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BARCELONA SCOLIOSIS PHYSICAL THERAPY SCHOOL

Adult Spinal deformity: Definitions, Clinical and Radiological Aspects

MANUEL RIGO MD, PhD

BARCELONA I SPAIN

info@bspts.net
www.bspts.net

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BARCELONA SCOLIOSIS PHYSICAL THERAPY SCHOOL

Manuel Rigo MD, PhD (Barcelona, Spain)

Not totally clearly defined conditions under different names. Lack of general consensus

Adult Scoliosis

Defined as a curvature in the coronal plane of 10 degrees or more in an skeletally mature patient (SRS beyond 17 years and 11 months)

Includes theoretically any type of scoliosis developed during growth, beyond the age of 17 years and 11 months.

Degenerative 'De Novo' Scoliosis (mostly lumbar/THL)

Adult Scoliosis

1) EOS (Infantile and Juvenile)
2) LOS (Adolescent)

- **Idiopathic**
- Neuromuscular
- Congenital
- Syndromic

3) Degenerative 'de novo' Scoliosis

Adult Scoliosis

J Child Orthop (2013) 7:37–41
DOI 10.1007/s11832-012-0462-7

CURRENT CONCEPT REVIEW

Natural history of adolescent idiopathic scoliosis: a tool for guidance in decision of surgery of curves above 50°

Aina J. Danielsson

Table 2 Summary of risk for negative outcome in terms of various variables for idiopathic scoliosis

Outcome variable	Increased risk or prevalence?	If?
Mortality	No increased risk	
Health impairment	Risk for respiratory failure after 20 years IF	Curve size >110° AND VC % predicted <45 %
Shortness of breath	Increased risk IF	Curve size >80° OR large degrees of rotation
Curve progression	Risk for progression for	Single thoracic curve 50–75° <1°/year
Back pain	Increased prevalence, but mostly mild/occasional	Lumbar curves not worse
Quality of life and function	As the normal population	
Cosmetic problems	Not a problem in most patients	

Adult Scoliosis

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CURRENT CONCEPT REVIEW

Natural history of adolescent idiopathic scoliosis: a tool for guidance in decision of surgery of curves above 50°

Aina J. Danielsson

Collis DK and Ponseti IV (1969) **Long term follow-up of patients with idiopathic scoliosis not treated surgically**. *J Bone Joint Surg* [Am] 51:425-445

Weinstein SL, Zavala DC, Ponseti IV (1981) **Idiopathic Scoliosis: Long term follow-up and prognosis in untreated patients.** *J Bone Joint Sur* [Am] 63:702-712

The Natural History of Adolescent Idiopathic Scoliosis

Weinstein, Stuart L. MD

Journal of Pediatric Orthopaedics: July 2019 - Volume 39 - Issue - p S44–S46

In total, 68% of the major curves in our Iowa cohort of untreated patients progressed after skeletal maturity. In general, major curves <30 degrees at skeletal maturity tended not to progress, regardless of the curve pattern. Major curves measuring between 50 degrees and 75 degrees at maturity, particularly thoracic curves, progressed the most. Major curves with both thoracic and lumbar involvement tended to balance with age and maintain coronal compensation.

Adult Scoliosis

J Child Orthop (2013) 7:37–41
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CURRENT CONCEPT REVIEW

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Back Pain

CONCLUSIONS

The summary findings of this unique lifetime natural history of AIS patients provides patients and parents a solid evidence base upon which to make informed decisions. By closely studying this group of patients for >50 years, we have learned that patients with untreated AIS can function well as adults, become employed, get married, have children, and grow to become active older adults. Unfortunately, untreated scoliosis may lead to increased back pain and pulmonary symptoms for patients with large thoracic curves. Patients with untreated AIS can also develop substantial deformity, and the cosmetic aspect of this condition cannot be disregarded. The physical outcomes demonstrated in this cohort born many decades ago can be used to predict the likely experience of future patients, although we doubt that a contemporary cohort (and their peers) would be as accepting of deformity as these patients have been.[14]

Adult Spinal Deformity (ASD)

All the Adult Scoliosis types

Sagittal Plane Deformities (Regional)

Sagittal deformities developed during growth
(like Scheuermann, Isthmic Spondylolisthesis)

Iatrogenic Flat Back after surgery

Degenerative Spine associated to sagittal Spino-Pelvic imbalance and degenerative Spondylolisthesis.

Adult Spinal Deformity (ASD)

All the Adult Scoliosis types

Sagittal Plane Deformities
Local

- Spinal stenosis and radicular compression
- Lateral Listhesis (Rotatory Listhesis)
- Sagittal instability

Max Aebi differentiates four categories or types

Type 1) Primary Degenerative Scoliosis
Type 2) Adolescent idiopathic scoliosis of the thoracic and/or the lumbar spine, which progresses in adult life, and is frequently combined with secondary degeneration and/or imbalance
Type 3) Secondary Adult Scoliosis.
3a in the context of an oblique pelvis, e.g. due to LLD, or Hip pathology or as a secondary curve in idiopathic, neuromuscular and congenital scoliosis, or asymmetrical anomalies at the lumbosacral junction.
3b in the context of a metabolic bone disease combined with asymmetric arthritis disease and/or vertebral fractures

