

Correlation of Spinopelvic Parameters in Lumbar Prolapsed Disc in Armed Police Personnel

Umash Karki¹, Sunder Chapagain¹, Netra Karki¹, Prabin Nepal¹, Sailendra Duwal Shrestha¹, Suman Lamichhane²

¹Department of Orthopaedics and Trauma, Nepal Armed Police Force Hospital, Balambu, Kathmandu, Nepal

²Department of Radiology, Nepal Armed Police Force Hospital, Balambu, Kathmandu, Nepal

Article Info:

Received Date: Dec, 2024

Acceptance Date: Jan, 2025

Corresponding Author :

Umash Karki

Assistant Professor and Consultant
Orthopedic Spine Surgeon,
Department of Orthopaedics and
Trauma,
Nepal Armed Police Force Hospital,
Balambu, Kathmandu, Nepal
Email: dr_umash@hotmail.com

Funding sources: None

Conflict of interest: None

Access the article online



DOI: doi.org/10.70027/jrahs24

Abstract

Introduction: A prolapsed intervertebral disc is a common problem in armed police personnel due to their demanding job nature. Spinopelvic parameters affect the stability of the spine and play a role in the load sharing of the intervertebral disc, contributing to the disc degeneration. Spinopelvic parameters measured in standing radiographs may provide a hint to disc degeneration. This study was conducted to assess the correlation of spinopelvic parameters in lumbar prolapsed intervertebral discs.

Methods: An observational, retrospective study was conducted at Nepal Armed Police Force Hospital based on the hospital records of patients over a period from January 01, 2020, to October 10, 2023. The spinopelvic parameters were measured on lateral lumbar X-rays of the armed police personnel and were collected from the picture archiving and communication system (PACS). The correlation between the spinopelvic parameters pelvic incidence (PI), sacral slope (SS), lumbar lordosis (LL), and pelvic tilt (PT) and prolapsed intervertebral disc (PIVD) was done.

Results: A total of 73 patients (55 M/18 F) with the most common site for PIVD being L4-L5 (50%), and L5-S1 (28%). The measured mean spinopelvic parameters were LL (30.43°±5.77°), PT (15.67°±8.04°), PI (48.99°±9.52°), and SS (30.02°±9.5°). Statistically significant weak correlations were found between LL and PIVD at the L4-L5 level as well as between PI and PIVD at the L4-L5 level.

Conclusion: There exists a negative correlation between the lumbar lordosis and pelvic incidence with PIVD at the most common site, L4-L5. So, patients with lower lumbar lordosis and pelvic incidence have a high chance of PIVD.

Keywords: armed police, pelvic incidence, PIVD, prolapsed intervertebral disc, spinopelvic parameters

Introduction

Prolapsed intervertebral discs (PIVD) represent a significant global health concern, particularly prevalent among individuals engaged in physically demanding occupations. Armed police personnel are especially vulnerable to lumbar PIVD due to the rigorous demands of their job, which makes it one of the leading causes of prolonged absences from duty.^{1,2} The physical requirements of their roles contribute to the increased mechanical

stress on the spine, predisposing this population to disc degeneration and injury.^{3,4}

Recent studies have underscored the critical role of spinopelvic parameters in influencing spinal stability and contributing to disc degeneration.^{5,6} The key spinopelvic parameters are pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and lumbar lordosis (LL), and these maintain the intricate balance of the spine and are considered crucial factors in the pathogenesis of disc-

Citation:

Karki U, Chapagain S, Karki N, Nepal P, Shrestha SD, Lamichhane S. Correlation of spinopelvic parameters in lumbar prolapsed disc in armed police personnel. *J. Rapti A. Health Sci.* 2024;1(2):31-35.

Copyright:

© Authors retain copyright and grant the journal right of first publication with the work simultaneously licensed under Creative Commons Attribution License CC - BY 4.0

related disorders.^{7,8}

While pelvic incidence is a fixed anatomical value unique to everyone, other spinopelvic parameters fluctuate depending on the position of the hip and spine, and the changes influence the biomechanical environment of the lumbar spine.^{5,7,9} Diagnosis of lumbar PIVD is done through MRI while spinopelvic parameters are assessed through standing lateral radiographs.

