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Research Article

The Impact of Spinopelvic Parameters on the Femoroacetabular Anteversion Angle

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Abstract

Background: We aimed to investigate the relationship between spinopelvic parameters, spinal deformities, and femoral and acetabular anteversion in patients who were candidates for total hip arthroplasty (THA).
Methods: The femoral and acetabular anteversion angles were measured using computed tomography (CT) scans. Additionally, spinopelvic parameters were assessed with the appropriate graphs. We utilized SPSS software to analyze the relationship between different types of spinopelvic deformities, spinopelvic parameters, and femoroacetabular anteversion angles.
Results: A one-way analysis of variance (ANOVA) showed a significant effect of deformity type on femoral and acetabular version ($P < 0.001$). Post hoc analysis using Tukey's honestly significant difference test (HSD) revealed that patients with stuck sitting deformity had significantly higher femoral and acetabular anteversion compared to others ($P < 0.001$). The anterior pelvic plane (APP) significantly predicted both femoral and acetabular anteversion in the regression model.
Conclusion: Our observations indicate that spinopelvic deformities significantly impact femoral and acetabular anteversion, with the "stuck sitting" group exhibiting the highest values.

Keywords: Total Hip Arthroplasty; Lumbosacral Region; Bone Anteversion; Bone Retroversion

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Background

Femoral anteversion, also referred to as femoral torsion or femoral version, is the angle created by two lines perpendicular to the shaft of the femur (1). This angle changes throughout development, starting at 0 degrees in the fetal period, increasing to about 30 degrees at birth, and typically stabilizing around 15 degrees in adulthood, with a normal variation between 5 and 20 degrees (1). Variations in femoral anteversion can influence the position of the greater trochanter and the functionality of the muscles around the hip (2). An increased anteversion angle may lead to shortened hip extension muscles and lengthened abductor muscles involved in hip flexion (3, 4). Notably, during internal rotation of the hip joint, about 96.5% of the length of pelvic muscles increases (4). There is a prominent link between femoral anteversion and various orthopedic issues, such as osteoarthritis (3, 5-8). An increased femoral anteversion angle can put more stress on the hip joint and alter its interaction with the acetabulum, potentially increasing the risk of developing osteoarthritis, a prevalent and debilitating condition (9). Total hip arthroplasty (THA) is a common and effective procedure for hip joint disorders, but one of the main complications that can arise post-surgery is prosthesis dislocation (10-12). Spinopelvic pathologies are significant contributors to this complication (13). Despite orthopedic surgeons' efforts to define safe zones for prosthesis placement and employing advanced technologies, the dislocation rates remain high among those with spinopelvic movement disorders due to spinal issues (13, 14).

Emerging evidence suggests that spinopelvic mobility disorders, whether due to lumbosacral pathology or surgical fusion, may contribute to prosthesis instability following THA. However, the specific impacts of these disorders on femoral anteversion and the acetabulum are not fully understood. It is essential for orthopedic surgeons to consider these relationships during joint replacement surgeries since femoral anteversion often guides femoral stem placement. Misalignment of prostheses can lead to instability and reduced lifespan of the implants.

Given the importance of this topic and the insufficient research available both in Iran and globally, further studies are warranted to explore the relationships between spinopelvic parameters, spinal deformities, and femoral and acetabular anteversion in patients preparing for THA.

Methods

Study Design: This study has been approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, Taleghani Hospital, Iran, and conducted in accordance with the latest version of the Declaration of Helsinki. This was a retrospective cross-sectional analytical study whose subjects were retrospectively identified from one major orthopedic referral center following Institutional Review Board approval.

Patients and Radiological Evaluation: A total of 234 patients over 18 years of age who were candidates for primary THA were enrolled in this study between April 2023 and September 2024. The following criteria were established for exclusion from the study: patients who had undergone emergency hip surgeries, bilateral THA, severe hip dysplasia, and femoral osteotomy, those requiring THA for revision, individuals with a history of ankylosing spondylitis or spinal fusion surgery, patients with a history of cancer and bone metastasis, those with neurological diseases that affect body positioning, and patients whose femoral head was not visible on radiographs, making it impossible to measure pelvic incidence (PI). After excluding 30 patients with spinal fusion, 20 with cancer and bone metastasis and neurological diseases, 12 with bilateral hip arthroplasty, 8 with recent vertebral fractures, and 6 due to the absence of visible femoral heads on radiographs, 160 patients were included in the analysis after signing an informed consent form.

