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The Effect of Pelvic Retroversion on Sagittal Balance and Clinical Outcomes

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ABSTRACT

Objective: Spinal disc degeneration and muscle atrophy with aging lead to reduced lumbar lordosis and sagittal imbalance. The body compensates by pelvic retroversion, which maintains posture but may increase disability despite preserved mobility. This study examined the relationship between pelvic retroversion and pain, disability, and quality of life in patients with low back pain.

Materials and Methods: A cross-sectional analysis was conducted on 122 patients presenting with low back pain. Patients with prior spinal surgery, advanced hip pathology, or major coronal deformities were excluded. Pain and disability were assessed using the Visual Analog Scale (VAS), Oswestry disability index (ODI), and Roland-Morris questionnaires. Standing full-length lateral radiographs were obtained to measure spinopelvic parameters. Pelvic retroversion was categorized according to the global alignment and proportion scoring system. Regression and correlation analyses were used to evaluate associations between radiological and clinical outcomes.

Results: The mean patient age was 43.5 years, and 47.6% exhibited pelvic retroversion. VAS scores did not differ significantly between retroversion groups. However, disability indices showed significant variation: Patients with severe retroversion demonstrated higher ODI scores, while those with mild retroversion had higher Roland-Morris scores compared with the balanced pelvis group. Multiple regression revealed that a balanced pelvis was associated with a 9-point lower ODI score. Negative correlations were observed between pelvic retroversion and both ODI (r_S=−0.31) and Roland-Morris scores (r_S=−0.28).

Conclusion: Pelvic retroversion, though a compensatory mechanism for sagittal imbalance, is more strongly associated with disability and quality of life than with pain severity. The results highlight the importance of evaluating pelvic tilt in low back pain patients, even in the absence of structural deformity. Routine radiographic assessment of pelvic parameters may identify individuals at risk for functional decline and guide timely preventive strategies.

Keywords: Pelvic retroversion, Quality of life, Sagital balance

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INTRODUCTION

With aging of the spine, multilevel disc degeneration, atrophy of the supporting erector muscles, and weakening of the ligamentous structures lead to a decrease in lumbar lordosis (LL).[1-4] Loss of LL disrupts sagittal balance, adversely affecting the patient's ability to stand upright, maintain gait stability, and preserve a forward gaze.[5]

Since the early 2000s, spinopelvic parameters have played a central role in the analysis of sagittal balance. While Roussouly classified lordosis and sacral orientation into types in the normal population, Schwab highlighted pelvic incidence (PI)-LL mismatch, pelvic tilt (PT), and sagittal vertical axis (SVA) as surgical targets with the adult deformity classification.[6-8] Le Huec formulated tilt and lordosis values based on PI, and Yilgör introduced the global alignment and proportion (GAP) score, providing a new perspective for patient-specific planning.[9,10] These findings demonstrate that pelvic measurements are not only morphological but are also closely related to functional outcomes in clinical practice.

Various compensatory mechanisms are developed by the body against sagittal imbalance.[9,11,12] The earliest and most effective of these is pelvic retroversion through an increase in pelvic tilt.[13,14] However, prolonged pelvic retroversion causes continuous contraction of the hip extensor muscles, leading to spasms and pain in the hip and hamstring muscles. In addition, it disrupts the three-dimensional joint configuration between the acetabulum and femoral head, accelerating the development of gonarthrosis.[15]

Pelvic retroversion is the primary compensatory mechanism that comes into play early in maintaining sagittal balance. However, its persistence may negatively affect hip biomechanics and may herald future spine–hip-related deformities.[16] Therefore, in pathologies that reduce lordosis, such as lumbar disc disease and spondylolisthesis, measurement of pelvic incidence, sacral slope, and pelvic tilt on standing plain radiographs is of clinical importance. The aim of this study was to investigate the relationship between the degree of pelvic retroversion and pain and quality-of-life scores in patients presenting with low back pain but without rigid sagittal imbalance.

MATERIALS AND METHODS

This study was approved by the Ankara Etlik City Hospital Institutional Review Board Committee (Date: 27.08.2025, Decision no: AEŞH-BADEK1-2025388). It was designed in accordance with the Declaration of Helsinki, and informed consent was obtained from all included patients.

Inclusion Criteria

- Presentation to the neurosurgery clinic with low back pain
- Age ≥18 years
- Ability to stand independently
- Mental status sufficient to complete standard questionnaires
- Clinical indication for obtaining standing scoliosis radiographs.