Although several studies have been conducted to explore the relationship between spinopelvic parameters and lumbar PIVD,^{6-8,10} there is a notable lack of research specifically focusing on armed police personnel. This population may exhibit distinct patterns in spinopelvic alignment and disc pathology compared to the general population. Consequently, this study aims to assess the correlation between these spinopelvic parameters and the incidence of PIVD within this population.

Methods

The study was conducted following ethical guidelines adhering to the principles in the Declaration of Helsinki. This study protocol was approved by the Nepal Health Research Council (Id: 655/2023; Ref: 1325). All the collected data were anonymized to ensure confidentiality.

This research was conducted, from October, 2023 to December, 2024, as an observational, cross-sectional, analytical, retrospective, single-center (hospital-based) study in the Nepal Armed Police Force (APF) hospital to investigate the correlation between spinopelvic parameters and the incidence of PIVD in the armed police personnel.

The study population consisted of armed police personnel with proven PIVD on MRI who visited our hospital from January 01, 2020, to October 10, 2023. This number came to 102, which was then subjected to the inclusion criteria. Inclusion criteria were APF staff aged 18-45 years with a confirmed diagnosis of lumbar PIVD through magnetic resonance imaging (MRI). Exclusion criteria included spinal tumours, inflammation, neuromuscular disorder, isthmus or deformities, trauma or diseases affecting lower limbs hampering their ability to stand; pregnant females; and patients with congenital anomaly of the spine. The sample size was then reduced to 73 after applying these criteria.

The sample size was determined based on the prevalence of lumbar PIVD in the population and the need to achieve sufficient statistical power for detecting significant correlations.

$$\text{Sample size } (n) = Z^2 \times p(1 - p) / d^2$$

Where:

n = required sample size

Z = Z-value (the number of standard deviations from the mean, corresponding to the desired confidence level, typically $Z = 1.96$ for 95% confidence)

p = Expected proportion in population based on previous

studies or pilot studies. This was found to be 5%.^{11,12}

d = Absolute error or precision. It was taken as 5%.

Using the above formula, the sample size was calculated to be 74.

Prior institutional approval was obtained before collecting the data from the hospital records, lateral radiographs, and MRI from the Picture Archiving and Communication System (PACS). MRI scans confirmed the presence and the level of PIVD. The standing lateral radiographs of the lumbosacral spine, including the femoral head of patients, were taken. All the spinopelvic parameters were measured by the radiologist from radiographs using the Surgimap Software version 2.3.

Results

Out of a total 73 patients in the study, 75% ($n=55$) were male, whereas 25% ($n=18$) were female. The mean age was 34.44 ± 5.77 years. We found the maximum number of patients within the age group 38-42 years, followed by the age group 33-37 years.

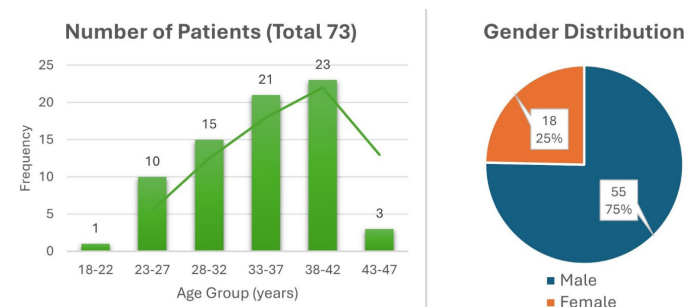


Figure 1: Age and gender distribution

The most common site for PIVD was seen to be at the L4-L5 level (50%), followed by the L5-S1 level (28%). The least common site was found to be at the L1-L2 level at 0.8%. A similar pattern was found in the male patients; however, the most common sites involved in females were both L4-L5 and L5-S, equally at 39%.

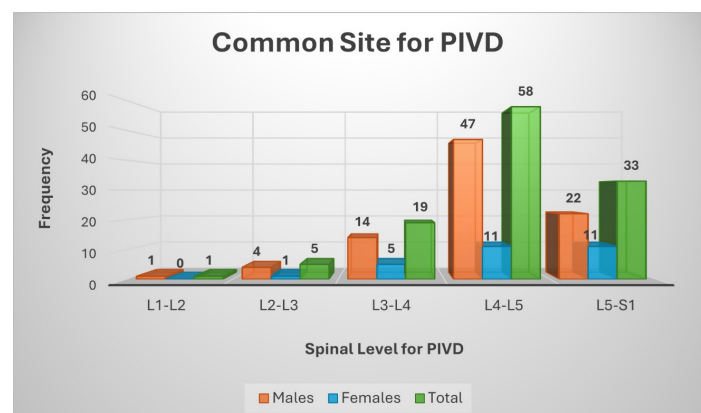


Figure 2: Common sites for PIVD

Most of the patients (59%) had their single disc involved, whereas 41% of patients had their multiple disc levels involved. (figure 2)