Before surgery, standing lateral radiographs of the pelvis and lumbar spine were obtained from all patients according to the standard hip arthroplasty planning protocol. Additionally, lateral sitting radiographs of the pelvis and lumbar spine were needed for further evaluation in this study.

The following parameters were measured from the lateral radiographs: lumbar lordosis angle (LLA; the angle formed by the proximal L1 vertebral body and the distal L5 vertebral body), pelvic angle (PA); the angle formed by a line perpendicular to the S1 endplate and another line from the midpoint of S1 to the center of the femoral head), sacral slope (SS; the angle formed by the S1 endplate and a horizontal line), and anterior pelvic plane [APP; the plane formed by the anterior-superior iliac spines (ASIS) and the symphysis pubis]. All these measurements were performed in the radiology department of the study center by a radiologist using specialized software (RadiAnt DICOM Viewer).

According to Heckmann and Lieberman (13), the PI-lumbar lordosis (LL) mismatch (PI minus LL) and APP were used to assess sagittal alignment, while ΔSS (standing SS minus sitting SS) was used to evaluate spinal and pelvic motion. Based on these parameters, different spinal and pelvic patterns were classified as follows (Table 1):

- Type 1A (normal sagittal alignment, normal motion): PI-LL < 10°, APP < 13°, ΔSS > 10°

- Type 1B (normal sagittal alignment, reduced spinal and pelvic motion/stuck standing): PI-LL < 10°, APP < 13°, ΔSS < 10°

- Type 2A (loss of LL, normal motion/flat back): PI-LL > 10°, APP > 13°, ΔSS > 10°

- Type 2B (loss of LL, reduced spine-pelvic motion/stuck sitting): PI-LL > 10°, APP > 13°, ΔSS < 10°.

Table 1. Different spinal and pelvic patterns classifications

Spinal patterns		Pelvic parameters		
		PI-LL	APP	ΔSS
Type 1	Type 1A (normal)	< 10°	< 13°	> 10°
	Type 1B (stuck standing)	< 10°	< 13°	< 10°
Type 2	Type 2A (flat back)	> 10°	> 13°	> 10°
	Type 2B (stuck sitting)	> 10°	> 13°	< 10°

PI: Pelvic inclination; LL: Lumbar lordosis; APP: Anterior pelvic plane; SS: Sacral slope

This classification helps in understanding different spinal and pelvic patterns among the patients studied.

In the axial view of a pelvic computed tomography (CT) scan in supine position, the femoral anteversion angle was defined as the angle formed between two imaginary lines: one running through the proximal femoral neck and the other passing through the condylar region located distal to the femur, known as the posterior condylar axis. Acetabular anteversion was also measured using the axial CT scan of the pelvis in supine position. The angle between the line passing through the anterior and posterior margins of the acetabulum and the line passing through the posterior margin of the pelvis at the level of the sciatic notch was considered the angle of acetabular anteversion.

Femoral and acetabular anteversion angles were measured using CT/radiographs according to standardized protocols. All measurements were independently performed by two experienced observers, and the mean values were used for analysis. Although inter-rater reliability and intra-observer error were not formally assessed in this study, previous studies using the same measurement techniques have demonstrated good reproducibility.

Statistical Analysis: All statistical analyses were performed using SPSS software (version 24, IBM Corporation, Armonk, NY, USA). Descriptive statistics were used to summarize the data. The normality of distribution was assessed using visual inspection and the Kolmogorov-Smirnov test. To compare differences between groups, one-way analysis of variance (ANOVA) was used. To identify predictors of femoral version, multiple linear regression analysis was conducted. Variables with P-values < 0.1 in univariate analysis were entered into the regression model. Statistical significance was set at P < 0.05.

Results

A total of 160 patients were included in the study, with a mean age of 66.56 ± 11.84 years. Men comprised 56.9% of the study population.

A one-way ANOVA was conducted to compare femoral anteversion among patients with different types of spinal deformities. There was a significant effect of deformity type on femoral version [F(3, 156) = 166.66, P < 0.001]. Post hoc analysis using Tukey's honestly significant difference test (HSD) revealed that patients with stuck sitting deformity had significantly higher femoral anteversion compared to those with stuck standing and flat back (P < 0.001) (Table 2).