Adult Spinal Deformity – Functional Disability

Symptoms ⟷ QoL

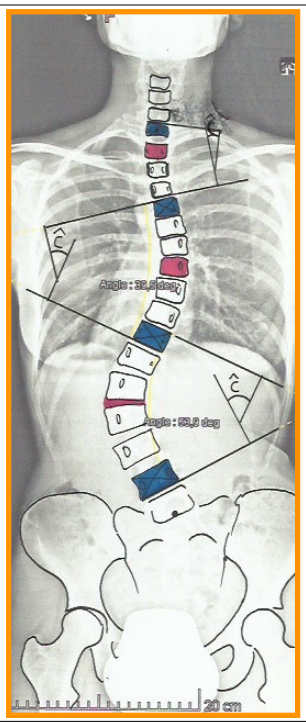
- Back/Neck Pain
- Leg/Arm Pain
- Neurological deficit
- Spinal muscle fatigue and tension
- Reduced ambulatory function
- Breathing impairment

- SRS-22r
- SF-36
- ODI
- Others

Clinical/Radiological Correspondence

- Direct Observation (Global, Trunk, Limbs, Regional)
- Signs (Exploration: Musculoskeletal, Neurologic, Pain Trigger Points and Motion)
- Observation and Assessment of Clinical Photos
- Assessment Throughout Surface Topography
- Observation and Assessment of Dynamics

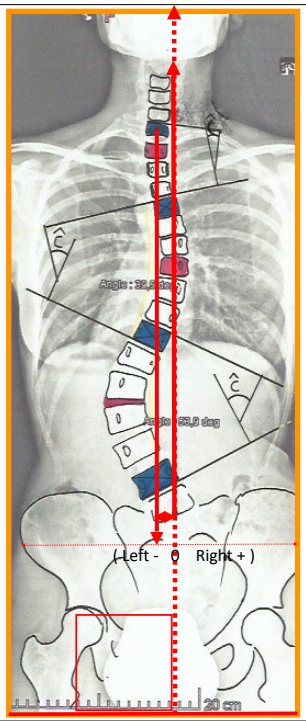
- Complementary Explorations others than Radiographs (MRI, CT, EMG, Breathing, etc.)
- Diagnostic Interventions (Facet Injections, etc.)



ASD CORONAL PLANE

COBB Angle

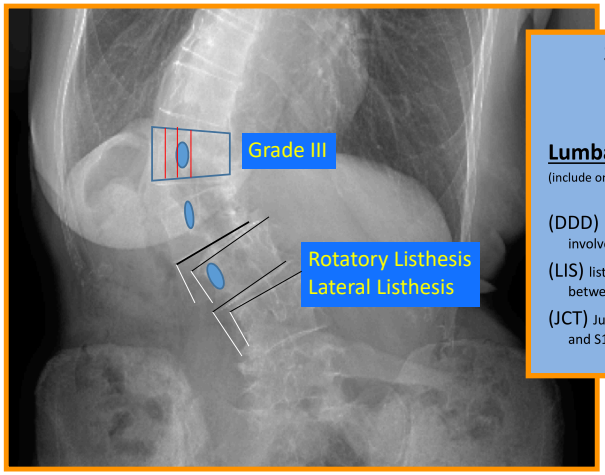
Proximal Thoracic
Main Thoracic
Lumbar / Thoracolumbar



ASD CORONAL PLANE

CSVL
C7PL
T1
Coronal Compensation/Decompensation
(Balance / Imbalance)

Nash and Moe Rotation and Segmental Instability



SRS Classification for Adult Spinal Deformity

Lowe T et al Spine 2006 31(19S):S119-S125

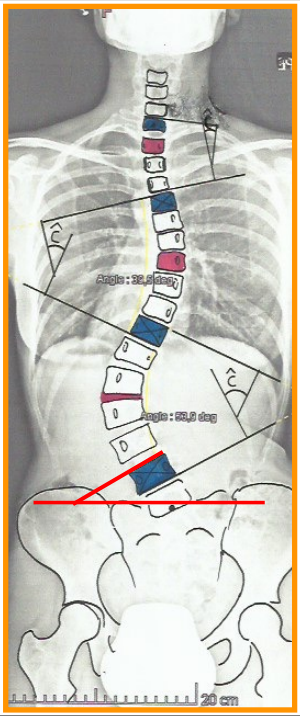
Lumbar degenerative modifier

(include only if present)

(DDD) ↓disc height and facet arthropathy based on X-ray include lowest involved level between L1 and S1

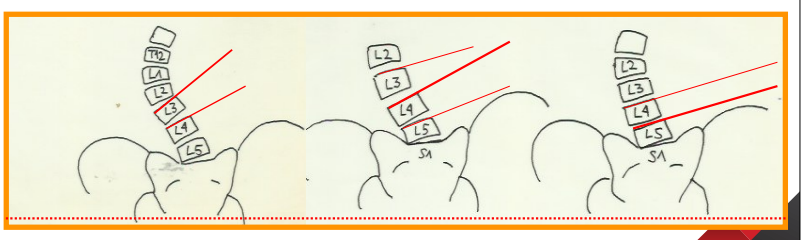
(LIS) listhesis (rotational, lateral antero, retro) ≥ 3 mm include lowest level between L1 and L5

(JCT) Junctional L5-S1 curve ≥ 10º (intersection angle superior endplates L5 and S1)



ASD CORONAL PLANE

COBB Angle
Fractional
Lumbo-sacral (L5/L4L3 TILT)



Adult Scoliosis

Weinstein study: When they knew they have scoliosis, back pain was more common than in general population but not related to curve magnitude

