



**GLOBUS
MEDICAL**

The Importance of Sagittal Balance
Mr Michael J H McCarthy
Consultant Spinal Surgeon
University Hospitals of Wales, UK

Fusion Portfolio Minimally Invasive Surgery Biomaterials Motion Preservation

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Spinal Surgery

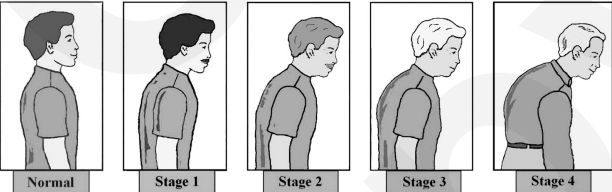
It's like removing your bendy spine..
and replacing it with a metal pole!



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Life is a Kyphosing Event!

Normal Stage 1 Stage 2 Stage 3 Stage 4



Causes of Sagittal Malalignment

- Congenital anomaly
- Ankylosing spondylitis
- Iatrogenic:
 - Flatback Syndrome
 - Kyphotic Decompensation Syndrome
 - Adjacent segment pathology
- Post-traumatic
- Infectious
- Neoplastic
- Osteoporotic Compression Fractures
- Degenerative Spinal disorders

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Iatrogenic Causes

- Posterior distraction instrumentation
- Anterior compression instrumentation
- Poor sagittal alignment in the instrumented segment
- Breakdown above long fusion



90/100GRID



The 7 Ps

- Proper
- Planning and
- Preparation
- Prevents
- P
- Poor
- Performance

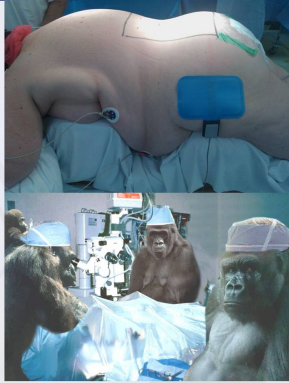


**Attention to detail
Never let your guard down**

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The other 3 Ps

- Personality - Patient
- Personality - Pathology
- Personality - Practitioner

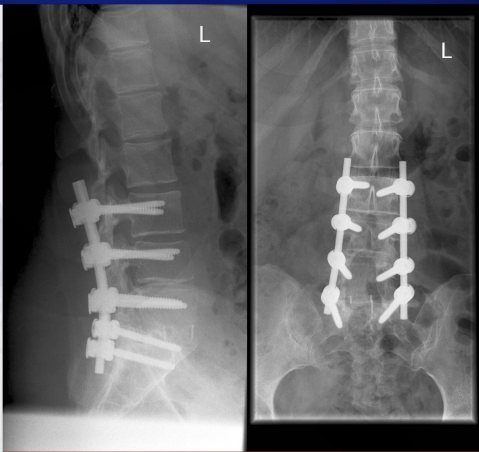


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Case Example

- 64 year old female
- Multiple previous surgeries
- Chronic LBP
- Unable walk upright

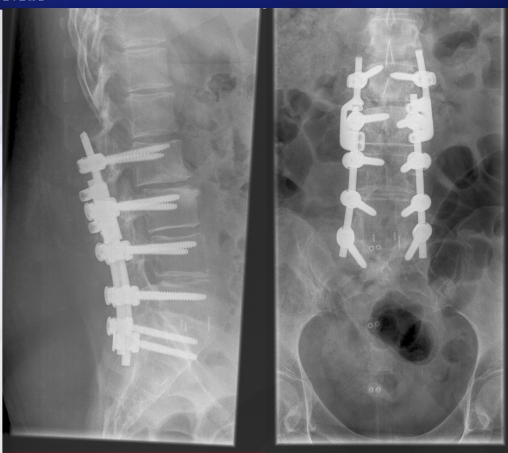
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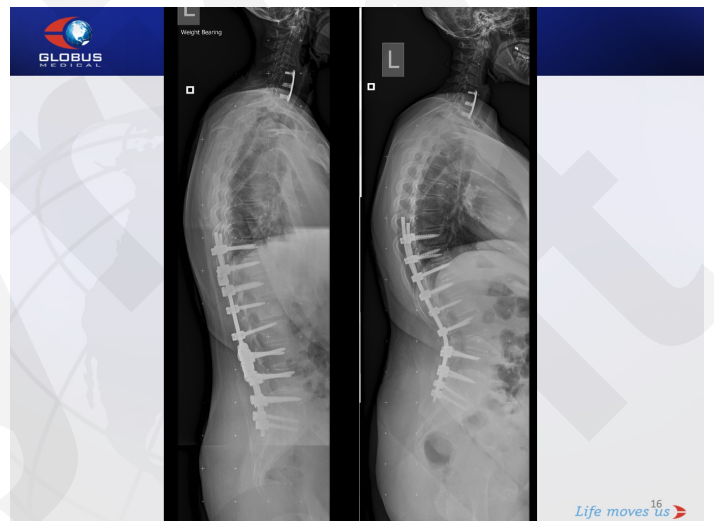
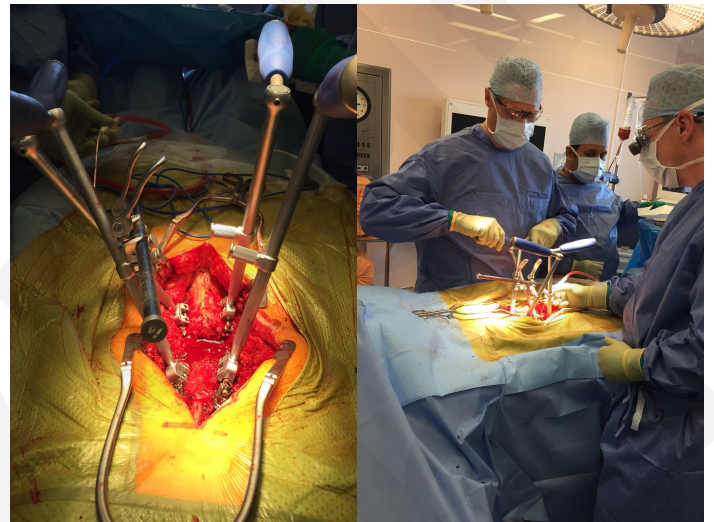
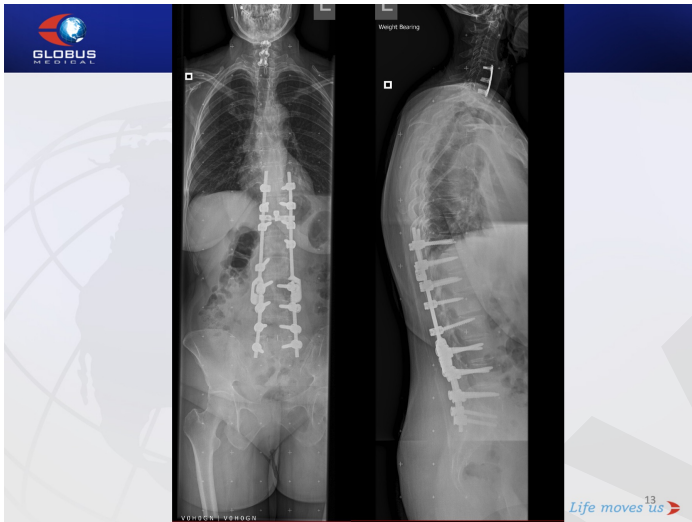
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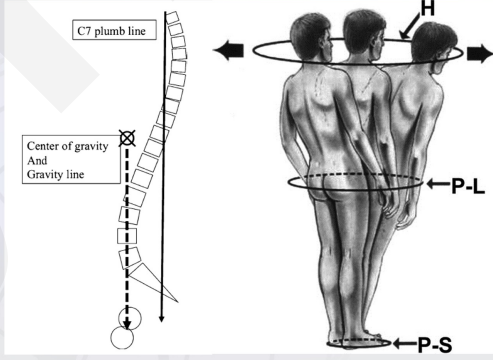


