

Spondylolisthesis I:

Update, Misnomers & Insights for Non-Specific Low Back Pain

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Isthmic Spondylolisthesis (IS)

Wiltse et al 1976 classified spondylolysis and spondylolisthesis into five categories. The most common are Isthmic Spondylolisthesis (IS) and Degenerative Spondylolisthesis (DS). This newsletter and subsequent editions examines features of IS (and later DS) particularly as it relates to an understanding of spinal function and **Non-Specific Low Back Pain (NSLBP)**. I will review the classic definition of IS and the more recent emphasis on Sagittal Alignment for its role in the definition of IS and how it pertains to quality of life with the condition and following surgical management.

Classic Definition: A Misnomer?

Misnomer #1: IS is classically defined as one vertebra sliding forward on another. This is not completely true. If L5 slides forward on the sacrum, what happens to the L4-5 junction? Does L5 also slide forward on L4? And then what happens to L4 on L3? Antoniadides et al (2000) correctly pointed out that **the entire spine slides forward on S1** (Figure 1 & Appendix). This becomes very clear with more advanced cases of IS and especially the Grade 5 IS where L5 and spine slips off the sacral plate, *i.e.* **Spondyloptosis** (Figure 1 & Appendix). Been et al (2011) reported that while L5-S1 descended from lordosis for IS, L4-5 disc space ascended into greater lordosis (13° to 11° and 9.8° to 14.8° respectively for Grades I-II L5 IS, Figure 1).

Reviewing IS is an opportunity to re-evaluate how we view spinal conditions- from local pathology only to include local, adjacent and global sagittal alignment parameters. What the extensive investigations of IS has lead to, is a view of the spine as an entire biomechanical entity from from head to toe: **Gravity Matters**. There is an ever lengthening list of parameters characterizing this condition.

There is **the fracture, the slip, lumbar lordosis (LL), lumbo-sacral kyphosis (LSK), sacral slope (SS), sacral inclination (SI), pelvic tilt (PT), pelvic incidence (PI), sacral doming, sacral kyphosis (SK) lumbar index (LI), thoracic kyphosis (TK), trunk tilt (T1, T9) and more...**

Spondylolysis is the defect and spondylolisthesis is the vertebral translation or slip. Fredrickson et al 1984 (and later Beutler et al 2003) followed 500 first graders over 40 years. 4.4% of the first graders had an initial defect, 19 of the 22 (86%) defects were at L5 and 15 were bilateral (79%).

The problem or the big question is- what comes first? What is the etiology of IS? The fracture? If yes, how does the fracture occur and why? L5-S1 kyphosis? Lumbar lordosis? Pelvic incidence? Turning six years of age? Athletics? Genetics?

First we review of some of the lengthy list IS parameters.

