The Effect of Pelvic Position on Pelvic Incidence

Abstract

Introduction: Given the importance of the stability of the pelvic incidence (PI) angle in evaluating spinal alignment and its significance in spinal fixation during surgical procedures, this study aims to investigate the PI angle and compare it in two positions: Full Flexion and Full Extension.

Materials & Methods: This cross-sectional study assessed 44 student volunteers using dynamic radiographic evaluation in two positions: Full Flexion and Full Extension. Dynamic radiographs were taken in two conditions: (1) seated with maximum forward bending (Full Flexion) and (2) lying supine with legs hanging off the edge of the bed to their maximum extent (Full Extension). The PI angle was measured using the PACS software.

Results & Discussion: The mean PI angles in the Full Flexion and Full Extension positions were not equal, demonstrating positional changes. The mean PI angle in Full Flexion was higher than in Full Extension. The mean difference in PI angle between the two positions was 3.6±3.9 degrees. In females, the mean PI angle in Full Flexion was 55.83±11.23 degrees, which was higher than in males (53.22±7.62 degrees), though this difference was not statistically significant (P = 0.390). In Full Extension, the mean PI angle in females was 51.61±9.87 degrees, which was again higher than in males (49.65±7.05 degrees), but the difference was not statistically significant (P = 0.608).

Conclusion: The study results indicate that pelvic positioning affects pelvic incidence, and PI measurements are not constant across different positions. Furthermore, PI in the Full Flexion position was greater than in the Full Extension position.

Keywords: Pelvis, Spine, Patient positioning.

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Introduction

From a biomechanical perspective, the spine is considered a single functional unit, and when assessing spinal pathologies, careful attention to spinal biomechanics is of great importance[(1)]. Degenerative diseases, particularly at advanced ages, induce significant alterations in the lumbar spine and pelvis, which often necessitate correction of these deformities over the patient's lifetime[(2,3)]. The lumbosacral spine and pelvis play a crucial role in maintaining sagittal balance of the body[(4)]. Evidence has shown that sagittal and coronal balance, and their interrelationship with other segments of the spine and pelvis, are critical; any disruption in lumbosacral sagittal balance can result in pain and functional disability[(5)]. Comprehensive knowledge of sagittal alignment is essential for achieving optimal clinical outcomes and minimizing complications in surgical correction of lumbosacral deformities such as degenerative disease, scoliosis, and spondylolisthesis[(6-8)].

The relationship between the sacrum and pelvis is defined by pelvic incidence (PI), which describes the spatial orientation and positioning of the sacrum. PI is measured as the angle between the perpendicular to the sacral plate passing through its midpoint and the line connecting this midpoint to the femoral head axis. Sacral slope (SS) is the angle between the sacral plate and the horizontal axis, while pelvic tilt (PT) is the angle between the vertical axis and the line drawn from the midpoint of the sacral plate to the femoral head axis[(9)].

The sagittal morphology of the pelvis has a substantial impact on upright posture, especially through its influence on lumbar lordosis.

Certain studies have reported that PI increases with age during the pre-pubertal period in individuals without spinal deformity, but remains relatively stable in the post-pubertal years[10]. Other investigations have indicated that the normal PI range in individuals may vary between 45° and 65°, yet in any given person, it remains constant across different postures[11].

Considering the clinical significance of the constancy of PI for spinal alignment assessment, and the importance of accurate angular measurements for proper fixation in spinal surgeries, this study was designed to evaluate PI and compare its values in the specified positions. The choice of surgical instrumentation and the ability to restore sagittal balance depend directly on the PI angle, thereby influencing surgical outcomes[12].

Materials & Methods

Students enrolled at Babol university of medical Sciences during the period from August 2020 to November 2021 volunteered to participate in this study. To evaluate their vertebrae, dynamic radiographs (dynamic views) were obtained. For each participant included in the study, radiographs were performed in two positions: (1) sitting and bending forward to the maximal voluntary extent (Full Flexion), and (2) lying supine with legs extended off the bed to the maximal voluntary extent (Full Extension). PI was then measured using PACS software. Inclusion criteria included age ≥ 20 years, no history of back pain, no history of trauma to the lumbar spine. Moreover, exclusion criteria involved congenital spinal deformities or disorders, vertebral anomalies, history of spinal surgery, clinical evidence of vertebral fracture, and pregnancy.