The mean LL was 30.43°±5.77°. The mean PT was 15.67°±8.04°, with a median value of 16.3° (2.6°-34.5°). The mean PI was 48.99°±9.52°, with the median 47.6° (29.2°-

84°). Likewise, the mean SS was found to be 30.02°±9.5°, whereas the median value of SS was 30.2° (5.5°-54.3°) (Table 1).

Table 1: Values of lumbar lordosis (LL), pelvic tilt (PT), pelvic incidence (PI) and sacral slope (SS)

| Parameters | Minimum | Maximum | Mean | SD | Median |
|------------------|---------|---------|-------|-------|--------|
| Age | 18 | 45 | 34.33 | 5.77 | 35.0 |
| Lumbar Lordosis | 0 | 62.6 | 30.43 | 15.12 | 27.5 |
| Pelvic Tilt | 2.6 | 34.5 | 15.67 | 8.04 | 16.3 |
| Pelvic Incidence | 29.2 | 84.0 | 48.99 | 9.52 | 47.6 |
| Sacral Slope | 5.5 | 54.0 | 30.02 | 9.50 | 30.2 |

The sum of the average of PT and SS (15.67 + 30.02) came to be 45.69°, which is near to the average value of PI. Thus, the known correlation of PI=PT+SS was found to be somewhat true in our study.

The overall correlation is visualized using the heatmap (Figure 3), where the warmer colors (closer to red) indicate positive correlations, while the cooler colors (closer to blue) indicate negative correlations. For LL and PT, the correlation coefficient (R) was found to be -0.113, indicating a very weak negative relation between PT and LL. So, an increase in LL would slightly decrease the PT, and vice versa, which can be visualized in the scatter plots as well (Figure 4). However, it was not statistically significant (p = 0.3). For LL and PI, the correlation was statistically significant (p < 0.001) with the coefficient (R) at 0.625, indicating a strongly positive relation between PI and LL. So, an increase in PI would increase the LL, and vice versa. For LL and SS, the correlation was statistically significant (p < 0.001) with the coefficient (R) at 0.676, indicating a strongly positive relation between SS and LL. So, an increase in SS would increase the LL, and vice versa. For PT and PI, the correlation was statistically significant (p = 0.013) with the coefficient (R) at 0.288, indicating a weakly positive relation between PT and PI. So, an increase in PT would slightly increase the PI, and vice versa. For PT and SS, the correlation was statistically significant (p < 0.001) with the coefficient (R) at -0.368, indicating a weakly negative relation between PT and SS. So, an increase in PT would slightly decrease the SS, and vice versa. For PI and SS, the correlation was statistically significant (p < 0.001) with the coefficient (R) at 0.629, indicating a strongly positive relation between PI and SS. So, an increase in PI would increase the SS, and vice versa.

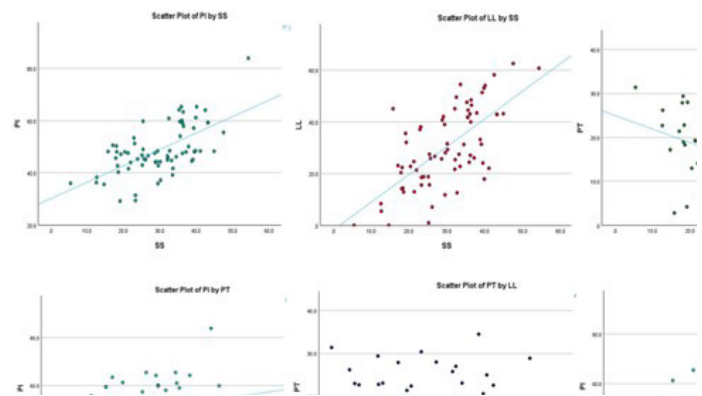


Figure 4: Scatter plots to show linear correlations between different spinopelvic parameters

Correlations between different spinopelvic parameters and disc pathology at different levels