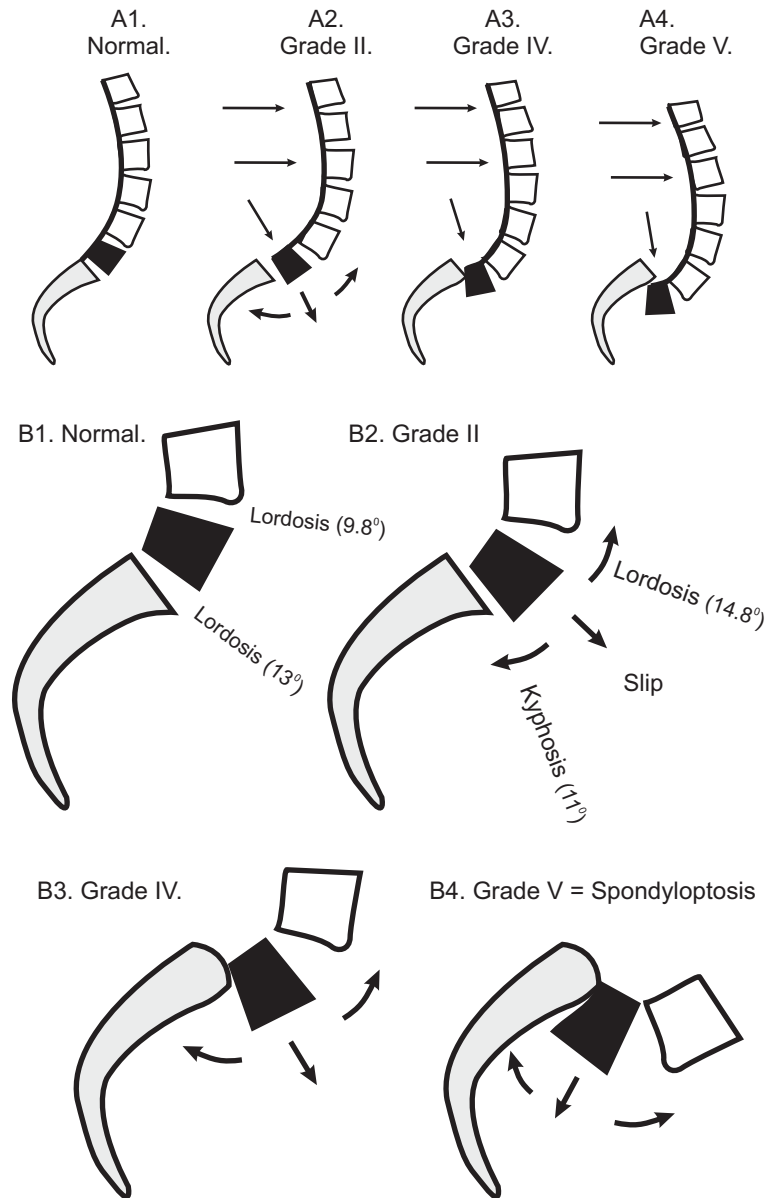


Figure 1 A & B: Spondylolisthesis- Slip & Lumbar Lordosis.
Adapted from Boxall et al 1979, Antoniadides et al 2000.

A1. & B1. Represents a normal lumbar spinal sagittal alignment.

A2. B2. Grade 2 Slip. L5 (and entire spine) slides forward on S1 (Middle arrow). L4-5 lordosis increases (Right arrow). L5-S1 lordosis decreases *i.e.* it becomes increasingly kyphotic (Left arrow).

A3. B3. Grade 4 Slip. L5 slips on S1. L4-L5 lordosis increased. L5-S1 lordosis decreased = kyphotic. S1 endplate rounded. Sacrum kyphotic.

A4. B4. Grade 5 Slip = **Spondyloptosis**. L5 falls off anterior edge of S1. Extreme L5-S1 kyphosis with extreme increased L1-5 lordosis.

The Defect, The Slip, First Graders & HRQoL

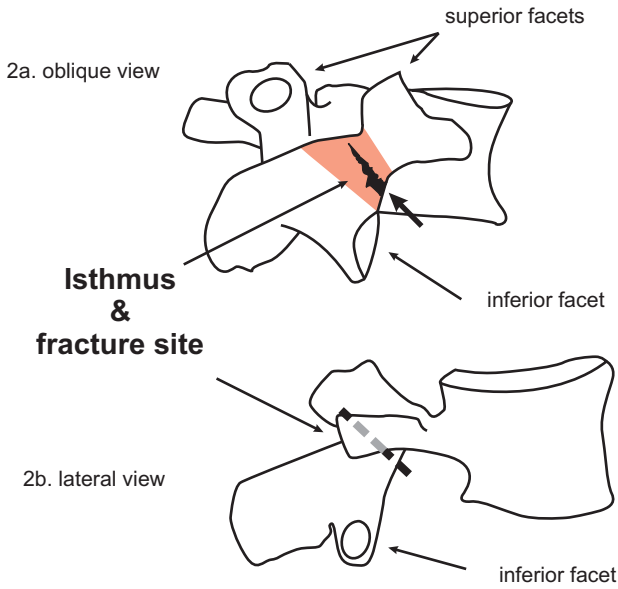


Figure 2. Isthmic fracture of a lumbar vertebra.

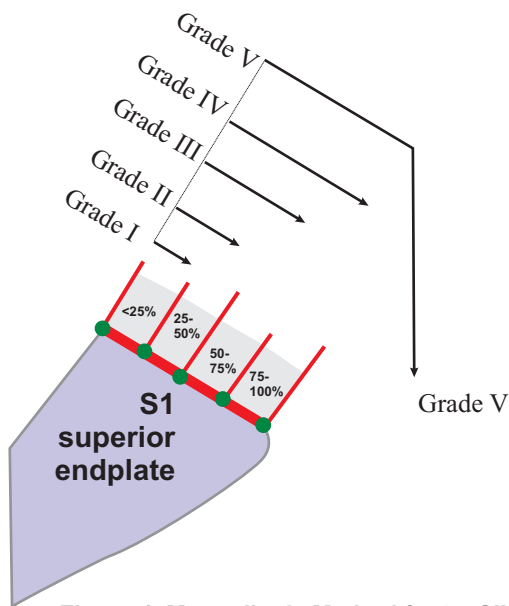


Figure 4. Meyerding's Method for L5 Slip

$$\text{Slip} = a-b \text{ (mm)}$$

$$\text{Slip}\% = \frac{a-b}{a-c} * 100$$

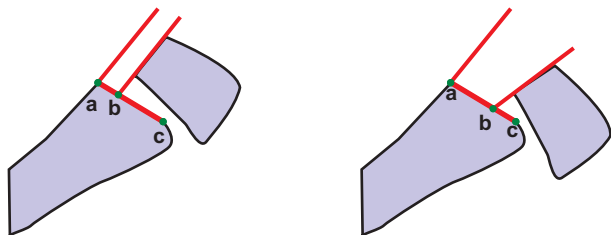


Figure 5. Taillard's L5 Slip + Low vs High Grade Slip.

