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A Flat Sagittal Spinal Alignment Is Common among Young Patients with Lumbar Disc Herniation

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Abstract

Background: Recent studies suggest a correlation between spinal sagittal alignment and different types of lumbar pathologies due to different load patterns on the lumbar spine. The main objective of this study was to investigate the preoperative spinal sagittal alignment in young patients (<25 years) undergoing lumbar disc herniation surgery. **Methods:** Information regarding preoperative clinical examinations was collected from the patient medical charts. Preoperative MRI examinations were used to classify lumbar types according to four sagittal spinal alignment groups (1: a long thoracic kyphosis, 2: a flat back, 3: a normal spine and 4: an increased thoracic kyphosis). Other MRI findings were also noted. Classification of lumbar types was performed independently by three spine surgeons. To compare two sample proportions the 2-sample z-test was performed. **Results:** The distribution of lumbar curve types was: Type 1, 17% (9 patients); Type 2, 62% (33 patients); Type 3, 17% (9 patients) and Type 4, 4% (2 patients). The distribution of operated levels was: L3 - L4, 2% (1 patient); L4 - L5, 47% (25 patients); L5 - S1, 42% (22 patients) and L4 - L5 + L5 - S1, 9% (5 patients). **Conclusions:** A majority of the young patients (62%) that underwent surgery due to herniated disc in the lumbar spine were classified as Type 2 indicating a flat back. Future studies are needed to increase the knowledge about spinopelvic sagittal alignment and the correlation to spinal pathologies.

Keywords

Intervertebral Disc Displacement, Sagittal Alignment, Spine, Surgery, Young Adult

1. Introduction

Several studies have suggested an association between certain pathologies in the spine, especially the lumbar spine, and an individual's spinal sagittal alignment. This is due to

that different spinal alignments have differences in the loading of the distal lumbar segments [1]-[7]. However, there is a large normal variation in spinal alignments between asymptomatic individuals [8].

The sagittal alignment of the thoraco-lumbar spine is highly regulated by pelvic parameters. Boulay *et al.* [9] have suggested an equation to predict Lumbar Lordosis (LL) based on the pelvic parameters. The sagittal alignment can be regulated and altered in two regions, overlying state (kyphosis, T9 tilt) and underlying state (Sacral Slope, SS, Pelvic Tilt, PT). Pelvic Incidence (PI) is well defined by several studies [9] [10] and is determined by SS and PT and is the only parameter that is non-positional and constant. Boulay *et al.* [9] showed that low PI (<44˚) correlates to low SS and flat lumbar lordosis, and high PI (>62˚) correlates to a more pronounced lordosis and a steeper SS.

The normal sagittal alignment in a healthy paediatric population has been reported in many studies [11]-[14]. Mac-Thiong *et al.* [13] showed that PI regulates SS in children and adolescents in the same way as in adults. The study involved 341 healthy children and adolescents of both genders of 3 - 18 years of age, and the mean SS was 41.4˚ (±8.2˚). Additionally, Mac-Thiong *et al.* [14] reported that the mean SS for 479 asymptomatic adolescents of both sexes of 10 - 18 years of age was somewhat smaller, 39.1˚ (±7.6˚).

Roussouly *et al.* [15] have established a classification system describing the normal variation in sagittal alignment of the human lumbar spine and pelvis. This classification is a system where the spine is evaluated by full-length radiographs of the spine in the antero-posterior and lateral planes, extending from the base of the scull to the proximal femora in erect position. The classification identifies 4 types of spine curves. Type 1 has a long thoraco-lumbar kyphosis and a short hyperextended lordosis. Type 2 has a flat thoracic kyphosis and a flat lumbar lordosis. Type 3 has what is considered as a normal spine alignment—a moderate thoracic kyphosis and a moderate lumbar lordosis. Type 4 has an increased thoracic kyphosis and an increased lumbar lordosis (**Figure 1**). The

