.89	0.131
Δ Pelvic Incidence	1.11 ± 8.24	0.34 ± 8.01	0.975
Δ Sacro-Acetabular Angle	8.18 ± 19.17	16.22 ± 23.43	0.305
Δ Acetabular Index	5.04 ± 23.80	25.72 ± 19.79	0.004*
Δ Proximal Femoral Angle	-0.92 ± 18.15	-8.58 ± 29.78	0.849
Δ Combined Sagittal Index	4.11 ± 31.43	17.14 ± 35.88	0.080
Standing Position			
Δ Lumbar Lordosis	3.95 ± 12.47	-2.38 ± 11.53	0.144
Δ Sacral Slope	-0.82 ± 11.63	-0.19 ± 9.63	0.899
Δ Pelvic Tilt	3.55 ± 8.25	0.87 ± 8.25	0.204
Δ Pelvic Incidence	2.66 ± 10.50	0.74 ± 8.72	0.294
Δ Sacro-Acetabular Angle	27.17 ± 28.66	26.62 ± 29.11	0.962
Δ Acetabular Index	20.15 ± 16.20	25.44 ± 18.16	0.236
Δ Proximal Femoral Angle	0.16 ± 12.23	-0.71 ± 13.10	0.830
Δ Combined Sagittal Index	20.31 ± 21.64	24.74 ± 18.50	0.535

*Values represent postoperative minus preoperative measurements. Δ indicates change. P-values from Mann-Whitney U test. Statistically significant (p<0.05).

Discussion

The principal finding of this study was that total hip arthroplasty caused significant postoperative changes in acetabular-related sagittal parameters, including sacro-acetabular angle (SAA), acetabular index (AI), and combined sagittal index (CSI). In contrast, most classical spinopelvic parameters, including lumbar lordosis (LL), sacral slope (SS), and pelvic incidence (PI), remained largely unchanged. These findings suggest that THA primarily influences functional acetabular orientation and hip-related sagittal mechanics rather than inducing major alterations in intrinsic spinopelvic morphology.

In the sitting position, SAA and AI increased significantly after surgery, while LL, SS, PT, PI, and PFA did not change significantly. Similarly, in the standing position, PT, SAA, AI, and CSI increased postoperatively, whereas LL, SS, PI, and PFA remained relatively stable. These results indicate that restoration of hip anatomy and motion following THA is associated with modifications in functional acetabular orientation rather than substantial changes in global spinopelvic alignment.

The subgroup analysis revealed that patients with a history of minor trauma demonstrated significantly greater increases in acetabular index in the sitting position compared to patients without trauma. This finding may reflect several underlying mechanisms. Patients with prior trauma—even if minor—may have pre-existing alterations in soft tissue compliance, periarticular scarring, or neuromuscular control that affect postoperative spinopelvic adaptation. Alternatively, the difference may be explained by the diagnostic heterogeneity between groups, as all patients with AVN, DDH, and major trauma were in the non-trauma group. These conditions may have distinct spinopelvic characteristics that influence postoperative changes.

The divergent trends in lumbar lordosis and sacral slope changes between groups—increasing in non-trauma patients but decreasing in those with trauma—suggest different compensatory patterns following THA. Patients without trauma may experience "normalization" of spinal alignment as hip pathology is relieved, while those with trauma may have more fixed spinopelvic adaptations due to prior injury. However, these differences did not reach statistical significance, possibly due to the small sample size in the trauma subgroup (n=19) and the heterogeneity of traumatic mechanisms.

These findings, while exploratory, suggest that preoperative trauma history may influence postoperative spinopelvic adaptation and should be considered in preoperative planning. Future studies with larger sample sizes and more detailed characterization of traumatic injuries are needed to confirm these observations and determine their clinical significance.

The absence of significant postoperative changes in pelvic incidence observed in our cohort was expected because PI is considered a morphologic parameter that remains constant throughout adult life. Legaye and colleagues originally described PI as an anatomical characteristic that determines the relationship between the pelvis and lumbar spine [21].

