Correlation of Pelvic Incidence With Low- and High-Grade Isthmic Spondylolisthesis

Darrell S. Hanson, MD,* Keith H. Bridwell, MD,† John M. Rhee, MD,‡ and Lawrence G. Lenke, MD†

Purpose. The development of isthmic spondylolisthesis is influenced by forces across the lumbosacral region of the spine. Pelvic incidence is a radiographic parameter that has been shown to be an independent parameter that influences both sagittal spinal balance and pelvic orientation. Our hypothesis then is that there is a positive correlation between pelvic incidence and spondylolisthesis.

Study Design. A radiographic analysis of cases with spondylolisthesis.

Objectives. To try to assess the correlation between pelvic incidence in both low-grade and high-grade spondylolisthesis in both a pediatric and an adult population.

Summary of Background Data. The concept of pelvic incidence has been introduced into the literature. Its exact association with spondylolisthesis has not yet been clarified.

Methods. Forty patients with spondylolisthesis were identified and divided into two groups: low-grade (Meyerding I–II) and high-grade (Meyerding III and higher). Radiographic parameters measured included lumbar sagittal alignment (T12–S1), sacral inclination, slip angle, and pelvic incidence. The spondylolisthesis was classified according to the Meyerding–Newman classifications and the slip angle. Radiographic measurements were also done in two control groups; there were 20 pediatric and 20 adult controls (mean age 11.8 years and 60.0 years, respectively). Unpaired t test analysis and Pearson correlation analysis were then done.

Results. Mean pelvic incidence was 47.4° in the pediatric control group, 57° in the adult control group, 68.5° in the low-grade isthmic spondylolisthesis group, and 79.0° in the high-grade isthmic spondylolisthesis group. Pelvic incidence was found to be significantly higher in the high- and low-grade spondylolisthesis groups compared with both control groups (P = 0.0001). Pelvic incidence was significantly higher in the high-grade isthmic spondylolisthesis group than in the low-grade isthmic spondylolisthesis group (P = 0.007). A significant correlation existed between pelvic incidence and Meyerding–Newman scores (P = 0.03).

Conclusions. Pelvic incidence was significantly higher in patients with low- and high-grade isthmic spondylolisthesis as compared with controls and had significant correlation with the Meyerding–Newman grades (P = 0.03). [Key words: pelvic incidence, isthmic spondylolisthesis, high-grade] Spine 2002;27:2026–2029

Sagittal alignment of the spine has been investigated in many studies, primarily in populations of normal patients.2,6,12 The relative values of thoracic kyphosis and lumbar lordosis show a wide range in the normal population and are somewhat dependent on the methodology of the investigators (depending on the levels of the spine included in the measurements). The correlation of sagittal parameters and the development of spinal disorders is still not clearly elucidated and is probably more complex than previously recognized.

When considering sagittal alignment of the spine, it has been recognized that the orientation of the lumbosacral pelvic junction plays a critical role in the overall alignment of the spine. There is a transition from the relatively flexible lumbar spine to the sacrococcygeal region that is much more inflexible. The pelvis and hips are the primary variables in lumbosacral pelvic orientation and play a critical role in the sagittal orientation of the spine. Parameters attempting to address the role of lumbosacral pelvic orientation in sagittal alignment include sacral inclination, pelvic tilt, and others that are still under investigation. None to date has been correlated firmly with spinal disorders involving sagittal alignment.

Legaye et al have recently proposed pelvic incidence as an anatomic parameter that is predictive of the sagittal balance of the spine.7 They define pelvic incidence as the angle between the perpendicular to the sacral plate at its midpoint and the line connecting this point to the midpoint of a line connecting the femoral heads. They demonstrated a strong correlation between pelvic incidence and sacral slope, pelvic tilt, and lumbar lordosis that was independent of other variables in both a normal population and a population of scoliosis patients. They concluded that pelvic incidence is an important determinant of sagittal alignment of the spine (Figure 1).

Isthmic spondylolisthesis is a disorder that is a combination of dysplastic morphology across the L5–S1 segment coupled with global forces across the lumbosacral joint.8,9,14,15 Most of the radiographic measurements (slip angle, degree of translation, sacral contour) are related to the dysplasia of the posterior elements and the resulting translation of L5.1,4,13 Global forces across the lumbosacral region are obviously important in the development of isthmic spondylolisthesis, as there has not been a reported case of spondylolisthesis in a non-

From the *Institute for Spinal Disorders, Houston, Texas, the †Department of Orthopaedic Surgery, Washington University School of Medicine, St. Louis, Missouri, and ‡Emory University School of Medicine, Decatur, Georgia.

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ambulatory patient. Pelvic incidence then might represent a valuable parameter in the evaluation of isthmic spondylolisthesis.