Kostuik study: When they mostly did not know about their diagnose, back pain was not more common than in normal controls but there was an association between severity of pain, disability, and curve magnitude (Idiopathic Lumbar Curves)

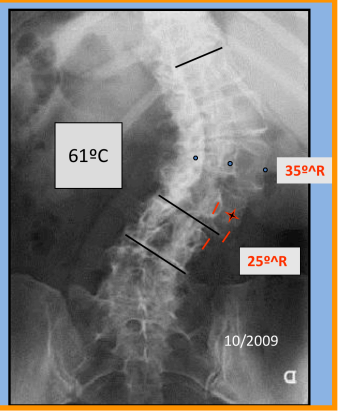
Coronal and Sagittal Plane Spinal Deformities Correlating with Back Pain and Pulmonary Function in Adult Idiopathic Scoliosis

ROGER P. JACKSON, MD,* EDWARD H. SIMMONS, MD,† and DANIEL STRIPINIS, MA, MSc‡

XX Century Coronal + Sagittal + TRANSVERSAL

Jackson RP et al (Spine 1989)

- *Scoliosis >40º*
- *Kyphosis>50º*



Highest Correlation

Rotation with Scoliosis
r = 0.7 p < 0.0001
Rotation with Pain
r = 0.59 p < 0.0001

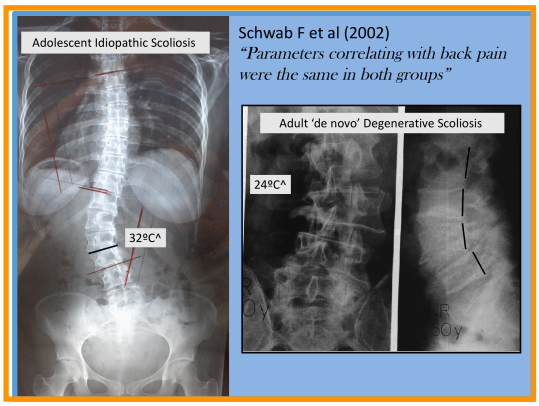
SPINE Volume 27, Number 4, pp 387–392
©2002, Lippincott Williams & Wilkins, Inc.

Adult Scoliosis

A Quantitative Radiographic and Clinical Analysis

Frank J. Schwab, MD,*† Vinson A. Smith, MD,* Michele Biserni, MD,‡ Lorenzo Gamez,§
Jean-Pierre C. Farcy, MD,*† and Murali Pagala, PhD‖

XXI Century CORONAL + SAGITTAL PLANE



Author's opinion:

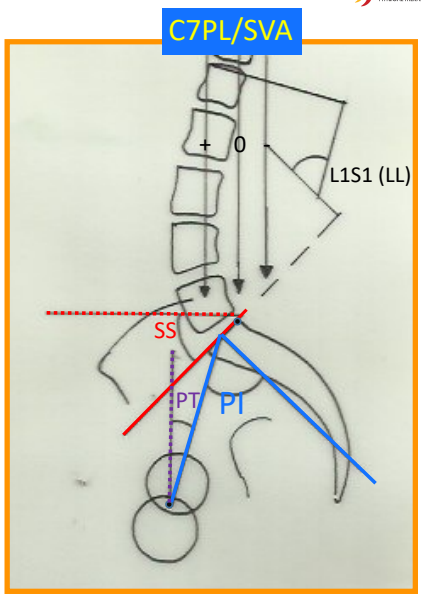
'Common end pathway
*- **degenerative instability and unfavorable lumbar vertebral alignment** –*
*Is related to symptoms rather than the degree of the curvature and the **cause of the original scoliosis'***

Adult Scoliosis

XXI Century SAGITTAL PLANE

Pelvic Indexes PI = PT + SS
PI – LL mismatch

During
Legaye and Duval Beaupere

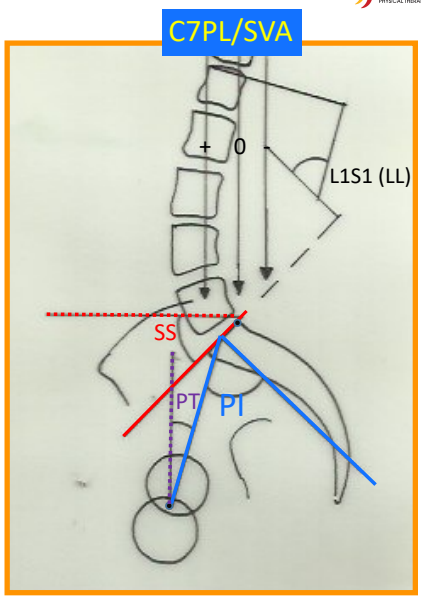


Adult Scoliosis

XXI Century
Schwab F et al (2006-2011)

Radiological Parameters predictive of an ODI 40%

PI – LL > 11º PT > 22º and SVA > 46 mm



Schwab F, Ungar B, Blondel B, et al. Scoliosis Research Society-Schwab adult spinal deformity classification: a validation study. *Spine*. **2012**; 37(12): 1077-1082

Coronal Curve Types	Sagittal Modifiers
T: Thoracic only With lumbar curve < 30º	PI minus LL 0: within 10º +: moderate = 10º - 20º ++: marked > 20º
L: TL /Lumbar only With thoracic < 30º	Global Alignment 0: SVA < 4 cm +: SVA = 4 – 9.5 cm ++: SVA > 9.5 cm
D: Double curve With T and TL/L > 30º	Pelvic Tilt 0: PT < 20º +: PT = 20 – 30º ++: PT > 30º
N: No major coronal deformity All coronal curves < 30º	