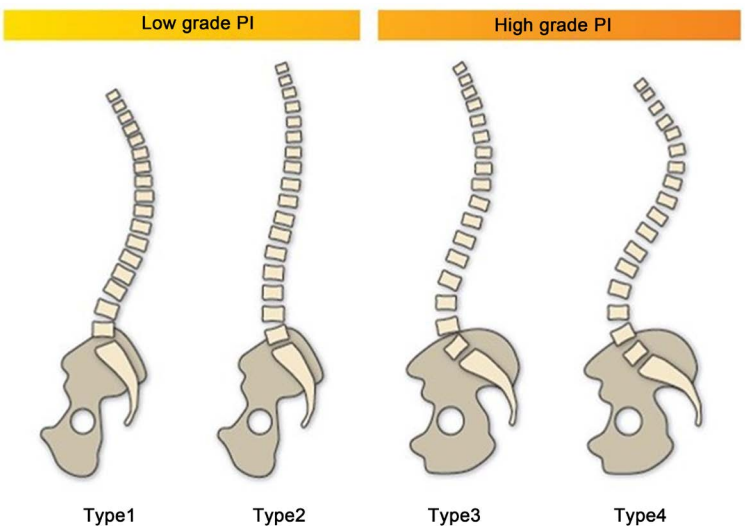

Figure 1. Roussouly Type 1 - 4 drawing. Drawing of the four different normal types of sagittal alignment of the human spine and pelvis: Type 1 and 2 have low grade of PI and Type 3 and 4 have high grade of PI.

normal variation of the sagittal alignment of the lumbar spine has been determined by an examination of 160 volunteers (mean age 30.8 years) with no history of back pain. In this group, 34 persons (21 %) had a Type 1 alignment, 18 persons (11%) had a Type 2 alignment, 60 persons (38%) had Type 3 alignment and 48 persons (30%) had a Type 4 alignment.

Roussouly and Pinheiro-Franco [1] described each of the four Roussouly types to be linked to specific pathologies. The Type 1 spine is suggested to have an increased risk of disc degeneration in the thoraco-lumbar kyphosis area. Further, in the kypho-lordotic junction area the discs are tilted with a greater risk of retrolisthesis. Type 2, which is the flat back, has a horizontal disc orientation. This is suggested to cause increased disc pressure with a higher risk of early disc degeneration and central disc herniations. This correlation is supported by publications such as Rajnics *et al*. [4], Barrey *et al*. [16] and Endo *et al*. [17]. Endo *et al*. [17] compared spinal alignment in healthy controls with patients that underwent surgery due to disc herniation. The results displayed less LL and SS, indicating a more flat back, in the disc herniation group compared to the control group. According to Roussouly and Pinheiro-Franco [1] the sagittal normal spine in Type 3 has not been linked to any certain pathological conditions. The Type 4 spine with its hyperlordotic lumbar curve is believed to cause increased force on the posterior elements where the disk plane is tilted forward. This may cause higher stress on the facet joints and thereby increase the risk of a fracture or elongation of the pars interarticularis area and spondylolisthesis (ventrolisthesis). This is supported by Marty *et al*. [5] that showed that a group of patients with spondylolisthesis had a larger angle of PI and SS than the normal population. In accordance with this, Labelle *et al*. [3] presented a cohort consisting of 214 patients with spondylolisthesis who had significantly greater lumbar lordosis, PI and SS, compared to a control population. Furthermore in Type 4, retrolisthesis is created where the intervertebral disc is tilted posteriorly.

The main objective of this retrospective cross sectional study was to investigate the sagittal spine types in a group of young patients (<25 years) with lumbar disc herniation that underwent discectomy surgery. The results from the observed group are also compared to the normal population according to Roussouly *et al*. [15]. The spinal alignment types were determined by preoperative radiologic examinations. To our knowledge, this has not been investigated previously.

2. Material and Methods

2.1. Study Population

All 53 patients <25 years of age of both genders who had undergone Disc Herniation (DH) surgery at the Sahlgrenska University Hospital during 2004-2012 were retrospectively included in the study. The age limitations was set to reduce age related confounders such as anatomical changes and degeneration.

2.2. Radiological Examination

Fifty-one patients were examined with preoperative supine Magnetic Resonance Imag-

ing (MRI) and two with supine Computer Tomography (CT). One patient was examined both with supine MRI and CT preoperatively. Eight patients were examined with both supine MRI and plain X-rays in the standing position preoperatively.

2.3. Study Protocol

All available preoperative radiological examinations were used to classify lumbar sagittal spinal type of each spine. Findings of scoliosis, transitional transverse processes, level of disc herniation or herniations, lumbo-sacral anomalies and spondylolisthesis were also registered.

The spines were classified in four different sagittal types according to Roussouly *et al*. [15]; a long thoracic kyphosis, a flat back, a normal sagittal spine and an increased thoracic kyphosis. These four types are similar to the Roussouly spinal alignment types with the difference that in the present study the majority (45 cases) were graded by horizontal radiological examinations and not with the vertical radiological examinations used in the Roussouly typing. In eight patients the grading was made on both standing X-rays and supine MRI.