Sagittal Balance Parameters

- Pelvic Incidence
- Pelvic Tilt
- Sacral Slope
- Lumbar Lordosis
- Thoracic Kyphosis
- Cervical Lordosis
- Centre of Gravity
- C7 Plumb Line
- Sagittal Vertical Axis
- Chin Brow Vertical Angle
- Kyphosis Tilt Angle
- Sacro Femoral Distance
- T9 Tilt (body centre mass level)
- T1 Spino Pelvic Inclination
- T1 Pelvic Angle
- T1 Sagittal Angle
- Global Tilt
- GAP Score
- Etc etc...



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- CoG and gravity line goes through hips
- C7PL always behind CoG in a balanced spine

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J. Legaye
G. Duval-Beaupère
J. Hecquet
C. Marty

Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves

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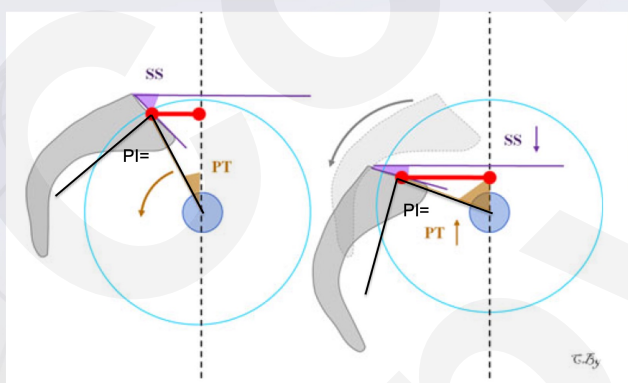
SS sacral slope
PT pelvis tilt
I incidence

$$PI = PT + SS$$



Fig. 10 Pelvic parameters: pelvis tilt, sacral slope, incidence angle.
SS sacral slop, PT pelvis tilt and I incidence

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Pelvic Incidence

- Average 52 to 53 (varies with age, sex and race)
- Important range is 44 to 62

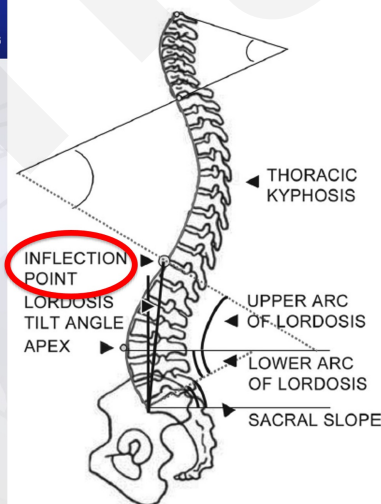
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SPINE Volume 30, Number 3, pp 346–353
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Classification of the Normal Variation in the Sagittal Alignment of the Human Lumbar Spine and Pelvis in the Standing Position

Pierre Roussouly, MD,* Sohrab Gollogly, MD,* Eric Berthonnaud, PhD,† and
Johannes Dimnet, PhD†

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Upper arc = inf arc TK

Lower arc = SS

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Roussouly

Type 1: T:L 80:20, Low grade PI
 Type 2: T:L 60:40, Low grade PI
 Type 3: T:L 50:50, High grade PI
 Type 4: T:L 20:80, High grade PI