Harima H, Carreon LY, Glassman SD Chapter 17. Section V Non Scoliotic Spine. Sagittal Balance of the Spine, from normal to pathology: a key for treatment strategy. Roussouly P., Pinheiro-Franco JL., Labelle H. Gehrchen M. Thieme Medical Publishers, Inc. ISBN 978-1-62623-732-2

Limitations:

Lack of clinical evidence
No dynamics
Influence of aging and ethnicity

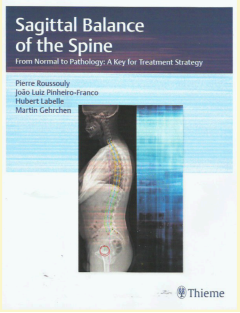
50 y
Stricter threshold values for youngers
More tolerant for older

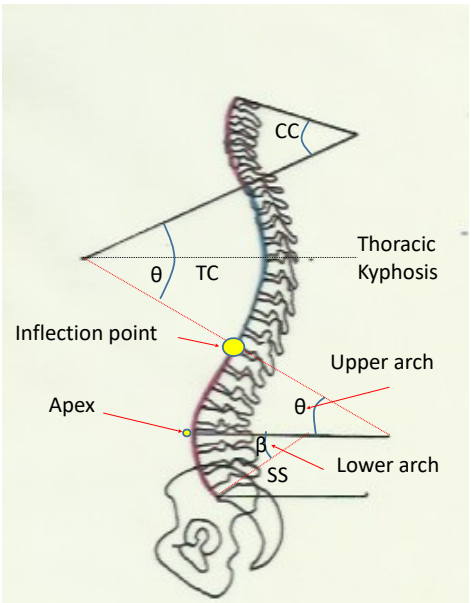
Functional spinal sagittal segmentation based on the inflection point.

(Berthonnaud et al J Spinal Disord Tech. 2005; 18(1): 40-47)

Pierre Roussouly

ISBN 978-11-62623-732-2
Also available as e-book
eISBN 978-1-62623-733-9

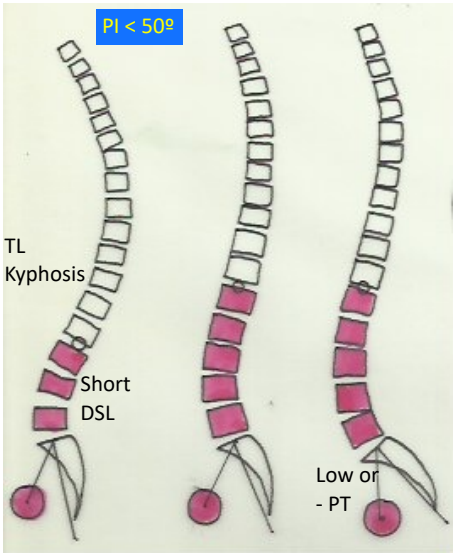


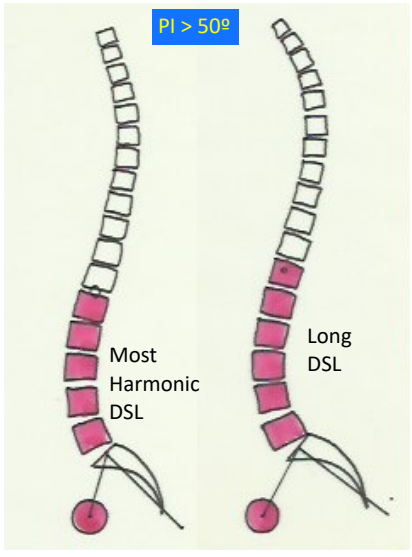


Reproduction from the original Figure

β = SS

Original Roussouly Types. Roussouly's Classification according to the Pelvic Incidence, the Sacral Slope and the extension and shape of the Distal Spinal Lordosis (DSL)





Type 1 Type Type 3AP Type 3 Type 4

Types 1 and 2

SS < 35º

Type 3

35º ≤ SS ≤ 45º

Type 4

SS > 45º

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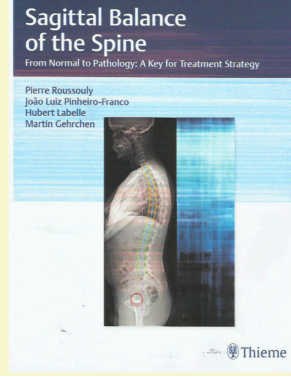

Table 7.1 Regional parameters of sagittal balance reported for the normal pediatric population in different age groups

Age group	Fetal	Infantile	Juvenile	Adolescent
Age	28.7 ± 6.2 weeks (19–40 weeks)	38.7 ± 23.1 months (12–108 months)	8.1 ± 2.0 years (3–10 years)	13.6 ± 1.9 years (>10 and <18 years)
Pelvic incidence	30.6° ± 5.6° (20°–40°)	39.5° ± 8.9° (22°–64°)	43.7° ± 9.0° (23°–84°)	46.9° ± 11.4° (22°–87°)
Pelvic tilt	—	—	5.5° ± 7.6° (-13°–40°)	7.7° ± 8.3° (-12°–34°)
Sacral slope	—	—	38.2° ± 7.7° (21°–56°)	39.1° ± 7.6° (18°–65°)
Thoracic kyphosis	—	—	42.0° ± 10.6° (8°–65°)	45.8° ± 10.4° (9°–84°)
Lumbar lordosis	—	—	53.8° ± 12.0° (16°–86°)	57.7° ± 11.1° (20°–102°)