The purpose of our study is to analyze the correlation between pelvic incidence and isthmic spondylolisthesis.

Materials and Methods

Forty patients with isthmic spondylolisthesis were identified from the clinic charts of the two senior authors. Patients were entered on a consecutive basis, and patients were only excluded if they did not have radiographs that visualized the femoral heads fully. The patients were divided into two groups of low-grade (Meyerding I-II) and high-grade (Meyerding III or higher) isthmic spondylolisthesis; there were 20 patients per group. Mean age of the low-grade isthmic spondylolisthesis group was 26.6 years (range 15–51 years) and the high-grade isthmic spondylolisthesis group was 17.7 years (range 10–50 years).

Controls were established from a consecutive group of volunteers who had no evidence or history of spine problems. Because there was a significant number of pediatric patients in the isthmic spondylolisthesis groups, both pediatric and adult control groups were established. There were a total of 20 patients in each control group. Mean ages of the pediatric and adult control groups were 11.8 years and 60 years, respectively.

Anteroposterior and lateral standing radiographs of each subject were then assessed. Radiographic parameters measured included overall lumbar lordosis (measured from the superior endplate of T12 to the sacral endplate), segmental sagittal alignment of the lumbar spine (Cobb measurement from the superior endplate of the proximal vertebra to the inferior endplate of the next distal vertebra), sacral inclination, and pelvic incidence (angle between the perpendicular to the sacral plate at its midpoint and the line connecting this point to the midpoint of a line connecting the femoral heads) (Figure 1). The spondylolisthesis was classified according to both the Meyerding–Newman classification and the slip angle (angle between a line along the superior endplate of L5 and a perpendicular to the line along the back of the sacrum).

Statistical analysis was then undertaken to examine significant variation between groups. Unpaired t test analysis was used to look for significant variations between groups, and Pearson correlations were analyzed for correlation of pelvic incidence and lumbar lordosis, slip angle, and Meyerding–Newman scores.

Results

Table 1 is a summary table of all of the parameters measured in each of the four groups. There were no significant differences between the four groups in the following parameters: lumbar lordosis (measured from T12 to the sacral endplate), sacral inclination, segmental sagittal alignment, and sacral inclination (except for the high-grade spondylolisthesis group). Significant differences were noted with the slip angle in the high-grade spondylolisthesis group alone; there were no other significant differences in the slip angle of the other three groups.

Mean pelvic incidence was significantly different between all groups studied (Figure 2). Mean pelvic incidence was 47.4° in the pediatric control group, 57° in the adult control group, 68.5° in the low-grade isthmic spondylolisthesis group, and 79.0° in the high-grade isthmic spondylolisthesis group. Both the low-grade and high-grade isthmic spondylolisthesis groups had significantly higher pelvic incidence values than either adult or pediatric control groups (P = 0.001). As well, the pelvic incidence of the high-grade group was significantly higher than the low-grade group (P = 0.007). Figure 3 shows representative cases.

Table 1. Radiographic Results

<table>
<thead>
<tr>
<th>Pelvic Incidence (°)</th>
<th>Lumbar Lordosis (°)</th>
<th>Sacral Inclination (°)</th>
<th>Slip Angle (°)</th>
<th>Meyerding Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pediatric controls</td>
<td>47.4 ± 7.5</td>
<td>−58.2 ± 11.5</td>
<td>51.6 ± 7.1</td>
<td>−12.1 ± 8.1</td>
</tr>
<tr>
<td>Adult controls</td>
<td>57.0 ± 11.5*</td>
<td>−58.3 ± 10.8</td>
<td>50.0 ± 8.7</td>
<td>−15.3 ± 6.4</td>
</tr>
<tr>
<td>Low-grade slips</td>
<td>68.5 ± 15.1†</td>
<td>−61.2 ± 14.8</td>
<td>48.2 ± 8.0</td>
<td>8.8 ± 7.6</td>
</tr>
<tr>
<td>High-grade slips</td>
<td>79.0 ± 15.2‡</td>
<td>−58.4 ± 15.8</td>
<td>41.5 ± 13.2</td>
<td>26.4 ± 14.4</td>
</tr>
</tbody>
</table>

* P = 0.004, adult controls significantly greater than pediatric controls.
† P = 0.001, low-grade slips significantly greater than adult or pediatric controls.
‡ P = 0.007, high-grade slips significantly greater than low-grade slips.

Note: Lumbar lordosis measured from T12 to sacral endplate. Slip angle measured from superior endplate of L5.
Pearson correlation analysis showed a significant correlation between the pelvic incidence and the Meyerding–Newman scores \((P < 0.03)\). Thus, the higher the grade of isthmic spondylolisthesis, the higher the pelvic incidence value. The lumbar lordosis also had significant correlation with pelvic incidence \((P = 0.04)\), confirming the findings of Legaye et al.\(^7\) There was no significant correlation of pelvic incidence with either slip angle or sacral inclination \((P = 0.53 \text{ and } 0.24, \text{ respectively})\).