- **Sacrum:**
- **Horizontal = High PI**
- **Vertical = Low PI**
- **PI-LL normally within 10°**

Fig. 4 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

ACTA ORTOP BRAS 14(4) - 2006

LUMBAR LORDOSIS: A STUDY OF ANGLE VALUES AND OF VERTEBRAL BODIES AND INTERVERTEBRAL DISCS ROLE

LUZ HENRIQUE FONSECA DIAMASCO¹, SILVIO RICARDO GUERRA CATAPÊ², ANTONIO DORNAL CAMPOS³, HELTON LUIS ANNECIDO DORNEL⁴

	Mean Angle (°)	Standard Deviation	Range (°)	% participation in curvature L1/S1 (range)
L1-L2	-4.99 *	2.9	4.0 to -12.0	8.16 (-8.57 to 24.00)
L2-L3	-6.89 *	2.73	0.0 to -15.0	11.35 (0.00 to 27.27)
L3-L4	-9.25 *	2.54	-2.0 to -20.0	15.38 (3.03 to 30.95)
L4-L5	-12.29 *	3.39	-2.0 to -26.0	20.43 (3.81 to 42.86)
L5-S1	-15.58 *	5.43	-4.0 a -35.0	26.07 (5.80 a 56.52)

(*)Averages different from each other with p<0.001

Tabela 2 - Intervertebral discs measurements

>50% LL @ L4-S1 (21deg vs 28deg)

Eur Spine J
DOI 10.1007/s00586-017-5111-x

ORIGINAL ARTICLE

Classification of normal sagittal spine alignment: refounding the Roussouly classification

Féthi Laouissat^{1,2} · Amer Sebaaly⁴ · Martin Gehrchen³ · Pierre Roussouly²

Type 1: 12% SS<35, PI 39, Inflexion L3/4, Short Hyperlordosis 51, Long Kyphosis
 Type 2: 16% SS<35, Low grade PI 48, Longer lordosis 64
 Type 3AP: 22% SS<35, PI 41, Inflexion L1/2, Flat Long Lordosis 48
 Type 3: 30% 35<SS<45, PI 53, Inflexion T12/L1, LL 58
 Type 4: 20% SS>45, PI 62, Inflexion T9/T10, LL 69

Low grade PI → High grade PI
 Low grade SS → High grade SS

Normal Distribution

C7 Plumbline: 13%, 49%, 38%
 F=7%, F=45%, F=48%
 M=22%, M=53%, M=25%

HA (Head Alignment) and S1 (Sacral Angle) are indicated.

Compensatory Mechanisms

SPINE: Reduction of TK, Retrolisthesis, Hyperextension
 PELVIS: Pelvis backtilt
 LOWER LIMBS: Knee flexum, Ankle extension

Reduced PI = poor ability to compensate

Pelvic incidence-lumbar lordosis mismatch predisposes to adjacent segment disease after lumbar spinal fusion

Dominique A. Rothenfluh · Daniel A. Mueller ·
Esin Rothenfluh · Kan Min

- **PI-LL <10 = 25% revision rate for ASD 4yrs vs**
- **PI-LL >10 = 78%**
- **ASD group had higher preop PI with non matched LL**

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- **Segmental Lordosis**
- **SVA<4-5cm**
- **Match PI and LL +/- 10deg**
- **PT<20 degrees**
- **GAP Score**

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Normative data for parameters of sagittal spinal alignment in healthy subjects: an analysis of gender specific differences and changes with aging in 626 asymptomatic individuals

Yasutsugu Yukawa^{1,2} · Fumihiko Kato² · Kota Suda³ · Masatsune Yamagata⁴ ·
Takayoshi Ueta⁵ · Munechito Yoshida¹

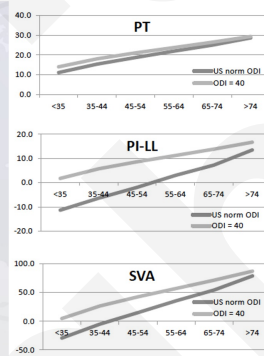
Table 8 Sagittal vertical axis (SVA)

Decade	Male	Female	P value
20–29	-2.1 ± 8.2	-4.6 ± 13.5	NS
30–39	3.0 ± 9.2	-4.1 ± 13.0	<0.01
40–49	5.0 ± 13.7	0.9 ± 9.0	0.070
50–59	4.5 ± 11.8	3.4 ± 11.1	NS
60–69	5.5 ± 14.0	4.6 ± 10.4	NS
70–79	10.3 ± 14.4	10.7 ± 15.2	NS
All	4.5 ± 11.9	1.8 ± 13.1	<0.01
Total	3.1 ± 12.6		



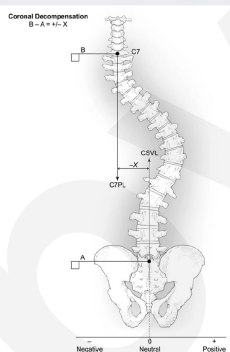
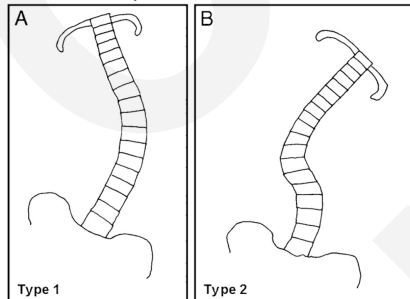
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Renaud Lafage, MS,¹ Frank Schwab, MD,² Vincent Chailier, MD,³ Jensen K. Henry, BA,⁴ Jeffrey Gum, MD,¹
Justin Smith, MD, PhD,⁵ Richard Hostin, MD,⁶ Christopher Shaffrey, MD,⁷ Han J. Kim, MD,⁸
Christopher Ames, MD,⁹ Justin Scheer, BS,¹⁰ Eric Klingenberg, MD,¹¹ Shay Bess, MD,¹² Douglas Burton, MD,¹³
and Virginio Lafage, PhD,¹ International Spine Study Group