Classification of the lumbar type was performed by three senior spine surgeons independently. If consensus was not obtained independently, a re-test was performed followed by a discussion to reach consensus.

Medical charts were used to collect data on baseline characteristics, preoperative clinical findings, symptoms (low back pain, radiating leg pain/sciatica) and activity level (earlier and/or on-going activity in organized sports).

2.4. Statistics

Data were statistically described in terms of mean and standard deviation (SD), median and range, or frequencies and percentage when appropriate. To compare two sample proportions, observed group vs normal population, the 2-sample z-test was performed. All tests were two-sided, and significance was set at $p < 0.05$ for each test. The analyses were carried out using SPSS (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.).

2.5. Ethical Statement

This study is a non-intervention retrospective observational cross sectional register and journal study. The information regarding the patients was retrieved through the Swe Spine Register (Swedish spinal register) and medical charts. All patients had given consent to be included in the Swedish Spine Register and research linked to the register. All patients were radiologically examined by normal standard clinical pre-operative protocol.

3. Results

3.1. Baseline Characteristics

The mean age for the whole group was 18.1 years (range 12 to 24) and 31 (58%) were

males and 22 (42%) females. All patients (53/53) experienced radiating leg pain or sciatica preoperatively. Thirty-four patients (64%) reported back pain. Fourteen patients (26%) had no back pain and for five patients (9%) the information was insufficient regarding back pain. The distribution of operated levels was L3 - L4, 1 patient (2%), L4 - L5, 25 patients (47%), L5 - S1, 22 patients (42%) and L4 - L5 + L5 - S1, 5 patients (9%). Out of the total cohort four patients had transitional L5 (8%). Three patients had transitional S1 vertebrae (6%). Seven patients had scoliosis (13%).

Twenty-six patients (49%) were active in organized sports such as soccer, track and field and handball. Twenty-one patients (40%) were not active in any organized sport activities. For six patients (11%) there was no information regarding sport activity. Of the patients that were active in organized sport activities, twenty-one patients (81%) were unable to participate in sports preoperative due to the symptomatic DH while five patients (19%) were able to continue to participate in sport activities.

3.2. Classification of Spine Type

In 50 out of 53 patient spinal type classifications reached consensus independently. In three cases consensus was obtained after discussion by the three surgeons.

Classification of the patients spine demonstrated a long thoraco-lumbar kyphosis (Type 1) in 17% (9 patients), a flat back (Type 2) in 62% (33 patients), a normal sagittal alignment (Type 3) in 17% (9 patients) and an increased thoracic kyphosis (Type 4) in 4% (2 patients) respectively (**Table 1**). There is no difference in the classification between MRI and X-ray examinations in the eight patients that were examined in both supine and standing position preoperatively (**Figure 2** and **Figure 3**).

3.3. Correlation to the Normal Population

When compared to the normal population according to Roussouly *et al.* [15], statistical

Table 1. Characteristics for total and spinal alignment Type 1 - 4.

	Total	Type 1	Type 2	Type 3	Type 4
Number of patients	53 (100%)	9 (17%)	33 (62%)	9 (17%)	2 (4%)
Back pain prior to surgery	34 (64%)	5 (55%)	22 (67%)	6 (67%)	1 (50%)
Mean age (range)	18.1 (12 - 24)	18.6 (15 - 24)	18.7 (12 - 23)	18.2 (14 - 22)	17 (16 - 18)
Op level L3 - 4	1 (2%)	0 (0%)	1 (3%)	0 (0%)	0 (0%)
Op level L4 - 5	25 (47%)	3 (33%)	17 (51%)	3 (33%)	2 (100%)
Op level L5 - S1	22 (42%)	6 (67%)	13 (39%)	3 (33%)	0 (0%)
Op level L4 - L5 - S1	5 (9%)	0 (0%)	2 (6%)	3 (33%)	0 (0%)
Sport participation	26 (49%)	5 (56%)	18 (55%)	3 (33%)	0 (0%)

% of group.

Figure 2. Sagittal spinal alignment Type 1 - 4 on supine MRI. MRI examinations showing the four groups of sagittal alignment of the spine in the study cohort.