Table 7.2 Global parameters of sagittal balance reported for the normal pediatric population

Age group	Juvenile	Adolescent	All
Age	8.1 ± 2.0 years (3–10 years)	13.6 ± 1.9 years (>10 and <18 years)	12.1 ± 3.1 years (>10 and <18 years)
Spinosacral angle	130.4° ± 9.0° (103°–154°)	132.7° ± 8.0° (109°–159°)	132.1° ± 8.4° (103°–159°)
Spinal tilt	92.2° ± 5.7° (76°–107°)	93.5° ± 4.1° (83°–106°)	93.2° ± 4.6° (76°–107°)

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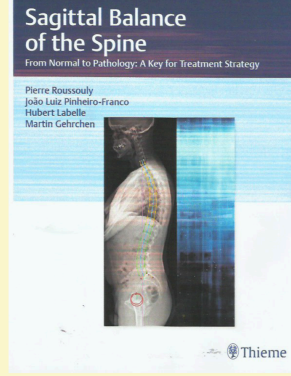

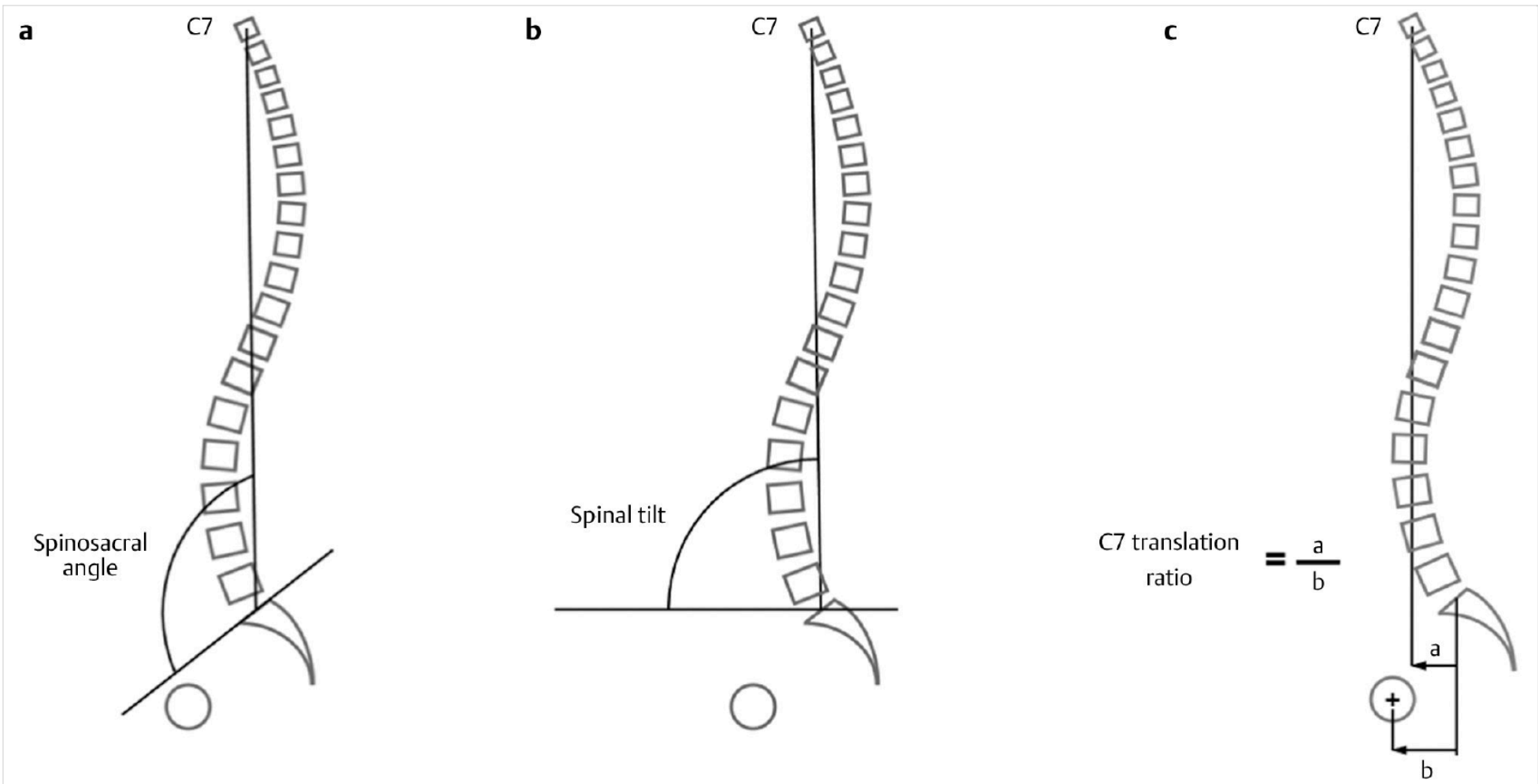

Fig. 7.2 Measurement of global sagittal balance. (a) Spinosacral angle: angle subtended by the upper sacral endplate and the line from the center of C7 vertebral body to the center of upper sacral endplate. (b) Spinal tilt: angle subtended by the horizontal line and the line from the center of C7 vertebral body to the center of upper sacral endplate. A value greater than 90° indicates that the center of C7 vertebral body is behind the center of the upper sacral endplate, whereas for values less than 90°, the center of the C7 vertebral body is in front of the center of the upper sacral endplate. (c) Instead of using a pure distance like SVA (sagittal vertebral axis) that needs precise X-ray calibration, we prefer to use the ratio between two distances (a/b, for example).