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Type 1 and 2 Coronal Decompen-sation. Relationship Of Shoulders To The Pelvis



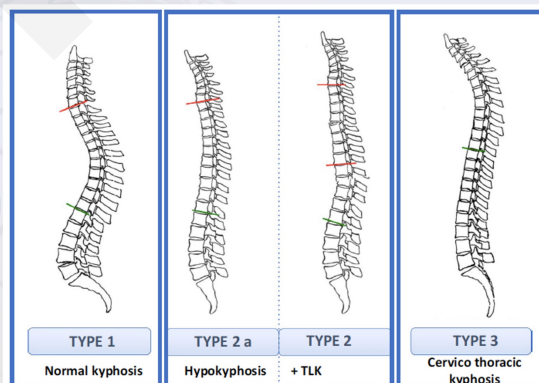
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Sagittal classification in adolescent idiopathic scoliosis: original description and therapeutic implications

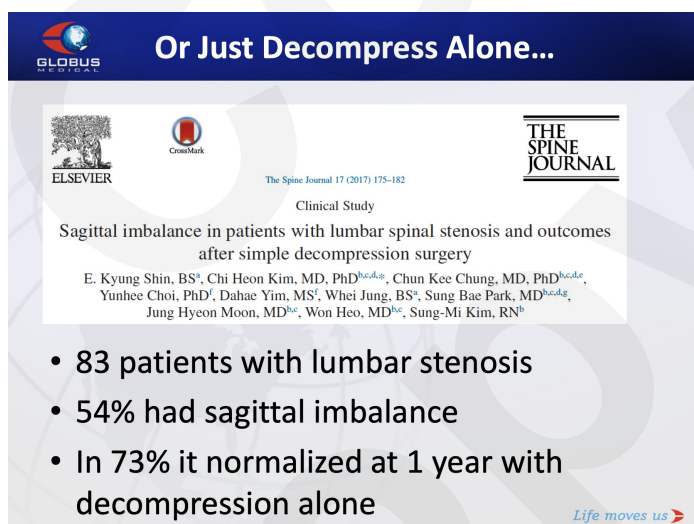
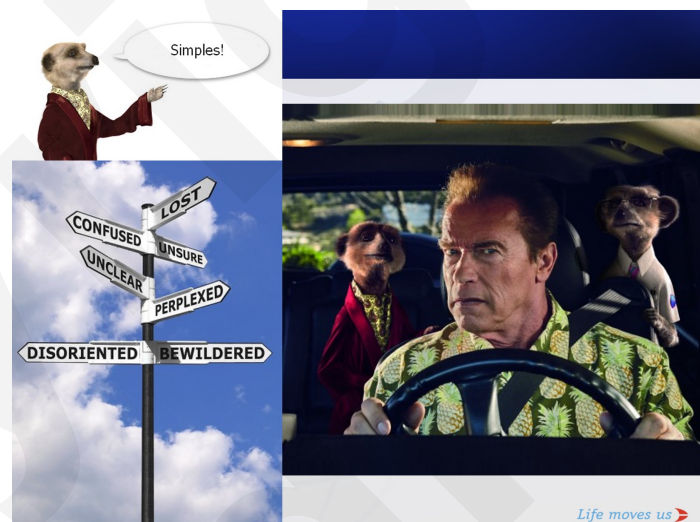
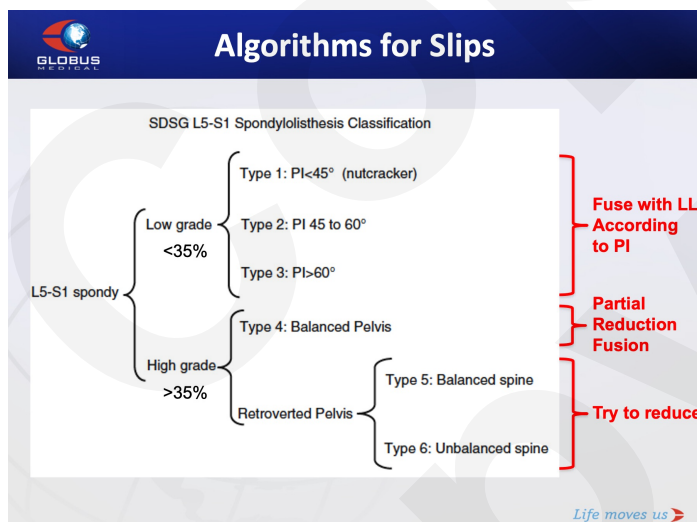
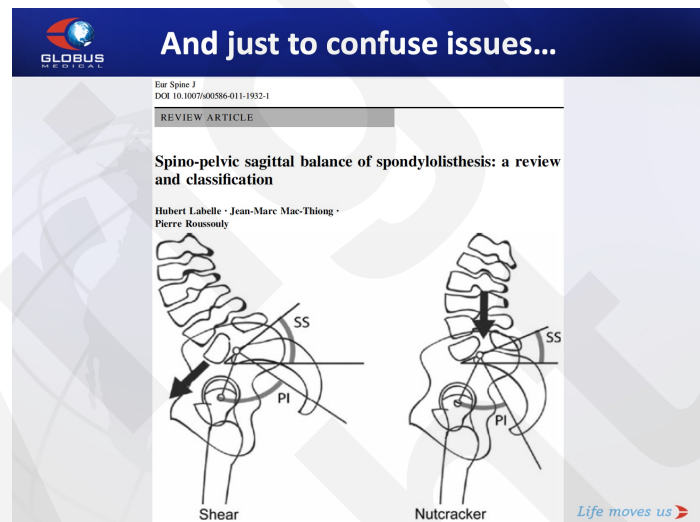
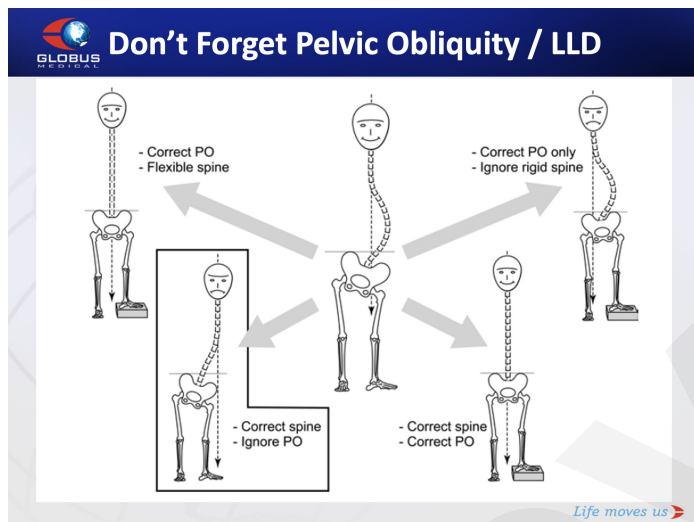
K. Abelin-Genevois¹ · D. Sassi¹ · S. Verdun² · P. Roussouly¹