Exclusion Criteria

- Previous lumbar/hip/pelvic surgery
- Advanced hip pathology
- Lower extremity deformity: Knee flexion contracture >10°, leg length discrepancy >2 cm
- Neuromuscular diseases (e.g., Parkinson's disease, myopathy) and inflammatory spondyloarthritis/ankylosing spondylitis
- Presence of acute fracture, tumor, infection, or pregnancy
- Significant coronal deformity (e.g., Cobb ≥20°) or high-grade spondylolisthesis (e.g., Meyerding ≥II)
- Insufficient image quality on radiographic acquisition
- Epidural injection/major analgesic change within the past 4 weeks.

Demographic data, such as age and sex, as well as body mass index (BMI), were recorded. The visual analog scale (VAS) was used to assess the severity of back and leg pain. To evaluate the impact of low back pain on quality of life and disability, the Oswestry disability index (ODI) and the Roland-Morris disability questionnaire were administered.

Standing full-length lateral lumbar radiographs were evaluated using the hospital's picture archiving and communication system (PACS). Pelvic incidence was defined as the angle between the line drawn from the centers of the femoral heads to the midpoint of the S1 endplate and the line perpendicular to the S1 endplate. Sacral slope was defined as the angle between the S1 endplate and the horizontal plane; pelvic tilt as the angle between the line drawn from the centers of the femoral heads to the midpoint of the S1 endplate and the vertical plane. LL was calculated as the Cobb angle between the upper endplate of L1 and the upper endplate of S1. The SVA was recorded as the horizontal distance between a plumb line dropped from the midpoint of the C7 body and the posterosuperior corner of S1 (Fig. 1). All measurements were performed using the digital angle and distance tools available in the PACS system. In addition, to avoid measurement error in cases with very high or very low pelvic incidence, the degree of pelvic retroversion was calculated according to the GAP scoring system using the formula "sacral slope – (pelvic incidence × 0.59+9). According to this formula, values below

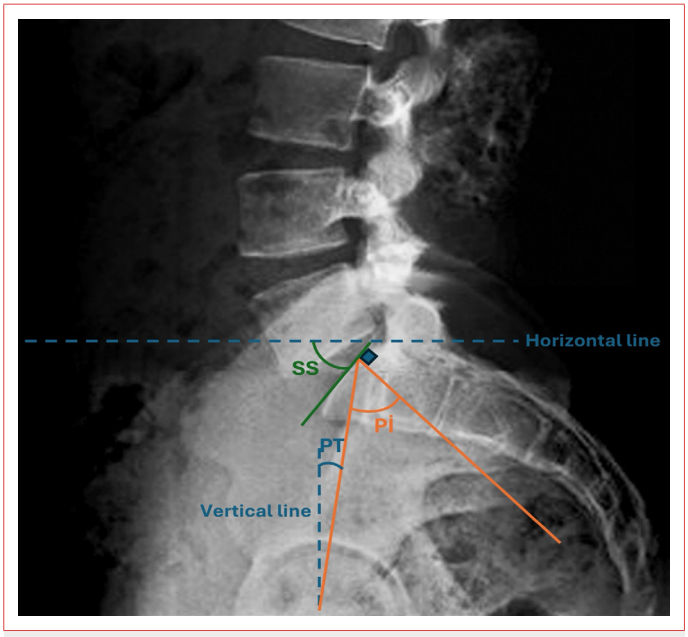

Figure 1. Radiological sssesment.
PI: Pelvic incidence, SS: Sacral slope, PT: Pelvic tilt

–15 were considered severe pelvic retroversion; between –15 and –7 moderate pelvic retroversion; between –7 and 5 balanced pelvis; and above 5 pelvic anteversion.[10]

Statistical Analysis

For four-group comparisons, the Kruskal–Wallis test was used due to non-normal distribution, and the Spearman correlation test was employed to evaluate relationships between two variables. To determine which independent variables (age, sex, occupation, BMI, and radiological parameters, etc.) affected the dependent variables (VAS, ODI, and Roland-Morris scores), univariate analyses were followed by multivariate logistic regression. For multivariate analyses, multiple linear regression was used, and overall model fit was assessed with the F test. The explanatory power of the model was expressed by the R^2 coefficient. Multicollinearity among variables was tested using the variance ınflation factor (VIF) values. Statistical analyses were performed using R Statistics. A $p<0.05$ was considered the threshold for statistical significance. Findings with p-values between 0.05 and 0.1 were interpreted as "marginal effects," assuming potential clinical relevance.