The Defect: A Childhood condition

IS is defined by a fracture of the **Isthmus**. The Isthmus also known as the **pars interarticularis** or just pars is defined as a land mass connecting two larger masses, that is the bony connection between the superior and inferior facets, and hence also then the definition of pars interarticularis becomes obvious (between articulations) (Figure 2). Fracture of the isthmus always begins anteriorly (Figure 2a) (Terai et al 2010). On a normal Xray the Isthmus is obscured from view by the transverse process and hence the use of an oblique view. Figure 3 shows the separation of the posterior and anterior vertebral elements for a bilateral spondylolisthesis.

IS presents in first graders at a rate of 4% which reaches 6% by adulthood (Fredrickson et al 1984).

Isthmic Spondylolisthesis is a childhood condition. What is it about turning six?

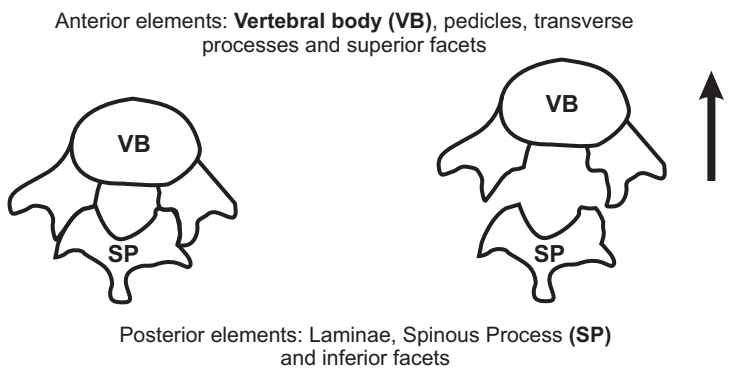


Figure 3. L5 Spondylolisthesis (Redrawn from Harris 1951).

The Slip & HRQoL

Slip measurement has been defined by Meyerding (1956) and Taillard (1976). Meyerding divided the sacral plate into four equal quarters Figure 4. L5 slip forward on S1 is then graded according to the quarter:

- 0-25% = Grade 1
- 26-50% = Grade II
- 51-75% = Grade III
- 76-100% = Grade IV
- >100% = Grade V = Spondylo-ptosis.

Taillard's method measures the amount of slip of L5 on S1 as a percentage of the L5 translation and the length of the superior endplate of the sacrum as shown in Figure 5.

IS is graded by millimeters, percentage or quarter but more recently it has been classified either as low grade or high grade (Figure 5a-b). Use of high and low grade classification and subsequent 6 sub-groups allows surgeons to better determine when and how to operate (Labelle et al 2011).

Unfortunately, only slip grades of III and IV correlate with **Health-Related Quality of Life (HRQoL)** measurements (SRS-22 & SF-12) while lumbo-sacral kyphosis (LSK) and pelvic tilt (PT) correlate with HQRoL independent of the degree of slip (Berven et al 2010).

That is, while slip is a defining feature of **IS** it is not as meaningful nor as significant as **Lumbo-Sacral Kyphosis** and **Pelvic Tilt** for assessing quality of life for this condition - *i.e.* how much the patient is **Suffering** with the condition.

Pelvic Incidence = Pelvic Tilt + Sacral Slope

Pelvic Tilt (PT), Sacral Slope (SS) & Pelvic Incidence (PI)

PT is the angle subtended by a vertical line through the center of the hip joints and the line from the center of the sacral plate to the center of the hip joints Figure 6c. Sacral slope is the angle between the horizontal and the line through the superior endplate of the sacrum (Figure 6b). Normal values are given in Table 1, Appendix.

Introduced by Legaye et al (French 1993, English in 1998), PI is the angle between the perpendicular line from the center of the sacral plate and the line from the center of the sacral plate to the center of the hip joints Figure 6a. PI is the arithmetic sum of SS and PT and is claimed to be a fundamental parameter for spinal posture (Legaye et al 1998).

Mangione et al (1997) measured PI in 30 fetuses (30°), 30 children (39°) and 30 adults (55°). PI increased most in the first months and years stabilizing by age 10. Whereas, Mac-Thiong et al (2004) reported that PI continued to change through out adolescence and stabilized by adulthood.

Pelvic Incidence is established in Childhood and Adolescence.