Sample size was calculated using G*Power software, yielding 41 participants. Collected data were entered into Microsoft Excel for preparation and statistical analysis. For descriptive statistics, measures of central tendency (mean, median, mode) and measures of dispersion (variance, standard deviation, range, coefficient of variation) were applied for quantitative variables, while frequency, percentage, and prevalence were used for qualitative variables. Graphical representation (bar and pie charts) was also performed. For inferential statistics, study hypotheses were examined using parametric tests (chi-square) and non-parametric tests (Mann–Whitney), as well as Spearman correlation analysis following normality testing of data. All statistical analyses were conducted using SPSS software version 25, with a significance level set at $p < 0.05$.

Results

In this cross-sectional study, 44 students volunteered and underwent dynamic radiographs in two positions: Full Flexion and Full Extension. PI was measured in both positions. The mean age of participants was 23.25 ± 1.31 years, with a median of 23.50 years, a minimum age of 21 years, and a maximum of 25 years. Among the 44 students who participated in the study, 18 (40.9%) were male and 26 (59.1%) were female (Figure 1).

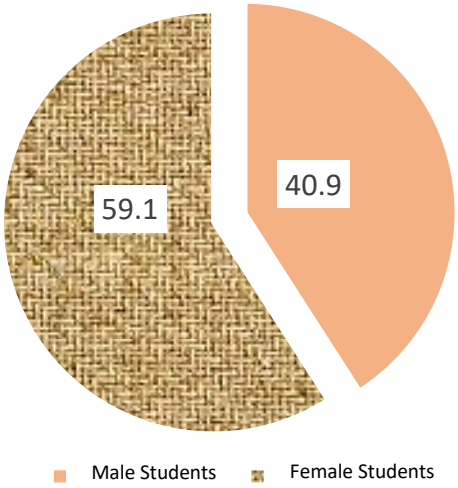

Figure 1: Distribution percentage of participants frequency based on gender

As shown in Table 1, the mean PI angle in the Full Flexion and Full Extension positions was not equal, and the angle demonstrated variation between the two positions. Specifically, the mean PI angle in Full Flexion was greater than that in Full Extension. The mean difference in PI angle between the two positions was calculated as 3.9 ± 3.6 degrees. This difference represents the change in PI angle between Full Flexion and Full Extension.

Mann–Whitney test

The mean PI angle in Full Flexion among females was 55.83 ± 11.23°, which was higher than that of males at 53.22 ± 7.62°, although the difference was not statistically significant (P = 0.390). Similarly, in Full Extension, the mean PI angle in females was 51.87 ± 9.87°, higher than that of males at 49.65 ± 7.05°, yet again, no statistically significant difference was observed (P = 0.608) (Table 2).

Spearman's correlation coefficient

The PI angle in Full Flexion showed a negative correlation with age, though it was not statistically significant (r = –0.044, P = 0.775). A negative correlation indicates that as age increases, the PI angle in Full Flexion tends to decrease. Similarly, the PI angle in Full Extension demonstrated a negative correlation with age, but again without statistical significance (r = –0.102, P = 0.511). This suggests that increasing age is associated with a decreasing PI angle in Full Extension. By contrast, a significant positive correlation was observed between PI angle in Full Flexion and PI angle in Full Extension (r = 0.915, P < 0.001). This positive correlation indicates that an increase in PI angle in one position is accompanied by an increase in PI angle in the other position (Table 3).

Discussion

Recent research has increasingly focused on parameters that govern spinal and pelvic alignment, collectively referred to as spinopelvic sagittal balance. These parameters include pelvic incidence (PI), sacral slope (SS), and pelvic tilt (PT). Normal static sagittal balance is defined as the physiological alignment of the spine in its most efficient posture. During gait, sagittal balance is constantly maintained through compensatory mechanisms of the lower limbs[13].