In this longitudinal study, Pelvic Tilt increased significantly after surgery (from 12.3 to 15.0 degrees, P=0.014), whereas changes in Sacral Slope and Pelvic Incidence did not reach statistical significance. Because the anatomical relationship PI = PT + SS holds for each patient, the mean changes show that the increase in PT (2.7 degrees) was primarily accompanied by a small, non-significant increase in PI (2.1 degrees) and a slight decrease in SS (0.6 degrees). This finding can be attributed to two factors. First, compensatory pelvic retroversion after surgery, occurring mainly through increased posterior tilt without a notable change in SS—a pattern consistent with reduced lumbar lordosis after fusion/instrumentation. Second, inherent measurement error in determining PI on standing radiographs (particularly after surgery and with altered sacral anatomy) can introduce random variability of approximately 3 to 6 degrees. It may have led to an apparent increase in PI at the group level. Thus, the significant increase in PT without significant changes in PI or SS does not contradict the mathematical relationship PI = PT + SS; rather, it reflects true pelvic retroversion accompanied by random measurement error in PI.

Our findings are consistent with previous reports demonstrating that many spinopelvic abnormalities observed before THA represent compensatory adaptations to hip pathology rather than fixed spinal

deformities. Innmann et al. reported normalization of abnormal spinopelvic motion patterns after THA, while static parameters such as LL, SS, and PT showed only limited change [22]. Similarly, Tateiwa et al. found that THA minimally affected global sagittal spinal alignment and that postoperative pelvic tilt remained strongly influenced by preoperative morphology, particularly pelvic incidence [11]. Similarly, a large prospective study of 424 hips found that PT increased by 2° from 15.1° (±8.9) to 17.1° (±9.7) after THA [23]. In that study, 16% of patients showed a moderate increase in PT, while 79.5% had no clinically significant change, and only 4.5% experienced a relevant PT decrease. The authors concluded that PT generally normalizes after THA, and patients with low preoperative PT due to hip flexion contractures tend to increase PT postoperatively. In contrast, few patients with high PT decrease after THA [23]. Our results support this concept; the mean increase in standing PT suggests a relief of fixed flexion contractures, allowing the pelvis to adopt a more neutral sagittal posture.

Interestingly, lumbar lordosis and sacral slope did not change significantly after surgery in either standing or sitting positions. Çetin et al. showed that standing SS remained unchanged at 1‐year follow‐up [24]. Similar findings have been reported by Miranda et al., who observed minimal postoperative alterations in global sagittal balance despite substantial clinical improvement following THA [7]. These observations suggest that symptomatic improvement after THA may not require major changes in spinal alignment and that other biomechanical factors, including restoration of hip range of motion and correction of acetabular orientation, may contribute more substantially to postoperative function.

We observed that spinopelvic hypermobility (i.e., excessive SS change from standing to sitting) was not prevalent in our cohort (ΔSS from standing to sitting was 16.1° preoperatively and 16.7° postoperatively, both within the normal range). Innmann et al. showed that spinopelvic hypermobility, defined as ΔSS > 30°, was present in 21% of THA candidates preoperatively but decreased to 6% postoperatively, matching the 0% rate in healthy controls [22]. The normalization of spinopelvic characteristics after THA is thought to occur because improved hip flexion reduces the need for compensatory pelvic and lumbar motion, allowing patients to move similarly to their healthy peers.

One of the most notable findings of the present study was the significant increase in acetabular index and sacro-acetabular angle in both standing and sitting positions. These changes likely reflect restoration of hip biomechanics and altered functional orientation of the acetabulum after implantation of the prosthetic components. Previous studies have demonstrated that pelvic orientation directly influences functional acetabular anteversion and inclination and that even small alterations in pelvic tilt may substantially affect cup orientation [1, 25, 26]. Therefore, the observed increases in acetabular-related parameters may have important implications for postoperative stability and impingement risk.

The combined sagittal index (CSI), defined as acetabular inclination (AI) + pelvic femoral angle (PFA), increases dramatically in standing (by nearly 22°) and represents the overall sagittal tension or alignment of the hip construct. The static spinopelvic parameters that are directly associated with increased risk of dislocation are lumbo-pelvic mismatch (pelvic incidence – lumbar lordosis angle >10°), high pelvic tilt (>19°), and low sacral slope when standing. A high combined sagittal index (CSI) when standing (>245°) is associated with increased risk of anterior instability, whilst a low CSI when standing (<205°) is associated with increased risk of posterior instability. Even when the cup is placed within Lewinnek's traditional "safe zone" in the supine position, dynamic changes in pelvic tilt and AI can bring the functional cup position outside a safe range in standing or sitting, potentially leading to dislocation [11]. Consequently, CSI has emerged as an important predictor of instability after total hip arthroplasty (THA). A postoperative increase in CSI may reflect improved sagittal functional alignment following restoration of hip anatomy and mobility; however, excessively high or low CSI values are associated with instability. Therefore, functional spinopelvic assessment is essential for accurate risk stratification, and individualized component positioning based on patient-specific spinopelvic characteristics is required.[18]