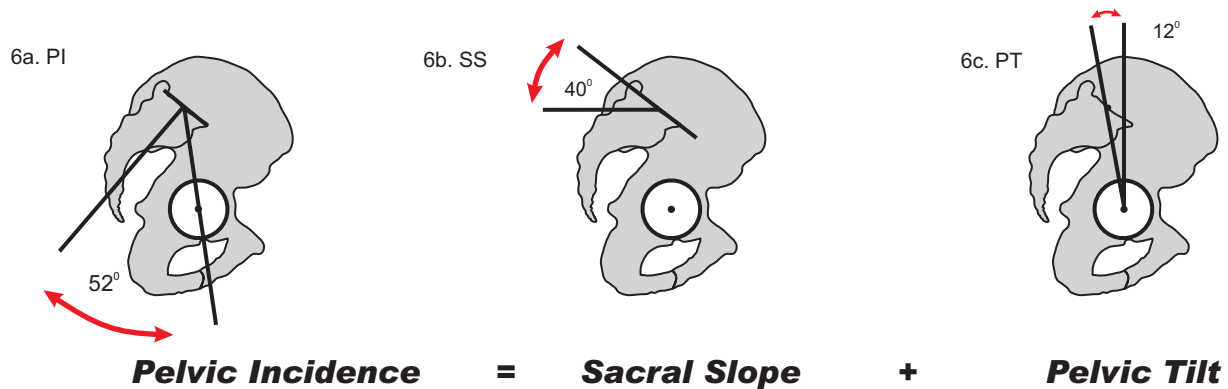


Figure 6. Pelvic Incidence

Pelvic Morphology & Upright Stance

PI is determined by PT and SS and is highly correlated with lumbar lordosis and all increase with increasing severity of IS slip (Labelle et al 2004). Mangione proposed that the process of obtaining the human upright stance influences pelvic morphology (*i.e.* PI). In the fetus, L5-S1 has a little lordosis while the rest of the spine is kyphotic (Cil et al 2005, Choufani et al 2009). By age 3 lumbar lordosis reaches 44° and by adulthood it measures 55°. Obtaining upright posture is complex and involves at least two major mechanical accomplishments:

Hip extension and **Sacral horizontal tilt** to allow for a normal spinal Lumbar Lordosis.... more another time...

The coordination or perhaps the battle between the trunk flexors and extensors in establishing an individual's upright stance may possibly be the primary etiological parameters causing IS. Unwanted, unnecessary, excessive flexor effort/tone could drive the kyphosis of L5-S1 that subsequently leads to an excessive extension response possibly determining the sacral and lumbar effects of IS (eg increased PT, SS, PI, LL & decreased TK). Any flexor action is matched by an extensor response, otherwise we would fall over. This mechanism may be the primary factor in IS, Degenerative Spondylolisthesis and even Non Specific Low Back Pain -Personal hypothesis from this author. Essentially, I wonder if our spinal ailments don't in fact evolve from how we stand in the world.... which is a learnt skill/habit and therefore available to modification....More to come another time...



Figure 7. Excessive Pelvic Incidence. With increasing PI, the pelvis is pulled apart- the sacrum tilts horizontally and the ilia rotate forward into excessive posterior pelvic tilt.

Lumbo-Sacral Angle: Lordotic to Kyphotic

LumboSacral Angle (LSA) for measuring Lumbo-Sacral Kyphosis (LSK)

Dubousset 1997 modified Boxall's Slip Angle to be the "Lumbo-Sacral Angle" or "LSA" or "DubLSA". LSA is a measure of the angle between L5 and S1 which is normally lordotic but descends toward zero and then becomes kyphotic for IS (Figure 9)(Boxall et al 1979, Vialle et al 2007). Boxall considered the Slip angle to be as significant as Slip translation in IS, while Dubousset noted that a LSK below 90° was a major factor in the progression of IS (i.e. when L5-S1 becomes kyphotic).