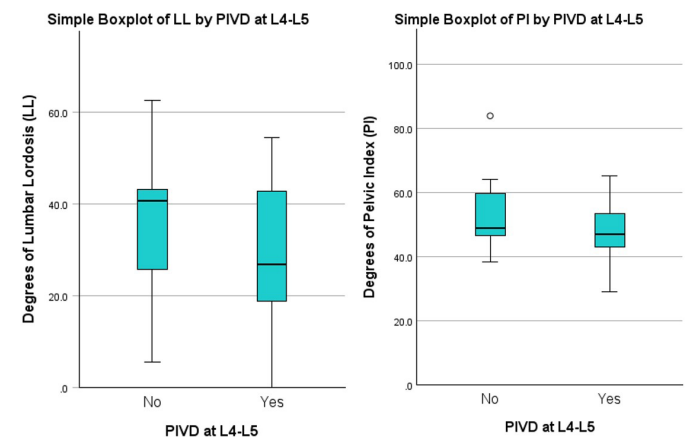


Figure 5: Simple box-plots of LL and PI by 'L4-L5'

Correlation Heatmap between different Spinopelvic Parameters

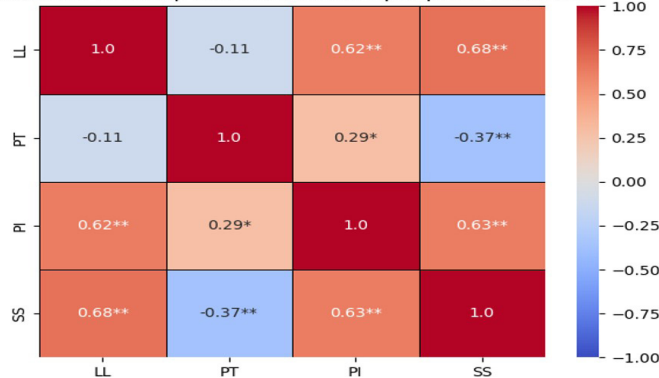


Figure 3: Correlation heatmap between LL, PT, PI, and SS

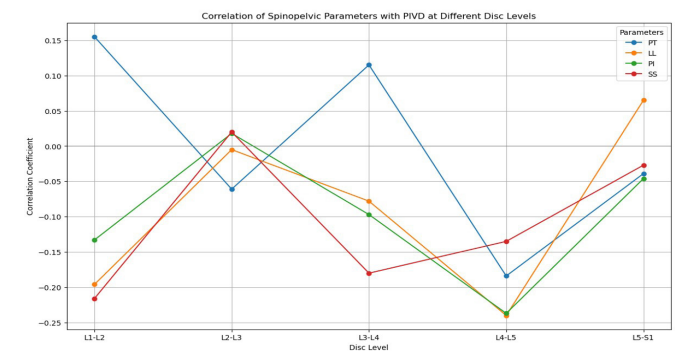


Figure 6: Correlation line graph of spinopelvic parameters with PIVD at different disc levels

On further investigating the results using a box plot, the patients having PIVD at the L4-L5 level were found to have significantly lower values of LL as compared to those who had PIVD at any other levels. Similarly, the patients having PIVD at the L4-L5 level had significantly lower values of PI as compared to those who had PIVD at any other levels (Figure 5).

This further solidified the results obtained from the

correlation tests. In addition, the line graph helps to visualize some of the interesting findings (Figure 6).

In our study, none of the findings showed strong positive or negative linear correlations between them (Table 2). However, statistically significant weak correlations were found between LL and PIVD at the L4-L5 level ($R = -0.240$, $p = 0.041$), as well as between pelvic incidence (PI) and PIVD at the L4-L5 level ($R = -0.237$, $p = 0.043$).