Table 2. Results of analysis of variance (ANOVA) for the relationship between spinopelvic deformities and femoral anteversion

Source of variation	SS	df	MS	F	P-value
Between groups	2041.450	3	680.483	166.669	< 0.001
Within groups	636.925	156	4.083		
Total	2678.375	159			

SS: Sum of squares; df: Degree of freedom; MS: Mean square

Patients in the "normal" group had the lowest anteversion [mean difference vs. stuck sitting: -6.16°, 95% confidence interval (CI): -7.34 to -4.97, P < 0.001 vs. stuck standing: -8.96°, 95% CI: -10.38 to -7.53, P < 0.001 vs. flat back: -6.77°, 95% CI: -7.89 to -5.65, P < 0.001]. The "stuck sitting" group exhibited the highest anteversion values, with a significant difference compared to "stuck standing" (mean difference: -2.802°, 95% CI: -4.48 to -1.12, P < 0.001). Differences between other groups are summarized in table 3.

Table 3. Post hoc comparisons of femoral anteversion between groups

Compared group		Mean difference	SE	P-value	95% CI	
					Lower bound	Upper bound
Stuck sitting	Stuck standing	-2.802	0.646	< 0.001	-4.480	-1.120
	Flat back	-0.610	0.550	0.676	-2.050	0.812
	Normal	6.160	0.450	< 0.001	4.970	7.340
Stuck standing	Stuck sitting	2.802	0.640	< 0.001	1.120	4.480
	Flat back	2.183	0.620	0.004	0.540	3.810
	Normal	8.960	0.540	< 0.001	7.530	10.380
Flat back	Stuck sitting	0.610	0.550	0.676	-0.810	2.050
	Stuck standing	-2.183	0.620	0.004	-3.810	-0.540
	Normal	6.770	0.430	< 0.001	5.650	7.890
Normal	Stuck sitting	-6.160	0.450	< 0.001	-7.340	-4.970
	Stuck standing	-8.960	0.540	< 0.001	-10.380	-7.530
	Flat back	-6.770	0.430	< 0.001	-7.890	-5.650

SE: Standard error; CI: Confidence interval

Table 4. Multiple linear regression results predicting femoral version

Predictors	Unstandardized coefficients		Standardized coefficients	t	P-value	Collinearity statistics	
	B	SE	Beta			Tolerance	VIF
Constant	6.727	6.701		1.004	0.317		
LLA	-0.008	0.099	-0.023	-0.077	0.939	0.035	28.842
PI	-0.103	0.097	-0.272	-1.060	0.291	0.048	20.736
PI-LL	-0.621	0.408	-0.414	-1.524	0.130	0.043	23.122
SS-sitting	-0.920	1.245	-0.483	-0.739	0.461	0.007	134.251
SS-standing	1.168	1.238	0.533	0.943	0.347	0.010	100.191
Total SS	-1.582	1.236	-0.898	-1.280	0.203	0.006	154.599
APP	1.142	0.390	0.756	2.927	0.004	0.048	20.962

SE: Standard error; LLA: Lumbar lordosis angle; PI: Pelvic inclination; LL: Lumbar lordosis; APP: Anterior pelvic plane; SS: Sacral slope; VIF: Variance inflation factor

A multiple linear regression was conducted to examine whether spinopelvic parameters could predict femoral anteversion. The predictors included APP, SS-standing, SS-sitting, PI, PI-LL, LLA, and total SS. The overall regression model was statistically significant [$F(7, 152) = 23.14$, $P < 0.001$], explaining 51.6% of the variance in femoral version ($R^2 = 0.516$, adjusted $R^2 = 0.494$). As shown in table 4, among the predictors, APP ($\beta = 0.756$, $P = 0.004$) significantly contributed to the model. Other variables were not statistically significant predictors ($P > 0.05$).

ANOVA indicated a statistically significant difference in acetabular version across the three spinal deformity groups [$F(3, 156) = 150.599$, $P < 0.001$].

Subsequent Tukey post hoc comparisons showed that individuals with stuck sitting deformity exhibited a significantly higher acetabular anteversion compared to those with stuck standing and flat back ($P < 0.001$) (Table 5).