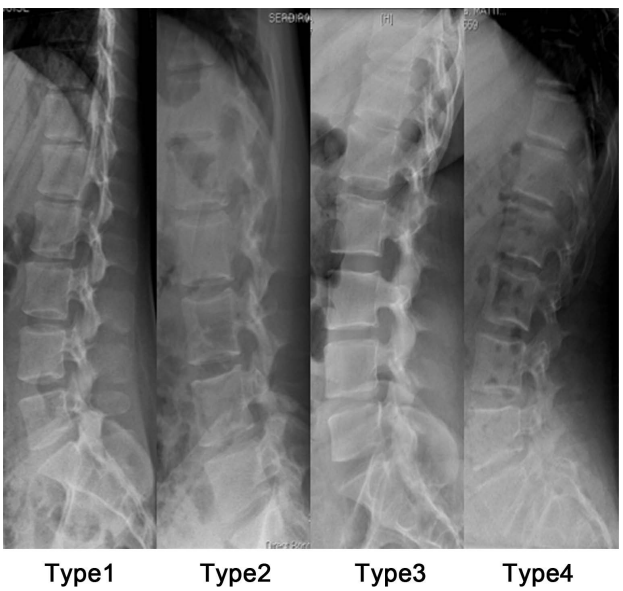

Figure 3. Sagittal spinal alignment Type 1 - 4 on standing X-ray. Standing X-rays showing the four groups of sagittal alignment of the spine in the study cohort. Eight patients had both X-ray and MRI examinations.

significant differences were found in spinal alignment Type 2 and 4 (Table 2 and Figure 4) in the present study. The study group displayed a much higher percentage of Type 2 compared to the normal population meanwhile a much less percentage of Type 4.

No statistical difference could be observed in Type 1 and 3.

Table 2. Observed group vs normal variation according to Roussouly *et al.* [15].

Spinal alignment/Roussouly type	Observed (%)	Normal population (%)	P-value
1	17	21.3	n.s.
2	62.2	11.3	<0.001
3	17	37.5	n.s.
4	3.8	30	<0.001

Observed population n = 53, and normal population n = 160 described in p-value or in not significant (>0.05). Chi-square test of proportions.

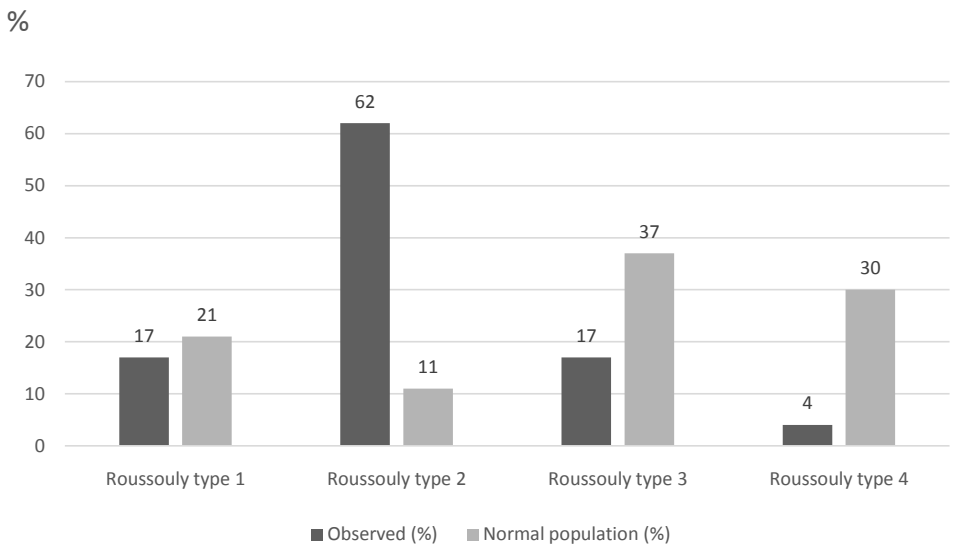

Figure 4. Observed group vs normal variation according to Roussouly *et al.* [15]. Sagittal spinal alignment type percentage comparison of observed group and normal population according to Roussouly *et al.* [15].

4. Discussion

The main finding in the present study was that 62% of the patients that underwent discectomy due to lumbar disc herniation were classified as having a flat back (Type 2), which is significantly higher when compared to the normal population according to Roussouly *et al.* [15]. These findings support the theory that a flat back and a straight spinal sagittal alignment is more likely to address maximum load on the lumbar disc and thereby creating central disc herniation in a young population.