Table 2: Pearson's correlations between spinopelvic parameters and the levels of disc prolapse

| Parameters | Correlation Statistics | L1-L2 | L2-L3 | L3-L4 | L4-L5 | L5-S1 |
|------------|------------------------|--------|--------|--------|---------|--------|
| PT | R | 0.155 | -0.061 | 0.115 | -0.184 | -0.039 |
| | P-value | 0.189 | 0.606 | 0.331 | 0.120 | 0.740 |
| LL | R | -0.196 | -0.005 | -0.078 | -0.240* | 0.065 |
| | P-value | 0.097 | 0.969 | 0.511 | 0.041 | 0.584 |
| PI | R | -0.133 | 0.018 | -0.097 | -0.237* | -0.046 |
| | P-value | 0.261 | 0.878 | 0.412 | 0.043 | 0.697 |
| SS | R | -0.216 | 0.020 | -0.180 | -0.135 | -0.027 |
| | P-value | 0.066 | 0.867 | 0.127 | 0.255 | 0.820 |

*: Correlation is significant at the 0.05 level (2 tailed)

The correlation coefficients between all the spinopelvic parameters and the disc prolapse at the L2-L3 level seem to come near zero, indicating no or very weak correlation between them. A similar situation can also be seen with the L5-S1 level, indicating very weak correlation, if any, between these parameters and the disc pathology. However, there is a negative correlation between all the spinopelvic parameters and disc pathology at the L4-L5 level. It shows that any decrease in the values of spinopelvic parameters can increase the occurrence of PIVD at L4-L5 level, and vice versa.

Discussion

A prolapsed intervertebral disc is a common problem in armed police personnel and those involved in physically demanding jobs. Intervertebral disc degeneration has been found to occur more frequently in military populations than in civilians of similar age.¹⁶ Potential contributors to the development of lumbar degenerative disc disease include genetics, heredity, age, sex, race, physical activity level, smoking, and body habitus.^{17,18}

The male preponderance in our case (75%) is similar to that described by Heliovaara et al.¹⁹ where men were found to have a 1.6 times greater risk of herniated lumbar intervertebral disc compared to women in relation to women. Similarly, Schroeder et al.²⁰ and Battié et al.¹⁸ also showed male preponderance; however, it is slightly higher in our case, as the male-female ratio in armed police personnel is usually higher.

The most common site for PIVD was found to be at the L4-L5 level (50%) and L5-S1 level (28%) in males; however, the most common sites involved in females were both the L4-L5 and L5-S1 levels equally. This aligns with Spangfort's study, in which 49 publications involving 15,235 operations show that most lumbar herniations occur at the L4-L5

(49.8%) and L5-S1 (46.9%) levels. These segments are the most biomechanically stressed in the spine, making them the most frequent sites for prolapsed intervertebral discs.²¹

The measured mean spinopelvic parameters were LL ($30.43^\circ \pm 5.77$), PT ($15.67^\circ \pm 8.04$), PI ($48.99^\circ \pm 9.52$), and SS ($30.02^\circ \pm 9.5$). The results are comparable to the study by Poonia et al., where the mean SS, PT, PI, and LL were 37.78° , 13.52° , 51.33° , and 41.01° , respectively.²² Similar findings were reported by Fei et al. with PI ($46.1^\circ \pm 10.0^\circ$), LL ($34.4^\circ \pm 15.3^\circ$), SS ($29.7^\circ \pm 9.1^\circ$), PT ($16.4^\circ \pm 8.4^\circ$),²³ and Okan and Beyhan with LL ($43.05^\circ \pm 11.73^\circ$); PT ($22.17^\circ \pm 7.9^\circ$); SS ($36.05^\circ \pm 8.38^\circ$); and PI ($67.65^\circ \pm 9.24^\circ$).²⁴

Spinopelvic parameters are measured on lateral standing radiographs of the lumbar spine, and there is a geometric relationship between these parameters: pelvic incidence = pelvic tilt + sacral slope. The pelvic incidence is a morphological parameter that is independent of the spatial orientation of the pelvis and is considered specific for each individual.⁹ In our study, we observed strong positive correlations between PT and LL, SS and LL, a weak positive relation between PT and PI, a strong positive relation between PI and SS, and a weak negative relation between PT and SS. These findings align with Sudhir et al. who reported a positive correlation between the PI and SS and a negative correlation between the SS and PT.²⁵ Okan and Beyhan similarly found moderately strong correlations between LL and SS ($p=0.001$), LL and PI ($p=0.002$), PI with SS ($p=0.001$), and PT ($p=0.001$).²⁴

In our study, when analyzing the correlations between different spinopelvic parameters and disc pathology at different levels, no strong positive or negative linear correlations were identified. However, we found statistically significant weak correlations between lumbar lordosis (LL) and PIVD at the L4-L5 level ($R = -0.240$, $p =$