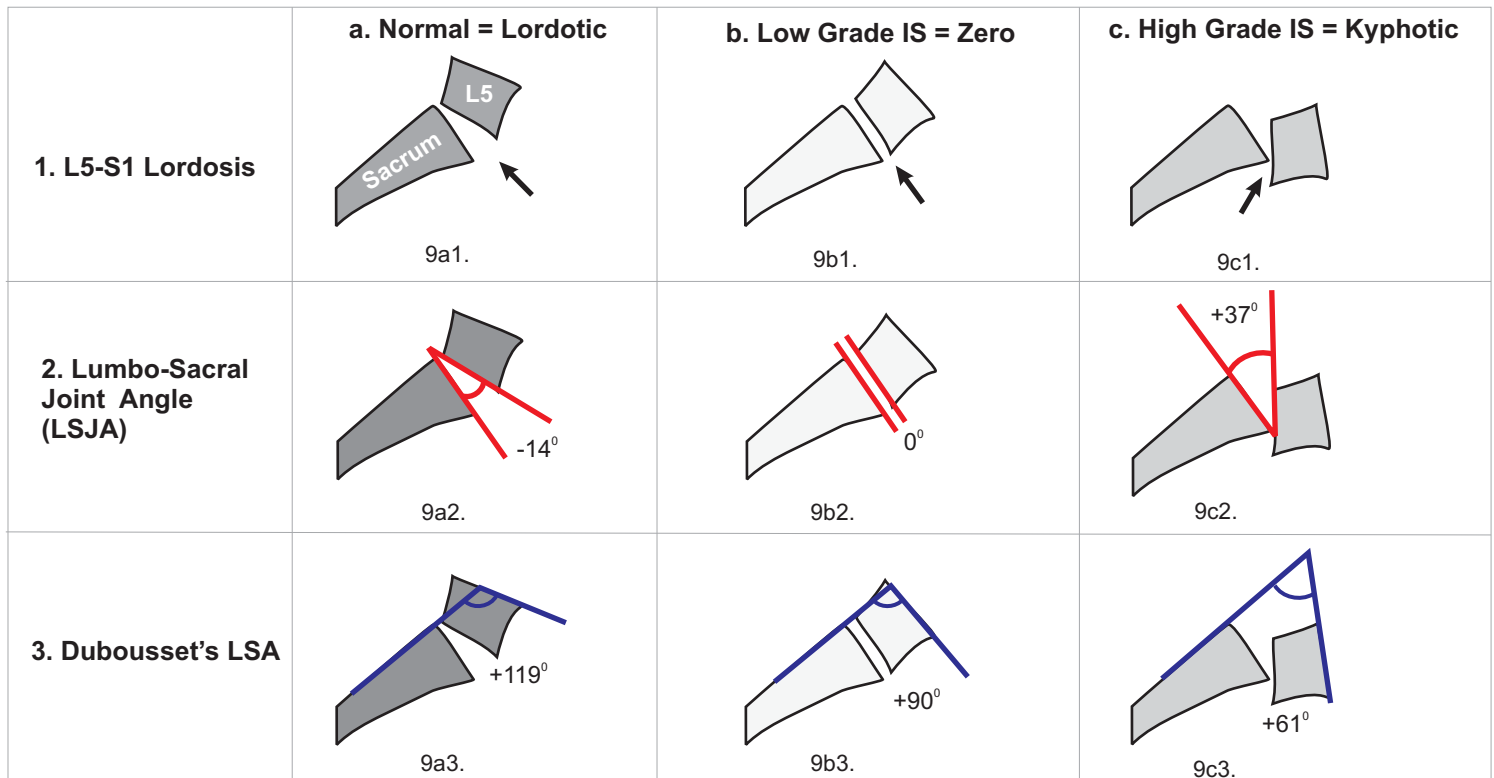


Figure 9. Measuring L5-S1 Lordosis for three orientations: lordotic, zero and kyphotic) using LSJA & Dub LSA.

Lumbo-Sacral Kyphosis (LSK)

Glavas et al (2009) evaluated six different methods for measuring LSA- two of these methods are illustrated in Figure 9. **Figure 9** illustrates 3 possible arrangements for the L5-S1 shape: **9a1-3. Normal Lordotic, 9b1-3 Zero, 9c1-c3 Kyphotic.** The Lumbo-Sacral Joint Angle (LSJA) is always negative for lordotic angles and positive for kyphotic angles. The Lumbo-Sacral Angle (LSA) however, is always positive.

Take Home Messages:

1. The entire spine slips forward on the sacrum for IS not just L5 on S1.
2. Pelvic tilt and lumbo-sacral kyphosis predict Health-Related Quality of Life (HRQoL) measurements better than slip grading.
3. L5-S1 can descend toward kyphosis while simultaneously L1 to L5 ascends into lordosis. And, L5-S1 kyphosis is positively and linearly correlated with the degree of Slip.
4. L5-S1 descent toward kyphosis, has been reported for chronic low back pain some 20 years ago and very recently (Jackson & McManus 1994, Chaleat-Valayer et al 2011).
5. **HYPOTHESIS:**
"L5-S1 kyphosis is the primary driving force for IS, & all Low Back Pain." *

Please contact me for references.

Dear Doctor,

I am writing a book about the kinematics of low back pain. I wanted to share with you some of my literature research at this time. Part of this research involves sagittal alignment of the spine (i.e. simply posture). It turns out that Sagittal Alignment not only predicts the successful outcome for surgical management of Scoliosis and Spondylolisthesis deformities but it also defines the patient quality of life or rather suffering with these conditions and may even define one etiology for chronic low back pain.

Newsletters are brief but I wanted to offer a little from the world of **Isthmic Spondylolisthesis (IS)** to inspire a **Local, Adjacent and Global View** of spinal conditions and a reconsideration of **Lumbar Lordosis** as having regional variability instead of being a uniform single entity- i.e. decreased L5-S1 lordosis concurrent with increased L1-L5 lordosis. Please contact me for any questions or articles: rburgess@hugginshospital.org.