Previous studies have consistently reported that PI remains a constant value for each individual, whereas other parameters such as SS and PT vary according to posture[14–18]. However, the present study demonstrated that PI values in each individual were not identical between Full Flexion and Full Extension positions. This finding has the potential to influence approaches in the assessment of sagittal parameters and the planning of spinal surgeries. Knowledge of PI variations across these positions may alter the extent and type of correction required during surgery.

Table 1: Measurements of Pelvic Incidence Angle in the Two Positions of Full Flexion and Full Extension

Pelvic Incidence Angle	Mean	Standard Deviation	Median	Minimum	Maximum
Full Flexion Position	54.76	9.90	52.25	38.7	85.7
Full Extension Position	50.81	8.79	48.20	36.5	77.2

Table 2: Measurements of Pelvic Incidence Angle in Full Flexion and Full Extension Positions by Sex

Pelvic Incidence Angle	Males (Mean ± SD)	Females (Mean ± SD)	P value*	Pelvic Incidence Angle	Males (Mean ± SD)
Full Flexion	53.22 ± 7.62	55.83 ± 11.23	0.390	Full Flexion	53.22 ± 7.62
Full Extension	49.65 ± 7.05	51.87 ± 9.87	0.608	Full Extension	49.65 ± 7.05

Table 3: Correlation Between PI Angle in Full Flexion and Full Extension Positions with Age and with Each Other

Variables	Age	PI in Full Flexion	PI in Full Extension
Age	r = 1	–	–
PI in Full Flexion	r = –0.044, P = 0.775	r = 1	–
PI in Full Extension	r = –0.102, P = 0.511	r = 0.915, P < 0.001	r = 1

It should be noted that this investigation is the first study of its kind conducted within the country; therefore, comparison with domestic research is not possible. Nonetheless, a study by Place and colleagues in 2017 examined the constancy of PI and reported that PI changed in 88% of participants when shifting from a resting position to maximal anterior pelvic rotation, and in 80% of participants when shifting from a resting position to maximal posterior pelvic rotation[17].

The variability of PI may partly be attributed to measurement error, since PI is assessed through radiographic imaging. However, such error cannot consistently account for repeated changes in the same individual, and it is possible that only a portion of PI variation is due to calculation inaccuracies. Ultimately, the observation that PI is not fixed across different positions represents an important finding that cannot be overlooked. Given that PI reflects the relationship between the sacrum and the iliac wings, or the sacroiliac joint, and that this joint is recognized as a mobile articulation, this mobility may explain, at least in part, the positional variability observed in PI.

The lack of consistency in PI across the studied positions under Full conditions can also be extended to explain certain complications encountered in spinal surgeries. In the past, surgical interventions for spinal deformities were performed under the assumption that PI is a fixed value in every individual regardless of posture. This assumption, however, occasionally led to complications such as transitional syndromes and junctional syndromes[13]. The present study, by challenging this long-held belief, may contribute to significant advances in spinal surgery, improving surgical efficiency and reducing postoperative complications.

Our findings also showed that PI in both Full Flexion and Full Extension positions was higher in women compared to men. Although this difference was not statistically significant, the lack of significance may be attributable to the relatively small sample size. With a larger sample, the difference in PI angle between men and women may reach statistical significance. In a study by Zhu and colleagues, sagittal parameters of the cervical spine were compared between men and women, and significant differences were reported in C2–C7 Cobb angle and C7 slope[18]. Although the variables examined in their study differ from those in the present investigation, the underlying hypothesis generated here may serve as a foundation for future studies.

Conclusion

The results of this study demonstrated that pelvic position has a measurable impact on pelvic incidence (PI), and that PI values are not identical across different positions. Moreover, PI was found to be greater in the Full Flexion position compared to the Full Extension position.