Inter-rater validity was in this study high as 50 out 53 classifications reached blinded consensus between all three spine surgeons.

Pelvic incidence has been proven by several studies [9] [10] to be constant and is also a dominating factor to affect the lumbar lordosis through sacral slope. This suggests that radiology examinations display a stable morphology rather than a variable situation. The radiological examinations in this study were all in the horizontal plane. There is evidence that the alignment of the spine is not changed when comparing horizontal and vertical examinations. Several recent studies [1] [9] [10] [18] have demonstrated

that the alignment of the thoraco-lumbar spine is dependent on the pelvic morphology. It is also well understood and presented by Marty *et al*. [5] that the spino-pelvic morphology alters during growth according to weight and pressure. Boulay *et al*. [9] have showed that many of the parameters that affect the alignment are not constant but are flexible such as pelvic retroversion and thoracic kyphosis. Pelvic incidence has though been proven to be constant and is also a dominating factor to affect the lumbar lordosis through the sacral slope.

If the lumbar lordosis is originated by spinal morphology or pelvic morphology is still unknown. The evidence supports a combined effect [9] [14]. There is a correlation between the pelvis, spine and also the hip joint through static morphology and compensatory mechanisms. Jonasson *et al*. [19] reported that top athletes in different sports had correlations between lumbar spine pain and hip joint pain. The study included a total of 75 ice-hockey players, divers, weight-lifters, wrestlers, orienteers and a control group who were assessed through a self-answered questionnaire regarding pain from joints and spine. Yoshimoto *et al*. [20] presented information that higher PI in younger individuals could be a reason for developing osteoarthritis of the hip in later life meanwhile lower PI was more common in patients with low back pain. The pelvic morphology could be the fundament that shapes the thoraco-lumbar curvature and the morphology of the hip joint. A speculation is that the correlation of spinal and hip pain could be described by reduced mobility in the hip as in femoro-acetabular impingement (FAI), affecting the spino-pelvic sagittal alignment and thereby the risk of lumbar back pain. The question still remains: is it the spine morphology that affects the pelvic and hip morphology or vice versa?

Disc herniations can possibly occur due to increased disc pressure by physical exercise. The increased disc pressure due to the morphology can be even greater in sports where extreme movements and stress are required [21] [22]. Cholewicki *et al*. [21] presented a study where the average load on the L3-L4 disc during competitive weight lifting was >17,000 N. In this study the patients with a spinal alignment Type 2, 55% were active in organized sports, which was a similar frequency as in the patients with the other spinal alignment lumbar types. Theoretically, this may support the idea that patients with the highest risk of disc herniation in the lumbar spine are patients with a flat back and that this further increase with adding a high physical demands such as sports. It is well known that patients active in organized sports have higher risk of disc degeneration [23]-[26]. This may be developed by the same pathology as stated above.

5. Limitations

The main limitation of the present study was that the MRI examinations were all performed with the patient in the horizontal plane whereas the Roussouly classification system is based on examinations in erect position. In the present study there was no difference between the supine MRI and the standing radiographs regarding the type of sagittal alignment in the same patient. Future studies should exam this type of patients in erect positioning radiographs both pre-and postoperatively to be able to compare

vertical and horizontal radiological examinations according to the spinal alignment.

Another limitation is that the distribution of curve types seen in this study could have been influenced by confounder such as low back pain due to the disc hernias. The present study included only patients that had undergone surgery due to symptomatic disc herniations in the lumbar spine. Lumbar types of asymptomatic patients or patients with a symptomatic disc herniation not undergoing surgery were not examined.

6. Conclusion

A majority of the patients (62%) that underwent surgery due to herniated disc in the lumbar spine had a flat back and the distribution differed significantly compared to the normal population. More detailed and prospective studies are needed to increase the knowledge about to what extent different types of spino-pelvic sagittal alignment may influence the occurrence of thoraco-lumbar pathologies. Further, it is of great interest to explore if children/teenagers with certain spine types have increased risk for lumbar pathologies if practicing certain sports, which may influence recommendations on exercises for a growing spine.

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Competing Interests

The authors have declared that no competing interests exist.

Authors' Contributions

OT carried out the data gathering, data analysis and is the main author of the manuscript. JB participated in data gathering and data analysis. KH, HB and AB did the radiological assessment. AB created the study design and is the secondary author. All authors read and approved the final manuscript.

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