RESULTS

The mean age of the 122 patients included in the study was 43.5±14.5 years (min: 18 and max: 82). The mean height was 167.3±9.39 cm, weight 78.2±13.3 kg, and BMI 28.04±5.0 kg/m^2. Regarding spinal parameters, the mean LL angle was 56.6±13.3°, L4–S1 lordosis angle 35.3±9.8°, and SVA –VAs±38.5 mm. The mean GAP score was 3.2±2.8. Clinical measures were as follows: VAS score 6.99±2.15, ODI score 39.6±21.6, and Roland-Morris score 9.89±6.97 (Table 1).

Table 1. Descriptive analysis of continuous variables

Variable (*n*=122)	Mean	SD	Median	Min	Max	Range
Age	43.459016	14.549515	42.500	18.00	82.00	64.00
Height of the patient	167.286885	9.390059	166.500	150.00	188.00	38.00
Weight of the patient	78.180328	13.315011	78.500	48.00	120.00	72.00
BMI of the patient	28.038033	4.998066	28.000	19.13	45.70	26.57
Pelvic incidence	53.463934	13.138393	52.500	20.00	89.00	69.00
Sacral slope	33.101639	10.012554	33.000	7.00	55.70	48.70
Pelvic tilt	20.362295	11.506910	19.750	–4.00	53.00	57.00
Relative pelvic retroversion	–7.442082	8.801600	–6.385	–32.48	11.89	44.37
Lumbar lordosis angle	56.596721	13.259364	55.000	24.00	89.00	65.00
L4-S1 lordosis angle	35.336066	9.767005	35.000	12.00	60.00	48.00
Sagittal vertical axis (mm)	–7.470492	38.462676	–12.000	–83.00	178.00	261.00
Global tilt	14.449180	11.433858	11.000	–5.00	62.00	67.00
GAP score	3.204918	2.810660	3.000	0.00	13.00	13.00
VAS score	6.991803	2.145516	7.000	2.00	10.00	8.00
ODI score	39.639344	21.626455	38.000	0.00	96.00	96.00
Roland Morris	9.885246	6.970062	9.000	0.00	24.00	24.00

BMI: Body mass index, SD: Standard deviation, mm: Millimeter, GAP: Global alignment and proportion, VAS: Visual Analog Scale, ODI: Oswestry disability index.

Of the participants, 63.9% were female and 36.1% male. Regarding working conditions, 46.7% reported moderate, 26.2% severe, and 9.0% very severe working conditions. Radicular pain was present in 63.1%, while 32.8% had chronic comorbidities. With respect to pelvic parameters, mild retroversion was observed in 31.2% and severe retroversion in 16.4%. A balanced pelvis was found in 45.9% of participants, whereas anteversion was present in only 5.7% (Table 2).

Regression Analysis Models

Univariate analyses showed that several variables significantly affected VAS scores. Increasing height was associated with lower VAS scores (r=–rores $p<0.01$), indicating that taller individuals reported less pain. Among categorical variables, individuals with radicular pain reported significantly higher VAS scores (mean 7.30 vs. 6.47, $p=0.04$). Similarly, those with chronic comorbidities also reported higher VAS scores (7.75 vs. 6.62, $p<0.01$).

Table 2. Descriptive analysis of categorical variables

Variable	*n*	%
Gender		
Female	78	63.93
Male	44	36.07
The level of working condition		
Very severe	11	9.02
Severe	32	26.23
Moderate	57	46.72
Mild	14	11.48
Very mild	8	6.56
Existence of radicular pain		
No	45	36.89
Yes	77	63.11
Chronic comorbid disease		
No	82	67.21
Yes	40	32.79
Severe retroversion of pelvis		
No	102	83.61
Yes	20	16.39
Mild retroversion of pelvis		
No	84	68.85
Yes	38	31.15
Balanced pelvis		
No	66	54.10
Yes	56	45.90
Anteversion of pelvis		
No	115	94.26
Yes	7	5.74

In the multiple regression model predicting VAS scores, height and chronic comorbidities contributed at a marginal significance level. Each 1 cm increase in height decreased VAS by an average of 0.042 points (B=–Bintse $p=0.1$). The presence of chronic comorbidities increased VAS by an average of 0.76 points (B=0.762, p=0.1). Other variables showed no significant effect. The overall explanatory power of the model was 14% ($R^2=0.14$) and was statistically significant (F[4.117]=4.61, p=0.002). No multicollinearity was observed (VIF<2) (Table 3).