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References

1 Mac-Thiong JM, Labelle H, Roussouly P. Pediatric sagittal alignment. European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society. 2011;20 (Suppl 5):586. https://doi.org/10.1007/s00586-011-1925-0

2 Grotle M, Småstuen MC, Fjeld O, Grøvle L, Helgeland J, Storheim K, et al. Lumbar spine surgery across 15 years: trends, complications and reoperations in a longitudinal observational study from Norway. BMJ open. 2019;9(8):e028743. doi:10.1136/bmjopen-2018-028743

3 Schwab F, Dubey A, Gamez L, El Fegoun AB, Hwang K, Pagala M, et al. Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. Spine. 2005;30(9):1082-1085. DOI: 10.1097/01.brs.0000160842.43482.cd

4 Jacob CJ, Cardoso IM, Batista JL, Maia TC, Roncaglio B. Spinopelvic parameters evaluation in a Brazilian population sample. European journal of orthopaedic surgery & traumatology: orthopedie traumatologie. 2015;25 (Suppl 1): 21-24. https://doi.org/10.1007/s00590-015-1647-9

5 Yukawa Y, Kato F, Suda K, Yamagata M, Ueta T, Yoshida M. Normative data for parameters of sagittal spinal alignment in healthy subjects: an analysis of gender specific differences and changes with aging in 626 asymptomatic individuals. Eur Spine J. 2018;27:426–432. https://doi.org/10.1007/s00586-016-4807-7

6 Chung NS, Jeon CH, Lee HD, Won SH. Measurement of Spinopelvic Parameters on Standing Lateral Lumbar Radiographs: Validity and Reliability. Clinical spine surgery. 2017;30(2): 119-123. DOI: 10.1097/BSD.0000000000000448

7 Henneman S, Antoneli P, de Oliveira G. Pelvic incidence: A fundamental parameter for defining the sagittal balance of the spine. Coluna/Columna. 2012;11(3):237-239. DOI: 10.1590/S1808-18512012000300011

8 Li WS, Li G, Chen ZQ, Wood KB. Sagittal plane analysis of the spine and pelvis in adult idiopathic scoliosis. Chinese medical journal. 2010;123(21):2978-2982. DOI: 10.3760

9 Golbakhsh MR, Siavashi B, Attar M, Ramim T. Correlation between Lumbar vertebral instability and severe degenerative spondylolisthesis Tehran University Medical Journal. 2013;71(1):46-52. ISSN:1683-1764
10 Ameri E, Ghandhari H, Vahid Tari H, Noori A, Hesarikia H, Nabizadeh N. Change in Sagittal Spine and Spinopelvic Parameters in Children during Growth. Iranian Journal of Surgery. 2013;21(3):44-52.
11 Kim D, Davis DD, Menger RP. Spine sagittal balance. 2023. PMID: 30521279
12 Legaye J, Duval-Beaupère G, Hecquet J, Marty C. Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. E Spine J. 1998;7(2):99-103. https://doi.org/10.1007/s005860050038.
13 Barrey C, Jund J, Noseda O, Roussouly P. Sagittal balance of the pelvis-spine complex and lumbar degenerative diseases. A comparative study about 85 cases. Eur Spine J.2007;16(9):1459-1467. https://doi.org/10.1007/s00586-006-0294-6.
14 Le Huec JC, Aunoble S, Philippe L, Nicolas P. Pelvic parameters: origin and significance. Eur Spine J. 2011;20 (Suppl 5):564-571. https://doi.org/10.1007/s00586-011-1940-1
15 Le Huec J, Thompson W, Mohsinaly Y, Barrey C, Faundez A. Sagittal balance of the spine. European spine journal. 2019;28(9):1889-1905. https://doi.org/10.1007/s00586-019-06083-1
16 Boulay C, Tardieu C, Hecquet J, Benaim C, Mitulescu A, Marty C, et al. Anatomical reliability of two fundamental radiological and clinical pelvic parameters: incidence and thickness. European Journal of Orthopaedic Surgery & Traumatology. 2005;15(3):197-204. https://doi.org/10.1007/s00590-005-0239-5
17 Place HM, Hayes AM, Huebner SB, Hayden AM, Israel H, Brechbuhler JL. Pelvic incidence: a fixed value or can you change it? The Spine Journal. 2017;17(10):1565-1569. https://doi.org/10.1016/j.spinee.2017.06.037
18 Zhu Y, Zhang X, Fan Y, Zhou Z, Gu G, Wang C, et al. Sagittal alignment of the cervical spine: radiographic analysis of 111 asymptomatic adolescents, a retrospective observational study. BMC Musculoskeletal Disorders. 2022;23(1):1-9. https://doi.org/10.1186/s12891-022-05792-x