All Newsletters: www.efeld.com/news

- 1. The Feldenkrais Method- Medical Application.** A brief introduction to the Feldenkrais Method and its application in medicine.
- 2. “The Snake, the Turtle and the Human Thorax”.**
The Snake is a Rib Cage with a Head and a Tail, while the Turtle's Shell is also a Rib Cage. Humans begin life with a flexible mobile thorax somewhat like the able snake thorax and progress through life toward the rigid turtle shell thorax. The thorax has functional mobility important to trunk action in addition to a role in breathing and protection.
- 3. Exercise your Thorax.** A few exercises for thoracic mobility and awareness.
- 4. Posture versus Posturing.** Posture as a habit of living and life.
- 5. Vertebroplasty- the Rise and Fall of a Convenient Truth: or perhaps a Half Truth!**
Video (Short 6 min or Long =28 min).
- 6. Core Stabilization: Rejected by Science.** The Transversus Abdominis does not act bilaterally and tonically as a stabilizer as claimed, instead it acts like all other muscles to produce movement. Does trunk stabilization actually exist? Probably not as rigidly as the current popular story holds and is practiced. I suggest that we need skilled mobility not rigid stability.
- 7. Isthmic Spondylolisthesis - An Introduction & Hints for Low Back Pain.**
 - A review of basic concepts: Newsletter.
 - IS Introduction I: A Spinal Story: (Video 10.45 min).

Appendix

Labelle et al 2004:

Linear Relationship significant and positive for Slip Grade and Lordosis, Pelvic Tilt, Sacral Slope & Pelvic Incidence and significant and negative for Thoracic Kyphosis.

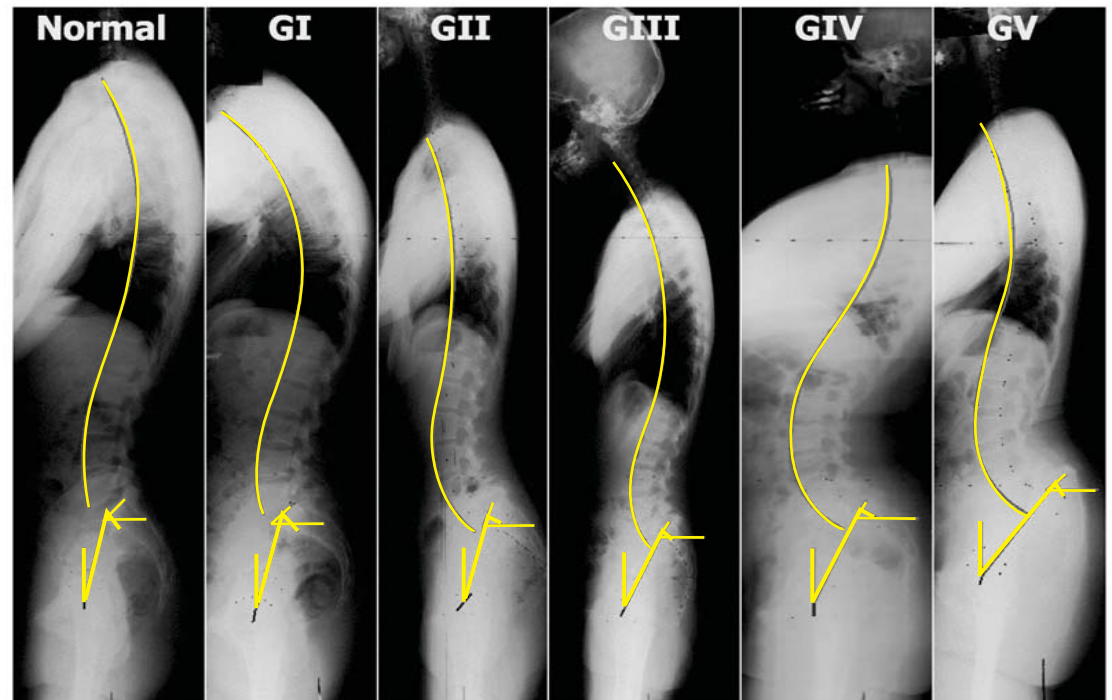
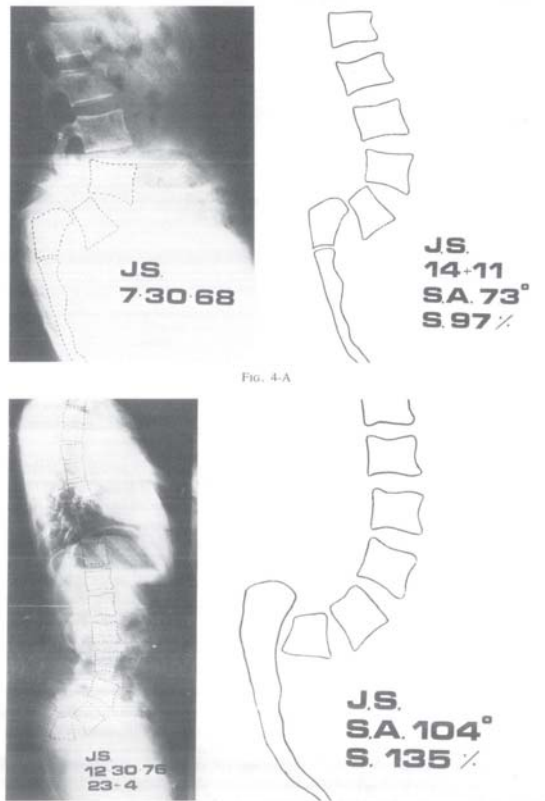