Several variables were significantly associated with ODI scores in univariate analyses. Age (r=0.33, p<0.001), BMI (r=0.27, p<0.01), and SVA (r=0.32, p<0.001) were positively correlated, whereas height (r=–right p<0.01) and L4–S1 lordosis angle (r =–rgles $p<0.001$) were negatively correlated. These findings indicate that age and spinal balance are closely related to disability levels. Among categorical variables, female sex, presence of radicular pain, presence of chronic comorbidities, and unbalanced pelvis were all associated with significantly higher ODI scores (all $p<0.05$).

In the multiple regression model for ODI, only the presence of a balanced pelvis had a significant effect. Individuals with a balanced pelvis had ODI scores that were on average 9.07 points lower (B=–Bwerse p<0.01). L4–S1 lordosis angle (negative) and radicular pain (positive) showed marginal associations (p=0.1). The overall explanatory power of the model was 28% ($R^2=0.28$), and the model was statistically significant (F[12,109]=3.55, $p=0.000$). No multicollinearity was found (Table 4).

Variables affecting Roland-Morris scores included age (r=0.26, p<0.01), SVA (r=0.28, p<0.01), and global tilt (r=0.19, p=0.04), all positively correlated, whereas height (r=–right p=0.01) and lumbar/L4–S1 lordosis angles were negatively correlated. This indicates that older individuals with postural imbalance experienced greater functional limitations. Among categorical variables, radicular pain, chronic comorbidities, mild pelvic retroversion, and unbalanced pelvis significantly increased Roland-Morris scores ($p<0.05$).

In the multiple regression model predicting Roland-Morris scores, no variable reached statistical significance, although some showed marginal effects. Each 1 mm increase in SVA increased functional impairment by 0.029 points ($p=0.1$). Radicular pain increased scores by an average of 1.99 points, and mild pelvic retroversion increased scores by an average of 2.78 points (both $p=0.1$). The explanatory power of the model was 21% ($R^2=0.21$), and the model was overall significant (F[10,111]=2.95, p=0.003). No multicollinearity was observed (Table 5).

Table 3. Full multivariate model - VAS_score

Predictor	B	SE	Beta (Standard)	*t*	*p*	VIF
(Intercept)	13.748	3.671		3.745	0.0***	
Height_of_patient	−0.042	0.021	−0.185	−1.972	0.1	1.19
Existance_of_radicular_pain Yes	0.493	0.410	0.111	1.201	0.2	
Chronic_comorbid_disease yes	0.762	0.408	0.167	1.870	0.1	
Balanced_pelvis yes	−0.551	0.381	−0.128	−1.444	0.2	

VAS: Visual analog scale, SE: Standard error, VIF: Variance ınflation factor. Model summary: R^2=0.14, Adj. R^2=0.11, F(4, 117)=4.61, p=0.002

Table 4. Full multivariate model – ODI score

Predictor	B	SE	Beta (Standard)	*t*	*p*	VIF
(Intercept)	75.633	55.331		1.367	0.2	
Age	0.193	0.174	0.130	1.109	0.3	2.074
Height_of_patient	−0.215	0.285	−0.093	−0.752	0.5	2.325
BMI_of_patient	0.248	0.430	0.057	0.576	0.6	1.499
Lumbar_lordosis_angle	0.042	0.191	0.026	0.219	0.8	2.074
L4_S1_lordosis_angle	−0.460	0.262	−0.208	−1.758	**0.1**	2.118
Sagittal_vertical_axscis	0.087	0.058	0.154	1.498	**0.1**	1.606
Global_tilt	0.028	0.223	0.015	0.124	0.9	2.111
GAP_score	−0.809	0.947	−0.105	−0.854	0.4	2.293
Gender male	−0.440	5.225	−0.010	−0.084	0.9	
Existance_of_radicular_pain yes	7.766	4.016	0.174	1.934	**0.1**	
Chronic_comorbid_disease yes	2.271	4.496	0.050	0.505	0.6	
Balanced_Pelvis yes	−9.070	4.435	−0.210	−2.045	**0.0***	

ODI: Oswestry disability index, SE: Standard error, VIF: Variance inflation factor, BMI: Body mass index, GAP: Global alignment. Model summary: R^2=0.28, Adj. R^2=0.20, F(12, 109)=3.55, p=0.000.