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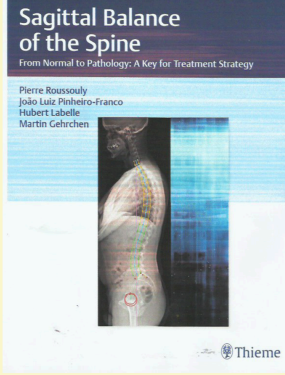

Table 7.4 Parameters of sagittal balance reported for the normal adult population in different age groups

Age group	>18 and <30 years	30–39 years	40–49 years
Pelvic incidence	52.3° ± 10.9° (22°–88°)	52.1° ± 10.4° (27°–89°)	53.2° ± 9.3° (32°–76°)
Pelvic tilt	12.5° ± 6.7° (-6°–33°)	12.1° ± 6.6° (-7°–28°)	12.8° ± 6.8° (-3°–28°)
Sacral slope	39.8° ± 8.0° (17°–63°)	40.0° ± 7.5° (25°-62°)	40.5° ± 7.3° (23°–56°)
Thoracic kyphosis	48.4° ± 9.3° (16°–74°)	49.7° ± 10.4° (22°–74°)	49.5° ± 10.7° (19°–72°)
Lumbar lordosis	54.5° ± 9.9° (20°–84°)	55.1° ± 10.4° (33°–84°)	56.7° ± 11.2° (31°–79°)
Spinosacral angle	130.7° ± 8.0° (102°–153°)	131.1° ± 7.4° (115°–148°)	131.7° ± 8.1° (112°–149°)
Spinal tilt	90.9° ± 3.1° (80°–101°)	91.0° ± 3.3° (82°–100°)	91.3° ± 3.4° (82°–101°)

Age group	50–59 years	>60 years	All
Pelvic incidence	53.6° ± 10.3° (25°–85°)	52.7° ± 10.5° (33°–78°)	52.6° ± 10.4° (22°–89°)
Pelvic tilt	14.8° ± 6.7° (0°–32°)	16.1° ± 6.9° (0°–32°)	13.0° ± 6.8° (-7°–33°)
Sacral slope	38.9° ± 7.5° (25°–62°)	36.7° ± 9.3° (14°–63°)	39.6° ± 7.9° (14°–63°)
Thoracic kyphosis	52.7° ± 9.9° (28°–79°)	56.5° ± 12.0° (21°–81°)	50.1° ± 10.4° (16°–81°)
Lumbar lordosis	54.3° ± 10.3° (33°–83°)	53.4° ± 12.1° (29°–84°)	54.8° ± 10.5° (20°–84°)
Spinosacral angle	128.9° ± 7.9° (113°–151°)	126.7° ± 3.9° (106°–150°)	130.4° ± 8.1° (102°–153°)
Spinal tilt	90.0° ± 3.9° (80°–98°)	90.0° ± 3.9° (77°–97°)	90.8° ± 3.4° (77°–101°)

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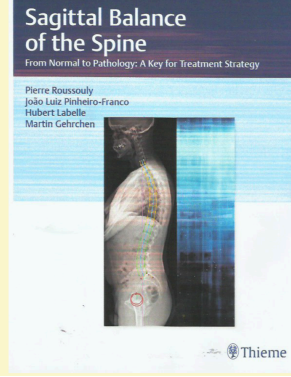
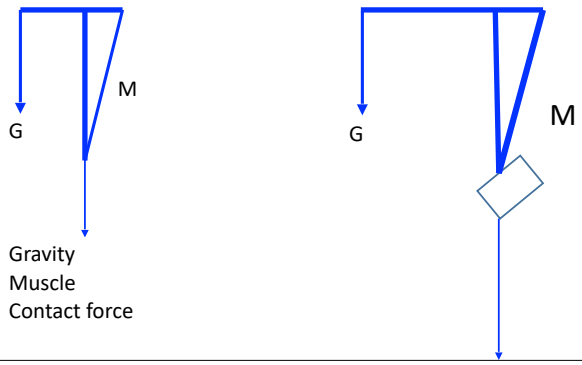


Table 7.7 Comparison of parameters of sagittal balance between normal pediatric and adult populations

Population	Pediatric	Adult
Pelvic incidence	46.0° ± 10.9° (23°–87°)	52.6° ± 10.4° (22°–89°)
Pelvic tilt	7.2° ± 8.2° (-13°–40°)	13.0° ± 6.8° (-7°–33°)
Sacral slope	38.9° ± 7.6° (18°–65°)	39.6° ± 7.9° (14°–63°)
Thoracic kyphosis	44.8° ± 10.6° (8°–84°)	50.1° ± 10.4° (16°–81°)
Lumbar lordosis	56.7° ± 11.4° (16°–102°)	54.8° ± 10.5° (20°–84°)
Spinosacral angle	132.1° ± 8.4° (103°–159°)	130.4° ± 8.1° (102°–153°)
Spinal tilt	93.2° ± 4.6° (76°–107°)	90.8° ± 3.4° (77°–101°)