Figure 3. Examples of changes in spinal and pelvic parameters from normal to Grade V spondylolisthesis

Boxall et al 1979

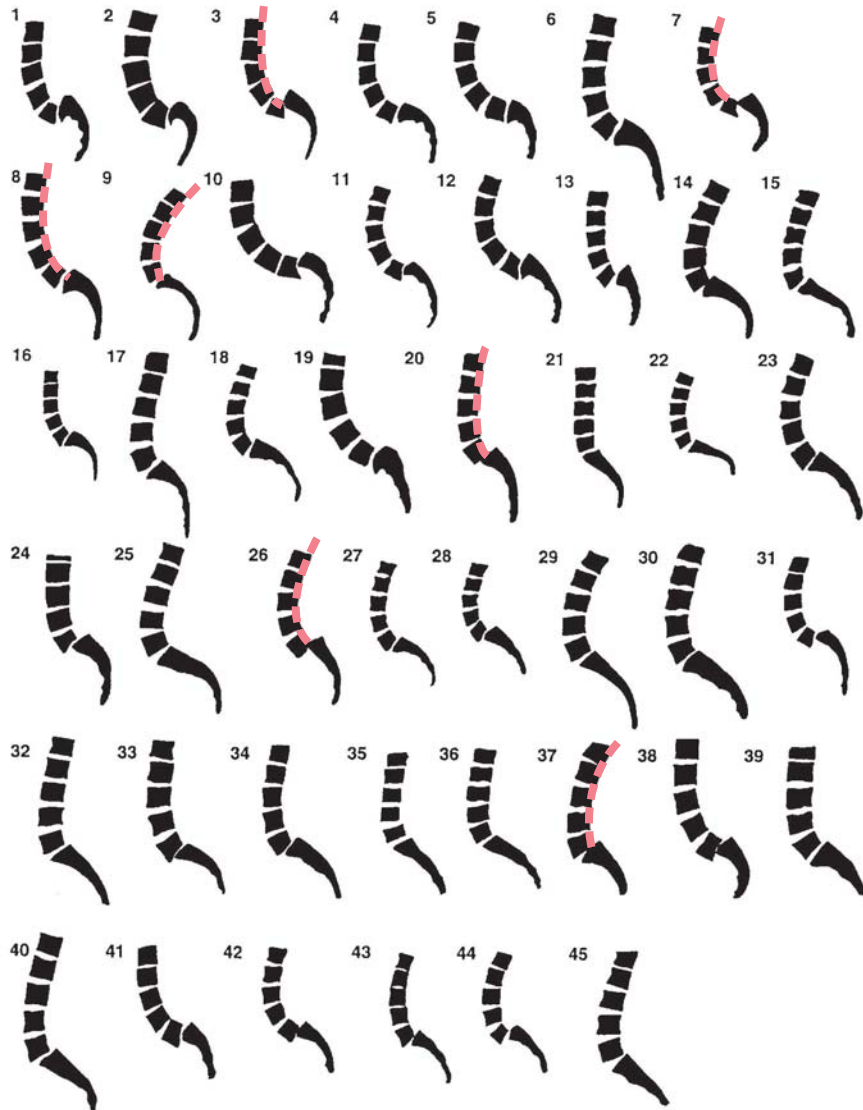
Management of severe spondylolisthesis in children and adolescents. Observe preservation of L1-L5 lordosis versus L5-S1 kyphosis. Note JS's progression of Slip from 97% to 135% in 10 years. Also obvious- a vertical sacrum and S1 endplate rounding.

TABLE I LABELLE ET AL 2004: RADIOGRAPHIC VARIABLES IN THE NORMAL AND SPONDYLSTHESIS POPULATION

variables	n	Normals	Spondylolisthesis	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
PI	Mean	51.8	71.6	57.7	66	78.8	82.3	79.4
SS	Mean	39.7	49.4	43.9	49.8	51.2	48.5	45.9
PT	Mean	12.1	22.2	13.8	16.2	27.6	33.9	33.5
LL	Mean	42.7	66.0	51.1	61.1	71.6	83.1	71.5
TK	Mean	47.5	38.9	42.2	41.3	36.1	38.2	33.4
SI*	Mean	50				44	38	22

* SI = Sacral Inclination- from Jackson & McManus 1994 (Normals) and Boxall et al 1979 (Grade 3-5)= "Vertical Sacrum" (Sacral Inclination is a forgotten measurement but appears as "vertical sacrum" very frequently in the literature. Look closely at the above figure- what is assessment of the SI angle for Normal vs. GI-II and then GIII-V).