0.041) and between pelvic incidence (PI) and PIVD at the L4-L5 level ($R = -0.237$, $p = 0.043$). This aligns with Zárte-Kalfópulos et al.²⁶ who reported significantly lower PI and LL in the lumbar disc degeneration group. Similarly, Tuncer et al.⁷ demonstrated a negative correlation between PI, LL, and disc herniation, concluding that individuals with low PI, LL, and SS values are at a greater risk of surgery for lumbar disc herniation. Barrey et al.²⁷ also showed lower PI and LL in the lumbar degenerative disc and herniation group as compared to the controls. Soydan et al.⁸ found that lumbar lordosis was lower in the degenerative disc group, and PI positively correlated with degeneration at the upper L1-L3 levels. However, our study did not find correlations at upper levels, instead showing a negative correlation at the L4-L5 levels. Similarly, Rajnics et al.²⁸ reported reduced lumbar lordosis in the disc herniation patients compared to healthy individuals, consistent with our findings.

In contrast, Poonia et al.²² found a positive monotonic correlation between disc pathologies at L2-L3 and L4-L5 levels with SS, PT, PI, and LL, while disc pathology at L5-S1 showed negative correlation with PI. Similarly, studies by Borkar et al.¹⁰ and Kaur et al.²⁹ showed lower PI and LL in healthy individuals compared to patients with lumbar listhesis and failed back syndrome. However, no significant correlation between lumbar disc degeneration and the healthy individuals was noted. Our findings also indicate lower LL values, suggesting that patients with reduced pelvic incidence and lumbar lordosis may have a higher chance of disc degeneration at L4-L5 levels.

Conclusion

Patients having lower pelvic incidence and lumbar lordosis have higher chances of developing PIVD, and so these measurements from plain radiographs can be of use in predicting lumbar disc degeneration. As a result, proper lifestyle modification and behavioral changes to minimize the disc degeneration process can be initiated early. It is a retrospective study, and the spinopelvic parameters of normal healthy individuals are not taken into consideration. Thus, a prospective study with controls would be more effective in providing a more accurate correlation between the spinopelvic parameters and prolapsed lumbar disc.

Acknowledgment

We would like to thank all the faculties of the Nepal Armed Police Force Hospital, Department of Orthopaedics and Trauma, Department of Radiology and Er. Dina KC for their continuous support and help during the whole process.

References

- Satpute K, Hall T, Bisen R, Lokhande P. The effect of spinal mobilization with leg movement in patients with lumbar radiculopathy—a double-blind randomized controlled trial. *Arch Phys Med Rehabil.* 2019;100(5):828-36.
DOI: [10.1016/j.apmr.2018.11.004](https://doi.org/10.1016/j.apmr.2018.11.004)
PMID: 30521781
- Singh V, Malik M, Kaur J, Kulandaivelan S, Punia S. A systematic review and meta-analysis on the efficacy of physiotherapy intervention in management of lumbar prolapsed intervertebral disc. *Int J Health Sci (Qassim).* 2021;15(2):49-57.
PMID: 33708044 PMCID: PMC7934127
- Choi YS, dong Y lim. Pathophysiology of degenerative disc disease. *Asian Spine Journal.* 2009.3(1):39-44.
DOI: [10.4184/asj.2009.3.1.39](https://doi.org/10.4184/asj.2009.3.1.39)
PMID: 20404946 PMCID: PMC2852042
- Martin MD, Boxell CM, Malone DG. Pathophysiology of lumbar disc degeneration: a review of the literature. *Neurosurg Focus.* 2002;13(2):E1.
DOI: [10.3171/foc.2002.13.2.2](https://doi.org/10.3171/foc.2002.13.2.2)
PMID: 15916393
- Wei X, Gengwu L, Chao C, Yifan L, Shang S, Ruixi H, et al. Correlations between the sagittal plane parameters of the spine and pelvis and lumbar disc degeneration. *J Orthop Surg Res.* 2018;13(1):137.
DOI: [10.1186/s13018-018-0838-6](https://doi.org/10.1186/s13018-018-0838-6)
PMID: 29866146 PMCID: PMC5987659
- Baran E, Karademir M. Evaluation of sagittal balance and spinopelvic parameters in patients with lumbar disc herniation. *Cumhuriyet Medical Journal.* 2018;40(4):446-53.
DOI: [10.7197/223.vi.502383](https://doi.org/10.7197/223.vi.502383)
- Tuncer C, Polat Ö, Er U. Correlation between spinopelvic parameters and the development of lumbar disc herniation. *Journal of Turkish Spinal Surgery.* 2019;30(4):245-8.
DOI: [10.4274/jtss.galenos.2019.0005](https://doi.org/10.4274/jtss.galenos.2019.0005)
- Soydan Z, Bayramoglu E, Sen C. Elucidation of effect of spinopelvic parameters in degenerative disc disease. *Neurochirurgie.* 2023;69(1)101388.
DOI: [10.1016/j.neuchi.2022.101388](https://doi.org/10.1016/j.neuchi.2022.101388)
PMID: 36502876
- Legaye J, Duval-Beaupère G, Hecquet J, Marty C. Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. *Eur Spine J.* 1998;7(2):99-103.
DOI: [10.1007/s005860050038](https://doi.org/10.1007/s005860050038)
PMID: 9629932 PMCID: PMC3611230
- Borkar SA, Sharma R, Mansoori N, Sinha S, Kale SS. Spinopelvic parameters in patients with lumbar degenerative disc disease, spondylolisthesis, and failed back syndrome: Comparison vis-à-vis normal asymptomatic population and treatment implications. *J Craniovertebr Junction Spine.* 2019;10(3):167-71.
DOI: [10.4103/jcvjs.jcvjs_70_19](https://doi.org/10.4103/jcvjs.jcvjs_70_19)
PMID: 31772429 PMCID: PMC6868542
- Schwarzer AC, Aprill CN, Derby R, Fortin J, Kine G, Bogduk N. The Prevalence and clinical features of internal disc disruption in patients with chronic low back pain. *Spine (Phila Pa 1976).* 1995;20(17):1878-83.
DOI: [10.1097/00007632-199509000-00007](https://doi.org/10.1097/00007632-199509000-00007)
PMID: 8560335