Local Stresses: Segmental Mechanism of Low Back Pain and Degeneration, and stresses according to spinal orientation – Contact Forces Theory (Chapter 9)

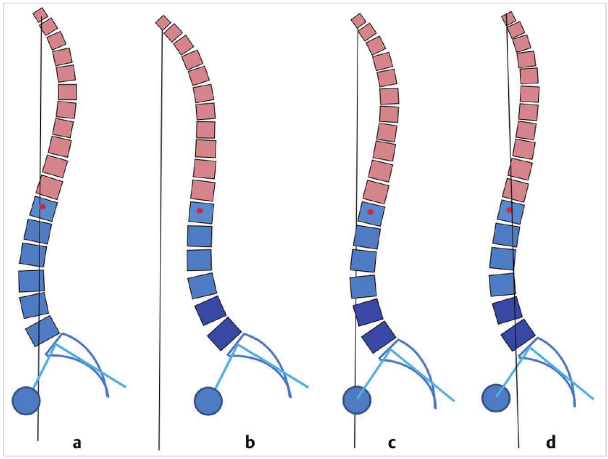
Amer Sebaaly, Joao Luiz Pinheiro-Franco, and Pierre Roussouly



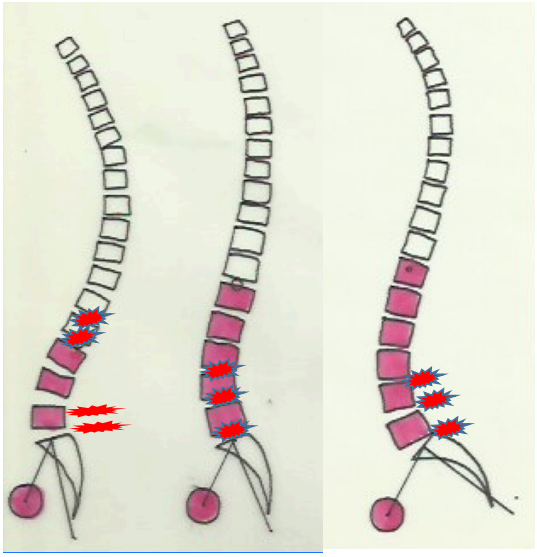
VII Adult Scoliosis (AS)

20 From Pathological to Normal Shapes in Adult Scoliosis

Pierre Roussouly and Amer Sebaaly



Compensatory Mechanisms

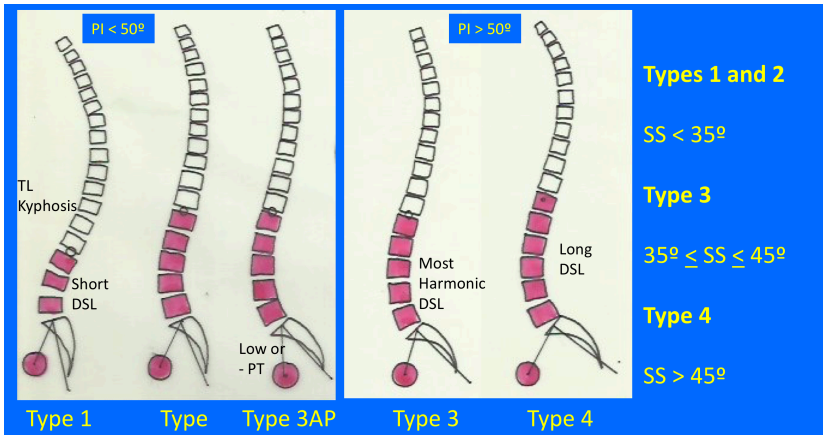


Type 1 Type 2 Type 4

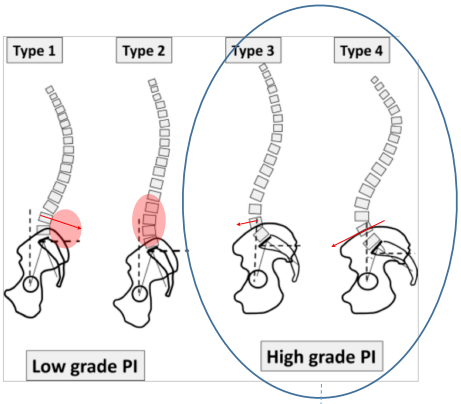
Degenerative local stress localization according to the sagittal Roussouly Type

Original Roussouly Type can be changed by:

1) Any spinal deformity developed during growth
2) Degenerative changes associated with aging
3) Degenerative changes associated to compensatory mechanisms to maintain Sagittal Balance
4) Any adult spinal deformity secondary to other causes



Degenerative Spondylolisthesis (DS) and Spinopelvic Alignment



Roussoully Classification

The shape of lumbar lordosis depends on SS orientation. Type 1 and 2 have SS < 35°; Type 3 has 35° < SS < 45°; Type 4 has SS > 45°. Generally Type 1 and 2 have a low PI and Type 3 and 4 have a high PI

85% of the DS population is Type 3 or 4 with a mean PI of 60º

In SD Population

- The MSL is slightly reduced (-10º)
- Lordosis is mainly reduced at L4S1 and it is compensated in the upper lumbar spine
- The disc degeneration associated with the anterior slippage results in a loss of lordosis, compensated with L1L4 hyper-L
- Global Sagittal balance is typically preserved even with some amount of pelvic compensation
- Most of variations were regional except in the cases of multilevel DS with severe and global lumbar kyphosis