European Spine Journal (2018) 27:2192–2202

<https://doi.org/10.1007/s00586-018-5613-1>



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Know When To Quit



A man's got to know his limitations



Beware



Pay attention to the detail
Never let your guard down

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And Finally...

Patient-specific Rods for Surgical Correction of Sagittal Imbalance in Adults
Technical Aspects and Preliminary Results

Federico Solla, MD,* Cédric Y. Barrey, MD, PhD,†‡ Evalina Burger, MD,§
Christopher J. Kleck, MD,§ and Vincent Fièvre, MD||

Eur Spine J (2016) 25:3658–3665
DOI 10.1007/s00586-016-4621-2

CrossMark

ORIGINAL ARTICLE

Influence of high-heeled shoes on the sagittal balance of the spine and the whole body

Tim Weitekunat¹ · Florian M. Buck² · Thorsten Jentsch³ · Hans-Peter Simmen¹ · Clément M. L. Werner¹ · Georg Osterhoff¹

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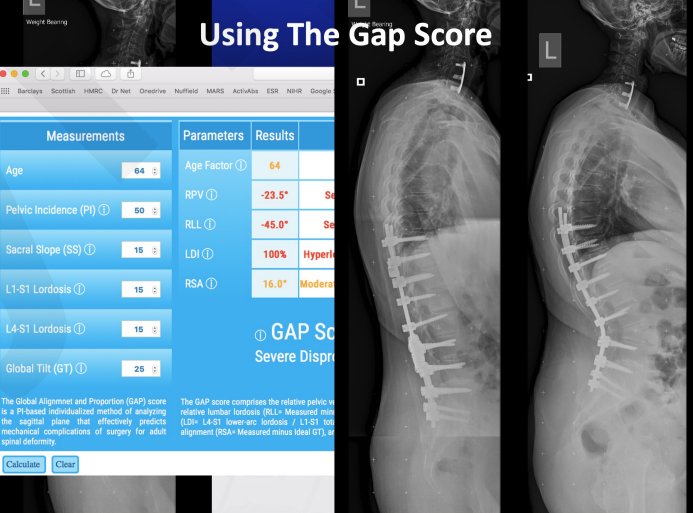
Thank you



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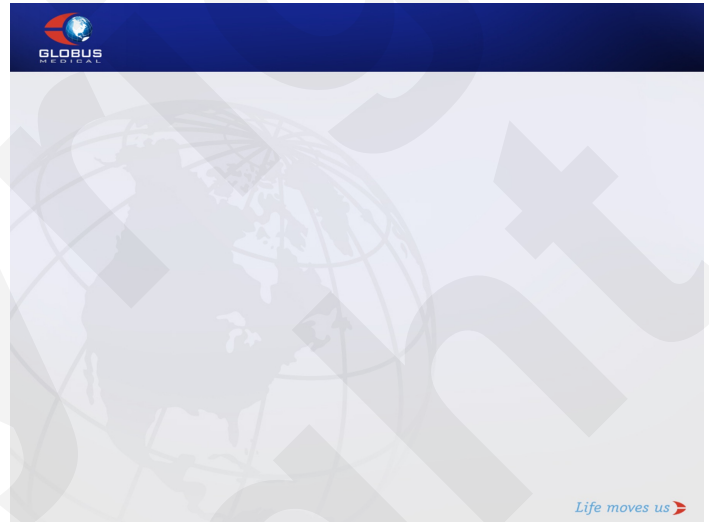
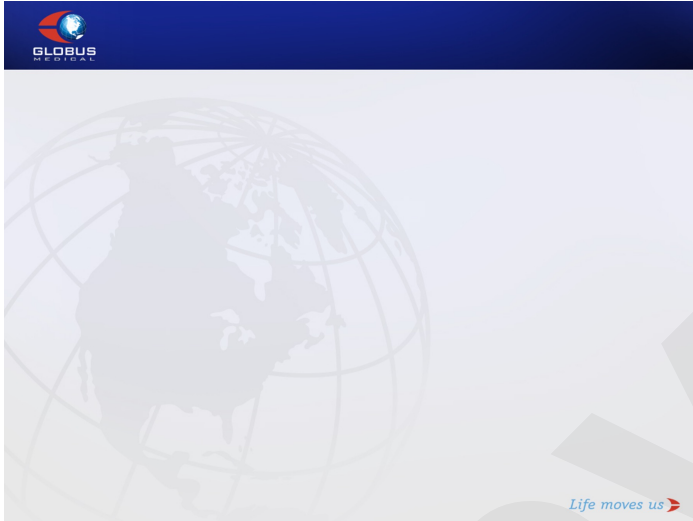
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Using The Gap Score