12. Fjeld OR, Grøvle L, Helgeland J, Småstuen MC, Solberg TK, Zwart JA, et al. Complications, reoperations, readmissions, and length of hospital stay in 34 639 surgical cases of lumbar disc herniation. *Bone Joint J.* 2019;101-B(4):470-7. DOI: [10.1302/0301-620x.101b4.bjj-2018-1184.r1](https://doi.org/10.1302/0301-620x.101b4.bjj-2018-1184.r1) PMID: 30929479
13. Boulay C, Tardieu C, Hecquet J, Benaim C, Mouilleseaux B, Marty C, et al. Sagittal alignment of spine and pelvis regulated by pelvic incidence: standard values and prediction of lordosis. *European Spine Journal.* 2006;15(4):415-22. DOI: [10.1007/s00586-005-0984-5](https://doi.org/10.1007/s00586-005-0984-5) PMID: 16179995 PMCID: PMC3489325
14. Le Huec JC, Aunoble S, Philippe L, Nicolas P. Pelvic parameters: origin and significance. *European Spine Journal.* 2011;20 Suppl 5(Suppl 5):564-71. DOI: [10.1007/s00586-011-1940-1](https://doi.org/10.1007/s00586-011-1940-1) PMID: 21830079 PMCID: PMC3175921
15. Völlner F, Grifka J. Biomechanical aspects of preoperative planning: What is really important? *Orthopade.* 2019;48(1):44-9. DOI: [10.1007/s00132-018-03673-7](https://doi.org/10.1007/s00132-018-03673-7) PMID: 30539205
16. Schoenfeld AJ, Nelson JH, Burks R, Belmont Jr. PJ. Incidence and risk factors for lumbar degenerative disc disease in the United States military 1999-2008. *Mil Med.* 2011;176(11):1320-4. DOI: [10.7205/milmed-d-11-00061](https://doi.org/10.7205/milmed-d-11-00061) PMID: 22165663
17. Onodera K, Berry DB, Shahidi B, Kelly KR, Ward SR. Intervertebral disc kinematics in active duty Marines with and without lumbar spine pathology. *JOR Spine.* 2019;2(2):e1057. DOI: [10.1002/jsp2.1057](https://doi.org/10.1002/jsp2.1057) PMID: 31463467 PMCID: PMC6686816
18. Battié MC, Videman T, Parent E. Lumbar disc degeneration: epidemiology and genetic influences. *Spine (Phila Pa 1976).* 2004;29(23):2679-90. DOI: [10.1097/01.brs.0000146457.83240.eb](https://doi.org/10.1097/01.brs.0000146457.83240.eb) PMID: 15564917
19. Heliövaara M, Knekt P, Aromaa A. Incidence and risk factors of herniated lumbar intervertebral disc or sciatica leading to hospitalization. *J Chron Dis.* 1987.40(3):251-8. DOI: [10.1016/0021-9681\(87\)90161-5](https://doi.org/10.1016/0021-9681(87)90161-5) PMID: 3818881
20. Schroeder GD, Guyre CA, Vaccaro AR. The epidemiology and pathophysiology of lumbar disc herniations. *Semin Spine Surg.* 2016;28(1):2-7. DOI: [10.1053/j.semss.2015.08.003](https://doi.org/10.1053/j.semss.2015.08.003)