Table 5. Results of analysis of variance (ANOVA) for the relationship between spinopelvic deformities and acetabular anteversion

Source of variation	SS	df	MS	F	P-value
Between groups	2001.356	3	667.119	150.599	< 0.001
Within groups	691.044	156	4.430		
Total	2692.400	159			

SS: Sum of squares; df: Degree of freedom; MS: Mean square

The "normal" group demonstrated the lowest acetabular anteversion values, showing a mean difference of -6.20° (95% CI: -7.44 to -4.96, $P < 0.001$) compared with the "stuck sitting" group, and -9.01° (95% CI: -10.50 to -7.53, $P < 0.001$) compared with the "stuck standing" group. In contrast, the "stuck sitting" group exhibited the highest anteversion, which was significantly greater than that of the "stuck standing" group (mean difference: -2.81°, 95% CI: -4.56 to -1.06, $P < 0.001$) (Table 6).

To assess whether spinopelvic parameters predict acetabular version, a multiple linear regression analysis was performed, incorporating APP, SS-standing, SS-sitting, PI, PI-LL, LLA, and total SS as independent variables. The regression model was found to be statistically significant [$F(7, 152) = 22.62$, $P < 0.001$], accounting for approximately 51% of the variability in acetabular version ($R^2 = 0.510$, adjusted $R^2 = 0.488$). Among the predictors, APP ($\beta = 0.839$, $P = 0.002$) emerged as a significant contributor to the model. The remaining variables did not reach statistical significance ($P > 0.05$), suggesting limited individual predictive value for acetabular version (Table 7).

Discussion

The findings of this study indicate that spinopelvic deformities have a significant impact on both femoral and acetabular anteversion angles. Notably, patients categorized in the "stuck standing" group showed higher anteversion angles compared to those with other types of deformities. This may be indicative of altered pelvic dynamics and specific compensatory mechanisms within this subgroup. Furthermore, the APP was identified as a significant predictive factor for both femoral and acetabular anteversion, highlighting its utility in preoperative assessments and surgical planning for THA. These anatomical variations in femoral anteversion are not merely descriptive findings but carry direct implications for surgical decision-making, as they may complicate component positioning and stability in THA.

The findings of this study align with and expand upon significant literature that emphasizes the impact of spinopelvic alignment on femoroacetabular angel, particularly about THA.

Phan et al. were among the pioneering researchers to demonstrate that sagittal spinal deformities can substantially influence acetabular anteversion (15). They cautioned that overlooking spinal alignment during THA planning could lead to component malposition (15). Their research underscored the necessity for individualized component alignment based on spinopelvic parameters, a concept that is supported by the present study's findings, which indicate that the type of spinopelvic deformity significantly affects both femoral and acetabular version angles.

Furthermore, Esposito et al. highlighted that patients with rigid spinal alignment —particularly those with a history of lumbar spinal fusion —faced a heightened risk of dislocation following THA due to the loss of compensatory pelvic tilt (16, 17). These individuals often demonstrate altered functional orientation of the acetabulum, a phenomenon evident in our observation that the "stuck sitting" group exhibited significantly higher anteversion angles compared to other deformity types. This implies that diminished spinopelvic mobility may result in a more anteverted functional position of the acetabulum, necessitating consideration in preoperative planning.

Table 6. Pairwise comparisons of acetabular anteversion using post hoc test

Compared group		Mean difference	SE	P-value	95% CI	
					Lower bound	Upper bound
Stuck sitting	Stuck standing	-2.810	0.673	< 0.001	-4.560	-1.060
	Flat back	-0.310	0.570	0.949	-1.802	1.180
	Normal	6.200	0.470	< 0.001	4.960	7.430
Stuck standing	Stuck sitting	2.810	0.670	< 0.001	1.060	4.560
	Flat back	2.502	0.650	0.001	0.800	4.204
	Normal	9.010	0.570	< 0.001	7.520	10.490
Flat back	Stuck sitting	0.310	0.570	0.949	-1.180	1.802
	Stuck standing	-2.502	0.650	0.001	-4.204	-0.800
	Normal	6.510	0.440	< 0.001	5.340	7.670
Normal	Stuck sitting	-6.200	0.470	< 0.001	-7.430	-4.960
	Stuck standing	-9.010	0.570	< 0.001	-10.490	-7.520
	Flat back	-6.510	0.440	< 0.001	-7.670	-5.340