Measurements	Parameters	Results
Age	Age Factor (1)	64
Pelvic Incidence (PI) (1)	RPV (1)	-23.5°
Sacral Slope (SS) (1)	RLI (1)	-45.0°
L1-S1 Lordosis (1)	LDI (1)	100% Hyperlordosis
L4-S1 Lordosis (1)	RSA (1)	16.0° Moderate
Global Tilt (GT) (1)		

① GAP Score: Severe Disproportion



Variation in Sagittal Alignment • Roussouly et al 351

Table 1. The Geometric Parameters Describing Sagittal Alignment for the Entire Cohort

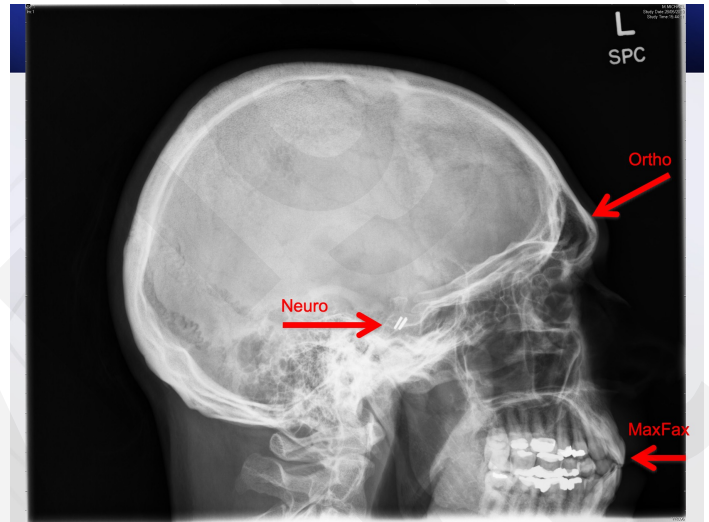
Parameter	Label	Average (°)	SD (°)	Minimum (°)	Maximum (°)
Pelvic incidence	PI	51.91	10.71	33.75	83.72
Sacral slope	SS	39.92	8.17	21.22	65.90
Pelvis tilt	PT	11.99	8.46	-5.06	30.59
Apex	1	Center of L4	1 vertebra	Base L5	Center of L2
Inflection point	2	Center of L1	1 vertebra	Center of L4	Center of T10
Lordosis tilt angle	3	-5.71	4.59	-16.15	10.76
Global lordosis	4	61.43	9.72	41.22	81.94
No. of lordotic vertebrae	5	4.50	0.90	1.50	7.50
Upper arc	6	21.50	5.02	7.00	35.00
No. of vertebrae	7	3.00	0.80	0.50	5.50
Lower arc	8	39.92	8.17	21.22	65.90
No. of vertebrae	9	1.50	0.60	0.00	3.50

Type	Description	Diagram	Reference
1	Resection of posterior elements from mid pars above to pedicle below with realignment of the spine through hinging through a mobile disc anteriorly		Ponte
2	Resection of posterior elements from mid pars above to pedicle below with realignment of the spine through hinging through a mobile disc anteriorly		Smith-Petersen
3	Posterior-based transpedicular decancellation of the vertebral body with realignment through controlled fracture of the anterior column		Heinig
4	Posterior-based intraosseous wedge resection of the vertebral body with realignment through osteoclasts of the proximal third of the anterior vertebral body		Thomassen (PSO)
5	Posterior-based wedge resection with extension of the osteotomy into the supra-adjacent disc and realignment hinging on the anterior column at the intervertebral space		Mod Thomassen (Ext PSO)
6	Posterior-based vertebral column resection including one or more vertebra with adjacent discs		Suk (VCR)

Osteotomy vs ALL Release

- Osteotomy - PSO
 - Direct canal decompression
 - Direct foraminal decompression (but no height restoration)
 - Shortening procedure
 - “Bone on bone” fusion if performed correctly
 - Correction = per level
 - Typically up to 30 degrees
- ALL release + Cage
 - Indirect canal decompression
 - Indirect foraminal decompression
 - “Lengthening” procedure
 - Fusion through a cage
 - Requires additional posterior procedure
 - Correction = per level
 - Depends on cage lordosis and facets at back

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Notes

- PI 52 range 34-84 fixed after skeletal maturity
- PT 12 range 5-30
- SS 40 range 20-65
- Reduced PI – poor ability to compensate
- CL 40 +/- 10
- TK 20-50
- LL 30-80