21. Spangfort E V. The Lumbar Disc Herniation: A Computer-Aided Analysis of 2,504 Operations. *Acta Orthop Scand.* 1972;43(sup142):1-95. DOI: [10.3109/ort.1972.43.suppl-142.01](https://doi.org/10.3109/ort.1972.43.suppl-142.01) PMID: 4516334
22. Poonia A, Lodha S, Sharma N. Evaluation of spinopelvic parameters in lumbar prolapsed intervertebral disc. *Indian Journal of Radiology and Imaging.* 2020;30(3):253-62. DOI: [10.4103/ijri.ijri_49_20](https://doi.org/10.4103/ijri.ijri_49_20) PMID: 33273757 PMCID: PMC7694732
23. Fei H, Li WS, Sun ZR, Ma QW, Chen ZQ. Analysis of spinopelvic sagittal alignment in young Chinese patients with lumbar disc herniation. *Orthop Surg.* 2017;9(3):271-6. DOI: [10.1111/os.12340](https://doi.org/10.1111/os.12340) PMID: 28960822 PMCID: PMC6584466
24. Okan S, Beyhan M. Relationship between lumbar subcutaneous adipose tissue thickness and spinopelvic parameters. *Cukurova Medical Journal.* 2020;45(3):1238-45. DOI: [10.17826/cumj.736745](https://doi.org/10.17826/cumj.736745)
25. Sudhir G, Acharya S, K L K, Chahal R. Radiographic analysis of the sacropelvic parameters of the spine and their correlation in normal asymptomatic subjects. *Global Spine J.* 2015;6(2):169-75. DOI: [10.1055/s-0035-1558652](https://doi.org/10.1055/s-0035-1558652) PMID: 26933619 PMCID: PMC4771498
26. Zárate-Kalfópulos B, Reyes-Tarrago F, Navarro-Aceves LA, García-Ramos CL, Reyes-Sánchez AA, Alpízar-Aguirre A, et al. Characteristics of spinopelvic sagittal alignment in lumbar degenerative Disease. *World Neurosurg.* 2019;126:e417-21. DOI: [10.1016/j.wneu.2019.02.067](https://doi.org/10.1016/j.wneu.2019.02.067) PMID: 30822583
27. Barrey C, Jund J, Nosedá O, Roussouly P. Sagittal balance of the pelvis-spine complex and lumbar degenerative diseases. a comparative study about 85 cases. *European Spine Journal.* 2007;16(9):1459-67. DOI: [10.1007/s00586-006-0294](https://doi.org/10.1007/s00586-006-0294) PMID: 17211522 PMCID: PMC2200735
28. Rajnics P, Templier A, Skalli W, Lavaste F, Illes T. The importance of spinopelvic parameters in patients with lumbar disc lesions. *Int Orthop.* 2002;26(2):104-8. DOI: [10.1007/s00264-001-0317-1](https://doi.org/10.1007/s00264-001-0317-1) PMID: 12078871 PMCID: PMC3620862
29. Kaur A, Chandak S, Panda S, Agarwal A, Malhotra A, Singh P. Evaluation of spinopelvic parameters in patients with different grades of intervertebral disc degeneration in lumbosacral spine vs normal asymptomatic population: a retrospective observational study. *Journal of Clinical and Diagnostic Research.* 2023;17(6):TC17-22. DOI: [10.7860/JCDR/2023/64790.18062](https://doi.org/10.7860/JCDR/2023/64790.18062)