Appendix



Antoniades et al 2000

45 Spondylolisthesis silhouettes:

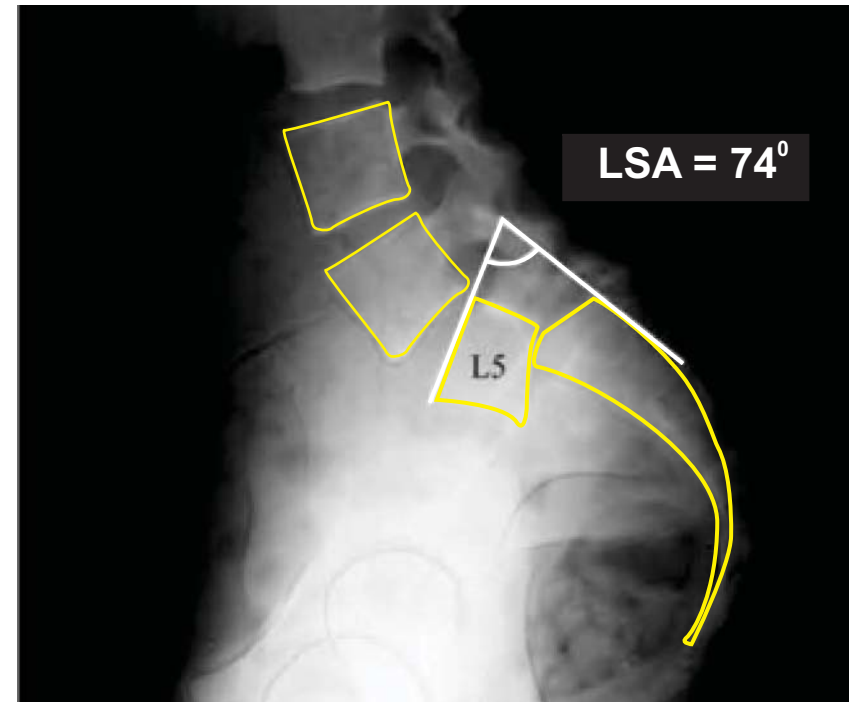
Note that the integrity of the lumbar spine from L1-L5 is maintained in L5 IS.
Look closely at dotted lines on 3,7,8,9,20,26,37. Increased lumbar lordosis- Cause or Consequence?

Observe the increasing sacral kyphosis with increasing Slip. Antoniades found sacral kyphosis to be significantly correlated with sacral slopl, lumbar lordosis, lumbar index and percent slip.

Vialle et al 2007 Lumbo-Sacral Angle (LSA). L5-S1 loses Lordosis and becomes Kyphotic.

LSA = angle between the line through the superior endplate of L5 and the line through the posterior border of S1.
Lumbo-Sacral Kyphosis = major deformity
- Cause or Consequence?

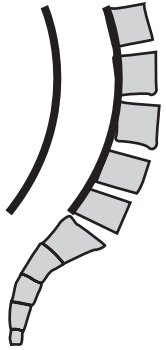
Vialle et al found a significant positive correlation between lumbo-sacral kyphosis (LSK) and slip.



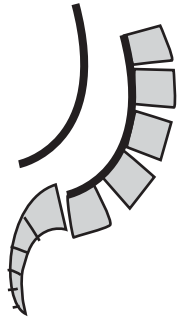
Spondylolisthesis:

Slip, Lordosis, LumboSacral Kyphosis, Sacral Kyphosis & Pelvic Tilt

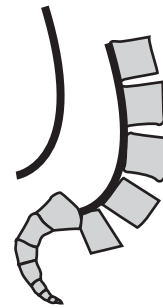
Normal



Slip Grade 2



Slip Grade 4

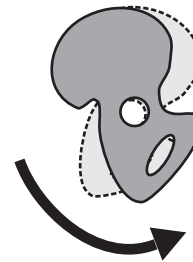
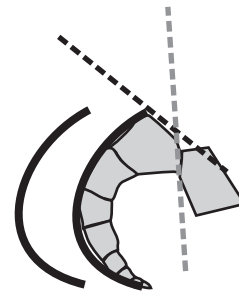
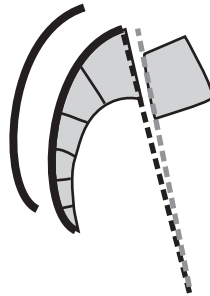
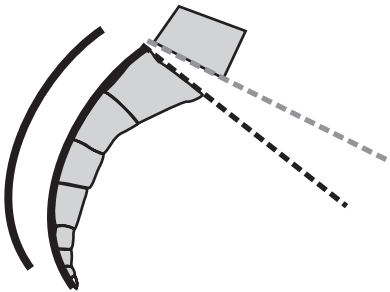


increased lumbar lordosis
(lumbar spine is more arched)

increased lumbosacral kyphosis
(L5-S1 becomes flexed, kyphotic)

increased sacral kyphosis
(sacrum more curved and smaller)

decreased sacral inclination
(sacrum becomes more vertical)



increased posterior pelvic tilt
(pelvis becomes retroverted)