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Notes

- Type 1 – discopathy TL junction, OA facets distal arc, retrolisthesis at junction, nutcracker spondylolysis L5 in hyperlordotic area
- Type 2 – increased risk disc herniation (central) at younger age, multilevel discopathy
- Type 3 – average
- Type 4 – L5 isthmic lysis, later age posterior OA and L4/5 SPL

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Notes

- SS never <0 or negative when standing
- Non pathological upper limit of PT is <50% PI
- Low PI – do not require significant operative correction to increase lordosis
- High PI and hypolordosis likely require PSO

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Notes

- PSO
- 2.8-7.8% risk permanent neurological injury
- 10% infection
- 1% mortality

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Indications for Surgery - DRS

- **Decompression**
 - Spinal cord / nerve roots
- **Realignment**
 - Correct deformity
- **Stabilisation**
 - Prevent / Treat
 - Neurological deficit / deformity / pain
 - (Non fusion technology form of "stabilisation")

All may require fusion
Require Instrumentation
Instrumentation increases fusion

Indications for Surgery

- **What are you trying to achieve?**
 - Non-maleficence - "first, do no harm" (primum non nocere).
- **DO THE APPROPRIATE OPERATION FOR THE PATIENT AND THEIR PATHOLOGY AND YOUR SKILL / ABILITY**

Real Purpose of Surgery

Summary

- **Examine the patient!**
 - Stand up straight - hips - lumbar - thoracic
- **Get decent preop radiographs**
 - Measure the PILL and you won't get caught out
- **XR Warning / Alerts:**
 - Flat back / Hyperlordosis
 - Vertical / Horizontal Sacrum
 - (High grade slips)

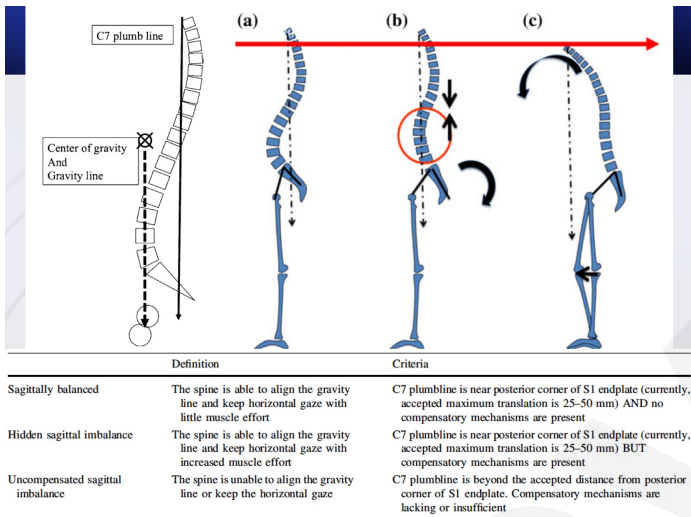


TABLE 3. Radiographic Thresholds Based on Age-Specific ODI US-Norms

Age Group	% in Database	Mean Age in Database	ODI US-Norm*	PT	PI-LL	LL-TK	SVA	TPA
<35	17.7	26.2	9.49	11.1	-11.3	29.2	-29.1	4.4
35–44	8.8	40.7	11.77	15.5	-6.2	21.9	-4.0	10.0
45–54	19.9	51.2	15.43	18.9	-1.7	16.4	16.5	14.5
55–64	28.0	60.5	20.87	22.1	3.3	11.1	37.0	18.8
65–74	19.5	69.7	24.62	25.2	7.5	6.1	55.6	22.8
≥74	6.2	79.6	32.54	28.8	13.7	0.2	79.9	27.8

TABLE 4. Radiographic Thresholds Based on Age-Specific SF-36 PCS US-Norms

Age Group	% in Database	Mean Age in Database	PCS US-Norm	PT	PI-LL	LL-TK	SVA	TPA
<35	17.7	26.2	53.72	10.8	-9.7	29.8	-31.9	4.0
35–44	8.8	40.7	52.15	15.2	-3.0	22.3	-7.0	9.6
45–54	19.9	51.2	49.64	18.6	2.6	16.5	13.6	14.1
55–64	28.0	60.5	45.9	21.9	8.3	11.1	34.6	18.5
65–74	19.5	69.7	43.33	24.9	13.4	5.9	53.4	22.5
≥74	6.2	79.6	37.89	28.7	20.2	-0.2	78.6	27.7

TABLE 5. Radiographic Thresholds Corresponding to an ODI of 20 (Left) and 40 (Right)

Age Group	Moderate Disability (ODI = 20)					Severe Disability (ODI = 40)				
	PT	PI-LL	LL-TK	SVA	TPA	PT	PI-LL	LL-TK	SVA	TPA
<35	11.3	-6.8	27.6	-17.4	6.2	13.2	1.8	24.5	5	9.8
35–44	15.1	-2.7	20.7	5.2	11.5	17	5.9	17.6	27.6	15
45–54	17.8	0.2	15.7	21.6	15.3	19.7	8.8	12.6	44	18.8
55–64	20.2	2.9	11.3	36.1	18.7	22.2	11.5	8.2	58.5	22.2
65–74	22.6	5.5	6.9	50.4	22	24.6	14.1	3.8	72.8	25.5
≥75	25.2	8.3	2.1	65.8	25.6	27.1	16.9	-1.0	88.2	29.1

The Impact of Positive Sagittal Balance in Adult Spinal Deformity

Steven D. Glassman, MD,* Keith Bridwell, MD,† John R. Dimar, MD,* William Horton, MD,‡ Sigurd Berven, MD,† and Frank Schwab, MD||

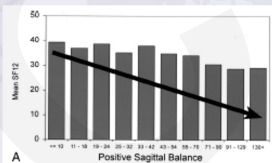


Table 1. Correlation Between Positive Sagittal Balance and Health Status Scores Using SF-12, SRS-29, and ODI Measures

Measure	Spearman rho	No. Cases	P
SF-12v2 PCS	-0.292	284	0.000001
SF-12v2 MCS	-0.075	284	0.206 (NS)
SRS pain	-0.207	251	0.0000917
SRS activity	-0.247	250	0.0000029
SRS total	-0.284	250	0.000001
Odyssey overall	0.291	249	0.000001

MCS = mental health composite score; NS = not significant.