**Discussion**

Marchetti and Bartolozzi have described isthmic spondylolisthesis as primarily developmental, being further divided into high and low dysplastic groups.\(^8\) High dysplastic features include kyphosis at the lumbosacral region, a trapezoidal fifth lumbar vertebra, elongation with or without fracture of the pars interarticularis,\(^3,13\) and dysplasia of the sacral dome.\(^1\) Low dysplastic types have a more parallel lumbosacral junction and normal sacral morphology. Although it has been postulated that the high dysplastic types are more likely to progress, this has never been accurately assessed.

There are undoubtedly many factors that influence the development of incompetence of the pars interarticularis. Hereditary predisposition has been well documented, especially in the Eskimo population, where the rates of spondylolysis are roughly 10 times those of a white population.\(^11\) Biomechanical stresses across the spine also play a role in the development of isthmic defects. Patients involved in activities with repetitive hyperextension of the lumbar spine, such as football or gymnastics, have been shown to have increased rates of spondylolysis. Thus, the causes of isthmic spondylolisthesis are probably multifactorial.

Once an isthmic defect develops, what predisposes to further progression of the spondylolisthesis? The reported incidence of spondylolysis in the white population is reported to be 3.6%.\(^5\) However, the overall risk of progression in this population is only 4–6%. Obviously, there are other factors involved in progression other than just the presence of spondylolysis.

There have been several investigations that have been done to examine radiographic parameters that may predict progression in patients with isthmic spondylolisthesis.\(^4,14\) Parameters that have been investigated include slip angle, slip grade, lumbar index, sacral inclination, sacral contour, and status of the lumbosacral disc. None of these parameters was shown to correlate with risk of progression. Most of these parameters measured are more related to dysplasia and may actually be secondary.
changes related to spondylolisthesis rather than primary causative factors.

There has been increased interest recently in the role that the lumbosacral pelvic region may play in spinal stability. Spinal sagittal alignment has been shown by Legaye et al.\(^7\) to be related to pelvic incidence, a measure that relates the orientation of the pelvis to the lumbosacral junction.\(^7\) A parameter described by Schwab et al.\(^10\) the sagittal pelvic tilt index, similarly describes the association between L5 and the acetabulum. In their study, they described the pelvic rotation that occurs with increasing verticalization of the sacrum and the resulting anterior displacement of the hip joint.\(^10\) They postulated that the sagittal pelvic tilt index may provide some insight into the rates of progression of isthmic spondylolisthesis.\(^10\)

This study shows that there is a significant correlation between pelvic incidence and the degree of isthmic spondylolisthesis (\(P = 0.03\)). There were significant differences between both the control groups and both the low- and high-grade groups (\(P = 0.001\), as well as significant differences between the low- and high-grade groups (\(P = 0.007\)). Pelvic incidence in the control population reflects the normal position of the hip to be directly vertical to the L5 vertebra. As the degree of spondylolisthesis increases, the pelvis rotates, causing verticalization of the sacrum and anterior displacement of the hip joint.

Our study also demonstrated that there may be age-related changes in pelvic incidence. The pediatric control group had a significantly lower pelvic incidence (47.4°) than the adult control group (57.0°) (\(P = 0.004\)). It has been shown that there is a gradual loss of lumbar lordosis as aging occurs; the increase in pelvic incidence might be a logical result as the pelvis rotates to maintain proper global alignment.

**Conclusion**

Pelvic incidence is significantly correlated with the degree of isthmic spondylolisthesis (\(P = 0.03\)). There were significant differences between both the control groups and the high- and low-grade spondylolisthesis groups (\(P = 0.001\)). As well, there were significant differences between the high- and low-grade spondylolisthesis groups (\(P = 0.007\)). Pelvic incidence may be a predictive factor for both high- and low-grade spondylolisthesis and should be considered a factor in treatment as well as in assessment for risk of progression. A higher pelvic incidence may be a causative factor for progression of spondylolisthesis. Whether pelvic incidence is cause or effect will require further study.

**Key Points**

- Pelvic incidence correlated with isthmic spondylolisthesis.
- Pelvic incidence correlated with high-grade isthmic spondylolisthesis.

**References**


**Address reprint requests to**

Keith H. Bridwell, MD

Department of Orthopaedic Surgery

Washington University School of Medicine

One Barnes-Jewish Hospital Plaza

Suite 11300 West Pavilion

St. Louis, MO 63110

E-mail: bridwells@msnotes.wustl.edu