Table 5. Full multivariate model - roland_morris_score

Predictor	B	SE	Beta (Standard)	*t*	*p*	VIF
(Intercept)	21.154	13.712		1.543	0.1	
Age	0.042	0.055	0.087	0.764	0.4	1.821
Height_of_patient	−0.067	0.072	−0.090	−0.929	0.4	1.330
Lumbar_lordosis_angle	−0.054	0.062	−0.103	−0.873	0.4	1.952
L4_S1_lordosis_angle	−0.006	0.086	−0.009	−0.074	0.9	2.021
Sagittal_vertical_axscis	0.029	0.019	0.160	1.522	0.1	1.556
Global_tilt	−0.027	0.069	−0.045	−0.394	0.7	1.801
Existance_of_radicular_pain Yes	1.994	1.324	0.139	1.507	0.1	
Chronic_comorbid_disease Yes	0.898	1.499	0.061	0.599	0.6	
Mild_retroversion_of_pelvis Yes	2.785	1.668	0.186	1.670	0.1	
Balanced_pelvis Yes	−0.849	1.604	−0.061	−0.529	0.6	

SE: Standard error, VIF: Variance inflation factor. Model summary: R^2=0.21, Adj. R^2=0.14, F(10, 111)=2.95, p=0.003.

Table 6. Comparison between groups according to relative pelvic tilt

	Severe retroversion	Mild retroversion	Balanced pelvis	Anteroversion pelvis	*p*
VAS score	7.15±2.43	7.45±2.04	6.59±2.12	6.86±1.68	*p*=0.3397[1]
ODI score	46.60±22.22	45.11±22.76	34.18±20.03	31.71±16.14	***p*=0.002**[1]
Rolland Morris score	9.25±6.87	12.82±7.33	8.11±5.97	8.29±7.70	***p*=0.043**[1]

VAS: Visual Analog Scale, ODI: Oswestry disabilty index. [1]Krukal–Wallis test. *Post hoc* Dunn test for ODI: The differences were between severe retroversion and balanced pelvis (*p*=0.0051) and between severe retroversion and anteversion (*p*=0.0078). *Post hoc* Dunn test for Roland-Morris: Difference was between the mild retroversion and the balanced pelvis group (*p*=0.0006).

Comparison of Pelvic Retroversion Groups

Comparison of ODI scores across pelvic retroversion groups showed significant differences (p=0.0020). *Post hoc* Dunn's test indicated that the differences were between severe retroversion and balanced pelvis (*p*=0.0051) and between severe retroversion and anteversion (*p*=0.0078) (Table 6). Comparison of Roland-Morris scores across groups also showed significant differences (*p*=0.043). *Post hoc* Dunn's test revealed that this difference was between mild retroversion and the balanced pelvis group (*p*=0.0006) (Table 6).

No significant differences were found in VAS scores across pelvic retroversion groups (Table 6). Spearman correlation analysis revealed no significant correlation between pelvic retroversion and BMI or VAS (*p*=0.44, p=0.08). However, pelvic retroversion was negatively correlated with ODI (rs=–sshel *p*=0.00054) and Roland-Morris scores (rs=–ssres p=0.0013).

DISCUSSION

Pelvic retroversion is one of the earliest compensatory mechanisms against sagittal imbalance and is defined as posterior rotation of the pelvis through an increase in pelvic tilt.[17-19] With the decrease in LL, the individual retroverts the pelvis to maintain upright posture and forward gaze, thereby rebalancing the SVA.[9] Although this adaptation stabilizes posture in the short term, continuous activation of the hip extensor muscles in the long term may cause muscle fatigue, hamstring spasms, and alterations in joint biomechanics.[20] As a result, even in the absence of rigid deformity, patients may experience disability and reduced functional capacity.[21]

In this study, the clinical implications of pelvic retroversion were investigated in patients with low back pain but without rigid sagittal deformity. The findings showed that pelvic retroversion was not directly associated with pain severity (VAS) (*p*=0.08), but significantly affected quality of life and functional capacity. Patients with severe retroversion had significantly higher ODI scores compared with those with a balanced pelvis (*p*=0.0051) and anteversion (*p*=0.0078) (*p*=0.0020 overall). Similarly, a significant difference in Roland-Morris scores was observed between the mild retroversion and balanced pelvis groups (*p*=0.0006; overall p=0.043). Multivariate regression analysis showed that having a balanced pelvis reduced ODI scores by 9 points (B=–Bintsd p<0.01). In addition, correlation analyses revealed significant negative associations between the degree of pelvic retroversion and both ODI (rs=–sshov *p*=0.00054) and Roland-Morris scores (rs=–ssres p=0.0013). These results support the hypothesis that pelvic retroversion is an early compensatory mechanism for sagittal imbalance and has serious negative effects on disability and quality of life rather than on pain itself.