Clinically, our findings reinforce the importance of comprehensive spinopelvic assessment before THA and challenge the adequacy of traditional planning approaches. Current standard practice often relies on supine CT scans or standing radiographs alone to position the acetabular component. However, our results

show substantial changes in acetabular-related parameters (SAA, AI, CSI) between standing and sitting, and these changes are already evident at two months postoperatively. This underscores a critical limitation: supine imaging—which is the standard for most preoperative CT-based planning—fails to capture the functional acetabular orientation that patients will experience during daily activities such as sitting, rising from a chair, or bending [11, 26, 27]. From a clinical perspective, our findings reinforce the importance of comprehensive spinopelvic assessment before THA. Traditional cup-positioning concepts based solely on static safe zones may not adequately account for patient-specific functional alignment. Recent studies show that dislocation can occur even when acetabular components are positioned within the classical Lewinnek safe zone because pelvic orientation changes substantially between standing and sitting positions [26, 27]. Therefore, evaluation of spinopelvic mobility should be incorporated into preoperative planning, particularly in patients with spinal pathology, previous lumbar fusion, or abnormal sagittal balance.

Several limitations should be acknowledged. First, the study was retrospective and included a relatively limited sample size from a single registry. Second, we analyzed patients with different underlying diagnoses together, which may have introduced heterogeneity in spinopelvic behavior. Third, the follow-up duration was limited, so we could not evaluate long-term adaptations in spinopelvic alignment. Fourth, we did not assess low back pain or patient-reported outcomes, so we cannot correlate the radiographic changes with clinical symptoms.

Conclusion

This registry-based THA analysis found that while static spinal parameters (LL, SS, PI) remain largely unchanged postoperatively, pelvic tilt (PT), sacro-acetabular angle (SAA), acetabular index (AI), and combined sagittal index (CSI) show substantial adaptive changes. The dramatic increases in SAA and AI in both sitting and standing positions, along with a modest but significant increase in standing PT, indicate that THA fundamentally alters the sagittal relationship between the sacrum and acetabulum even when the lumbar curve and sacral slope remain stable. In conclusion, THA is associated with significant postoperative changes in acetabular-related sagittal parameters (SAA, AI, CSI) rather than global spinopelvic morphology. These findings reinforce the importance of functional, posture-specific spinopelvic assessment in preoperative planning. Incorporating spinopelvic analysis into routine THA planning enables personalized component positioning, reduces instability risk, and ultimately improves patient outcomes. The presence of minor trauma history appears to influence postoperative acetabular adaptation, particularly in the sitting position. These early postoperative adaptations suggest that THA induces rapid acetabular reorientation, though the long-term trajectory of these changes remains to be determined.

Acknowledgments

The authors would like to thank the Clinical Research Development Unit of Baqiyatallah Hospital for all their support and guidance during the carrying out of this study.

We acknowledge the Deputy of Research and Technology of Baqiyatallah University of Medical Sciences for their support of the disease/Data registry “Total Hip Arthroplasty Registry” (Ethical Code: [IR.BMSU.REC.1404.191]), from which the data for this study were extracted

Conflict of Interest Disclosures

The authors declare that they have no conflicts of interest related to this study.

Funding Sources

No external funding was received for this study.

Authors’ Contributions

All authors contributed to the conception and design of the study. Clinical data collection and analysis were performed by the authors. All authors participated in drafting and revising the manuscript and approved the final version for publication.

Ethical Statement

Written informed consent was obtained from the patient

and/or their legal guardian for publication of this case report and any accompanying images. All procedures were performed in accordance with the ethical standards of the institutional and/or national research committee and the Declaration of Helsinki.

Declaration of Generative AI and AI-assisted Technologies

The authors declare that no generative AI or AI-assisted technologies were used in the preparation, writing, or editing of this manuscript.

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