CI: Confidence interval; SE: Standard error

Table 7. Multiple linear regression results predicting acetabular version

Predictors	Unstandardized coefficients		Standardized coefficients	t	P-value	Collinearity statistics	
	B	SE	Beta			Tolerance	VIF
Constant	12.466	6.757		1.845	0.067		
LLA	0.019	0.100	0.059	0.193	0.847	0.035	28.842
PI	-0.136	0.098	-0.357	-1.381	0.169	0.048	20.736
PI-LL	-0.755	0.411	-0.501	-1.837	0.068	0.043	23.122
SS-sitting	-0.985	1.255	-0.516	-0.784	0.434	0.007	134.251
SS-standing	1.228	1.248	0.559	0.984	0.327	0.010	100.191
Total SS	-1.645	1.246	-0.932	-1.320	0.189	0.006	154.599
APP	1.270	0.393	0.839	3.227	0.002	0.048	20.962

SE: Standard error; LLA: Lumbar lordosis angle; PI: Pelvic inclination; LL: Lumbar lordosis; APP: Anterior pelvic plane; SS: Sacral slope; VIF: Variance inflation factor

Haffer et al. (18) and Stefl et al. (19) further support the notion that categorizing patients based on their spinopelvic mobility –specifically distinguishing between "hip users" and "spine users" –can facilitate the tailoring of surgical strategies. Our identification of the APP as a significant predictor of both femoral and acetabular anteversion corresponds with their emphasis on the role of sagittal pelvic parameters in determining implant orientation. In particular, APP, as a static measure of pelvic tilt, may serve as a surrogate marker for more complex dynamic assessments, offering valuable insights even within standard radiographic evaluations.

Innmann et al. also emphasized the compensatory patterns observed in patients with limited spinal mobility, noting that such patients increasingly rely on hip joint motion, thereby elevating the mechanical demands on the joint and its components (20).

This biomechanical adaptation may, in part, elucidate the increased anteversion angles observed in the "stuck sitting" group within our cohort.

Lazennec et al. conducted detailed imaging studies that illustrated how the acetabular version varied with posture, thereby reinforcing the argument that static anatomical landmarks alone are insufficient (21). This highlights the importance of evaluating spinopelvic behavior in various functional positions, particularly in patients with fixed deformities or stiffness (21).

Finally, the investigations conducted by An et al. (22) and Eneqvist et al. (23) provide clinical context for these biomechanical insights, demonstrating that spinal pathology or prior lumbar surgery not only alters hip mechanics but also adversely affects clinical outcomes and increases the likelihood of revision surgery after THA. These findings underscore the necessity for a multidisciplinary approach to surgical planning that incorporates both spinal and hip pathologies as interrelated components.

While previous research has often concentrated on isolated assessments of acetabular or femoral anteversion angles, our study brings to light the combined influence of spinopelvic alignment on both components.

Despite the strengths of this study, several limitations should be acknowledged. First, the retrospective design inherently carries the risk of selection bias, as patient allocation to deformity categories was based on available clinical and radiographic data rather than prospective stratification. Second, our analysis relied on static imaging modalities, which limited the ability to capture dynamic spinopelvic motion across different functional positions. The lack of dynamic radiographic assessment may have led to an underestimation of compensatory mechanisms that occur during postural transitions. Future prospective studies incorporating functional imaging and larger, more diverse patient cohorts would provide more robust insights and help validate these findings.

From a clinical perspective, these findings highlight the importance of incorporating spinopelvic assessment into preoperative planning for THA. Identifying patients with limited spinopelvic mobility, such as those in the "stuck sitting" or "stuck standing" categories, can help anticipate higher femoral and acetabular anteversion angles and guide individualized implant positioning. The recognition of the APP as a significant predictor further suggests that even standard radiographs may offer valuable parameters for surgical planning. Surgeons should consider adjusting cup orientation or femoral component version in patients with rigid or altered spinopelvic mechanics to reduce the risk of malposition, instability, or dislocation.

These findings may also inform prosthesis design by emphasizing the need for components that can accommodate variations in femoral and acetabular anteversion associated with different spinopelvic alignments.

Conclusion

Spinopelvic deformities significantly impact femoral and acetabular anteversion, with the "stuck sitting" group exhibiting the highest values. APP emerged as a key predictor for both angles, highlighting its clinical importance in preoperative planning for THA. These findings underscore the necessity of incorporating spinopelvic assessments into surgical decision-making to optimize outcomes and minimize complications. Future prospective or biomechanical studies are warranted to validate these results and further refine individualized surgical strategies.

Conflict of Interest

The authors declare no conflict of interest in this study.

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