With the widespread use of magnetic resonance imaging (MRI), patients presenting with spinal complaints, such as low back pain often undergo lumbar MRI.[22-24] However, as MRI scans are performed in the supine position, parameters, such as pelvic tilt and LL may be misinterpreted.[25,26] For example, a patient with hypolordotic lumbar spine in the standing position may appear to have normal lordosis on supine MRI.[27] Therefore, standing lumbar radiographs – which are more accessible and cost-effective than MRI – remain critically important in evaluating patients with low back pain, though they have been neglected by many spine surgeons in recent years. With the development of MRI technology, upright MRI scans will likely be increasingly used to assess spinopelvic parameters; however, this technique is still available only in a limited number of centers worldwide.[28,29]

In patients with high PT, acetabular tilt, anteversion, and external coverage increase, whereas anterior acetabular coverage angles decrease significantly, as demonstrated by Assi *et al*.[30] These changes disrupt load distribution on the acetabular cup, concentrating greater force on a smaller surface area, thereby predisposing to gonarthrosis and impingement. Hirata *et al*.[31] showed that preoperative posterior pelvic tilt in patients undergoing hip surgery negatively affected postoperative gait speed and quality-of-life measures. In a review by Morimoto on hip–spine syndrome, spinopelvic parameters, such as pelvic incidence and pelvic tilt, were shown to influence load distribution on the acetabular cup.[32]

Kellis reported that hip extensor muscles were stronger in patients with anterior pelvic tilt compared with those with posterior tilt.[33] This may suggest that in sagittal imbalance, pelvic compensation is linked to hamstring fatigue and overuse.

In Assi's study, an increase in PT negatively affected ODI scores but had no significant effect on short form 36 (SF-36) physical component summary or SF-36 mental component summary scores.[30] In the 222-patient series by Yilgor *et al*.,[21] relative pelvic version (RPV) – also used in our study – showed a stronger correlation with deterioration in ODI, core outcome measures index, SF-36, and scoliosis research society-22 scores compared with PT. They emphasized that PT is reliable only in patients with pelvic incidence close to the normal range, whereas RPV, as an individualized measure, is more dependable. Yiming Fan reported that degenerative spine patients with pelvic tilt >18.4° were 3.1 times more likely to require surgical intervention than those with pelvic tilt <18.4°, highlighting PT as a determinant in surgical decision-making.[34] Won-Deuk Kim, in a controlled study of office workers with low back pain, found that those with pelvic tilt imbalance had poorer muscle endurance, reduced hip mobility, and worse quality-of-life indices.[35]

Limitations

As computed tomography scans were not performed, 3D reconstructions could not be obtained, and measurements were made using two-dimensional radiographs. The observer dependency of radiological measurements makes standardization difficult. The absence of long-term follow-up limited the ability to monitor dynamic changes, leaving the study cross-sectional. Moreover, only static measurements were available, and dynamic spinopelvic parameters during gait could not be assessed.

Strengths

The main strength of this study is its focus on the clinical implications of pelvic retroversion before the development of rigid deformity, addressing a patient group relatively underexplored in the literature. Another strength is the use of validated questionnaires (VAS, ODI, Roland-Morris) to link pelvic retroversion not only to morphological changes but also to functional outcomes. The relatively large sample size (n=122) for a single-center study further increases the statistical power of the results.

CONCLUSION

This study demonstrated that in patients with low back pain without rigid deformity, pelvic retroversion is associated more with functional capacity and quality of life than with pain. The finding that severe retroversion led to deterioration in ODI and Roland-Morris scores suggests that pelvic retroversion may represent not only an important early compensatory mechanism of sagittal balance but also a precursor of progressive deformity. Therefore, in the evaluation of patients presenting with low back pain, routine consideration of pelvic tilt and RPV measurements is of great clinical importance.

DECLARATIONS

Ethics Committee Approval: This study was approved by the Ankara Etlik City Hospital Institutional Review Board Committee (Date: 27.08.2025, Decision no: AEŞH-BADEK1-2025388).

Informed Consent: Informed consent was obtained from all included patients.

Conflict of Interest: None declared.

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