These draws are copied from the original draws published by Barrey CY, Peltier Ch, Rahal AH, Broussoulle Th and Roussouly P. Chapter 13. Degenerative Spondylolisthesis: Does the Sagittal Balance Matter? pp 134-145. In Section V Non Scoliotic Spine. Sagittal Balance of the Spine, from normal to pathology: a key for treatment strategy. Roussouly P., Pinheiro-Franco JL., Labelle H. Gehrchen M. Thieme Medical Publishers, Inc. ISBN 978-1-62623-732-2

How degeneration may affect Spinal Structure

◉ **Type 1** stays in Type 1 or turns into global kyphosis without retroversion

◉ **Type 2** may

- Stay in Type 2
- Turn into type 2 + TK
- Turn into Type 1 (TLK)
- Turn into lumbar kyphosis with compensated thoracic lordosis
- Turn into global Kyphosis without retroversion

◉ **Types 3 and 4** may

- Stay in Types 3 or 4 slightly retroverted
- Turn into retroverted false type 1
- Turn into retroverted false type 2 + TK
- Turn into retroverted false type 2 (compensated hypokyphosis or Global Flat Back)
- Turn into global kyphosis with retroverted pelvis

Obeid Classification according to CM (For surgery)

Table 1 Treatment-oriented classification of coronal malalignment

Main types	Subtypes	Main features
Type 1 Concave CM		Coronal malalignment toward the concavity of the main curve
	Type 1A Main L/TL curve	Main curve with apex between T12 and L4
	Type 1A1 Flexible main L/TL	Main curve is flexible on bending or potentially after posterior release
	Type 1A2 Rigid main L/TL	Main curve is very rigid or fused
	Type 1B Main thoracic curve	Main curve with apex above T12
Type 2 Convex CM		Coronal malalignment toward the convexity of the main curve
	Type 2A Main L/TL curve	Main curve with apex between T12 and L4
	Type 2A1 Normal LS junction	L4–S1 not degenerated and coronally mobile
	Type 2A2 Rigid/degenerated LS junction	L4–S1 degenerated or stiff
	Type 2B Main LS curve	Main curve with apex below L4[a]

European Spine Journal (2019) 28:94–113
https://doi.org/10.1007/s00586-018-5826-3

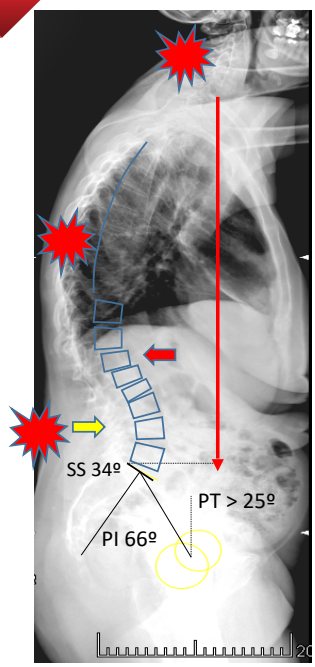
ORIGINAL ARTICLE

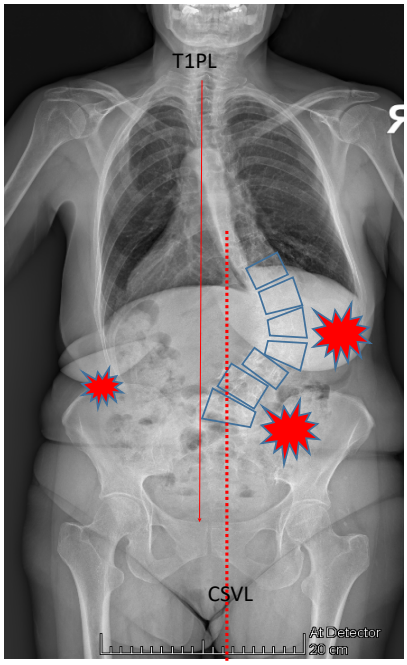
Classification of coronal imbalance in adult scoliosis and spine deformity: a treatment-oriented guideline

Ibrahim Obeid[1] · Pedro Berjano[2] · Claudio Lamartina[2] · Daniel Chopin[3] · Louis Boissière[1] · Anouar Bourghli[4]

Received: 29 August 2018 / Accepted: 6 November 2018 / Published online: 20 November 2018

- Stiffness of the main coronal curve:
  - Flexible
  - Rigid or fused
- Coronal mobility of the lumbosacral (LS) junction
  - Mobile
  - Rigid
- Degeneration of the lumbosacral junction
  - Absent or mild
  - Moderate or advanced (Table 1)





61 y old women

Original Roussouly Type 4
Current Retroverted Type 2 + TK

Kyphosant TL scoliosis
TL discopathy
Pelvis Retroversion
Low Hyper-lordosis maldistribution
Coronal Rigid TL Major curve
Obeid 1 A2
Schwab PT>25 PI-LL 10-20 SVA>9.5
Imbalanced from TL and T Kyphosis
Chronic Back Pain
Leg Pain only standing
No neurological deficit
ODI > 40% SRS-22 < 3 all domains

Adult Spinal deformity:
Definitions, Clinical and Radiological Aspects

RIGO CONCEPT
BARCELONA SCOLIOSIS PHYSICAL THERAPY SCHOOL

Manuel Rigo MD, PhD (Barcelona, Spain)

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"LOOKING AFTER THE PERSON, NOT JUST THE CURVE"

MANUEL RIGO, MD

info@bspts.net
www.bspts.net