Spine

DEFORMITY

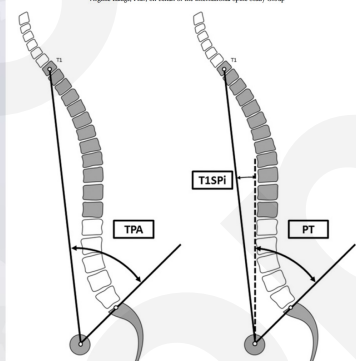
Discrepancy Between Standing Posture and Sagittal Balance During Walking in Adult Spinal Deformity Patients

Hideyuki Arima, MD, PhD,*† Yu Yamato, MD, PhD,* Tomohiko Hasegawa, MD, PhD,* Daisuke Togawa, MD, PhD,* Sho Kobayashi, MD, PhD,* Tatsuya Yasuda, MD,* Tomohiro Banno, MD,* Shin Oe, MD,*† and Yukihiko Matsuyama, MD, PhD*



The T1 Pelvic Angle, a Novel Radiographic Measure of Global Sagittal Deformity, Accounts for Both Spinal Inclination and Pelvic Tilt and Correlates with Health-Related Quality of Life

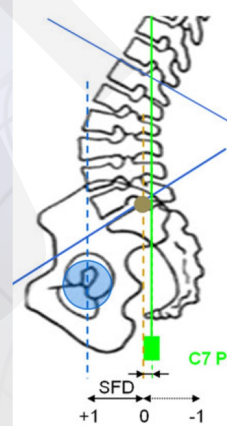
Thomazios Protopoulos, MD, Frank Schwab, MD, Nicolas Roussard, MD, Justin S. Smith, MD, PhD, Eric Klingenberg, MD, Gregory Menden, MD, David J. Bess, MD, Richard Horton, MD, Robert Hart, MD, Douglas Burton, MD, Christopher Arino, MD, Christopher Baffes, MD, Shap Bess, MD, Thomas Erwin, MD, and Virginia Lattape, PhD, on behalf of the International Spine Study Group



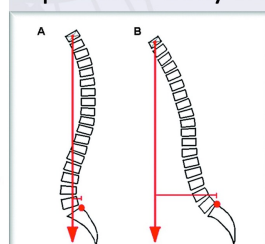
Aim < 14°



Aim C7PL : SFD <0.5



- SacroFemoral Distance – horizontal line posterior body S1 to Femoral Heads
- SVA = horizontal line posterior body S1 to C7PL



Technical Report

The use of the T1 sagittal angle in predicting overall sagittal balance of the spine

Patrick T. Knott, PhD, PA-C^{a,*}, Steven M. Mardjetko, MD^b, Fernando Techy, MD^c

Individual variable influence on the SVA

Measurement	Correlation value (r) with SVA
T1 sagittal angle	0.65 (Strongest correlation)
Lumbar lordosis	0.38
Cervical lordosis	0.37
Pelvic incidence	0.33
Sacral slope	0.26
Thoracic kyphosis	0.26
Dens angle	0.18
Femoral-sacral angle	0.16
Dens-occiput angle	-0.14

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Results of the linear regression analysis of the effect of each spinal parameter on SVA

Measurement	Value	Statistical significance (p)
T1 sagittal angle	2.485	.002*
Pelvic incidence	1.447	.002*
Lumbar lordosis	1.645	.006*
Femoral-sacral angle	0.928	.263
Cervical lordosis	0.211	.553
Sacral slope	-0.572	.583
Thoracic kyphosis	0.145	.727
Dens angle	0.128	.825
Dens-occiput angle	0.120	.869

SVA, sagittal vertical axis.

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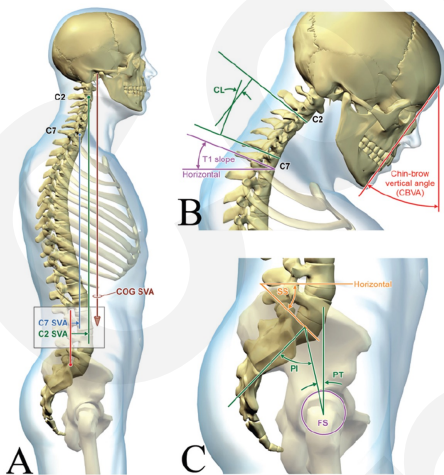
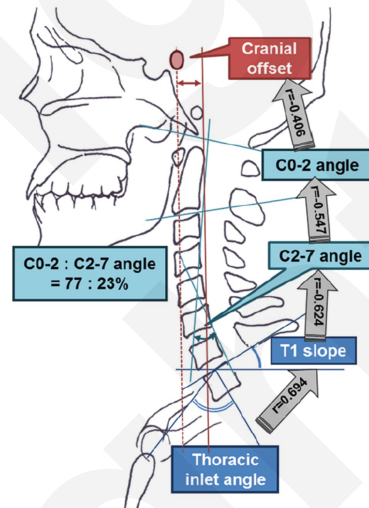
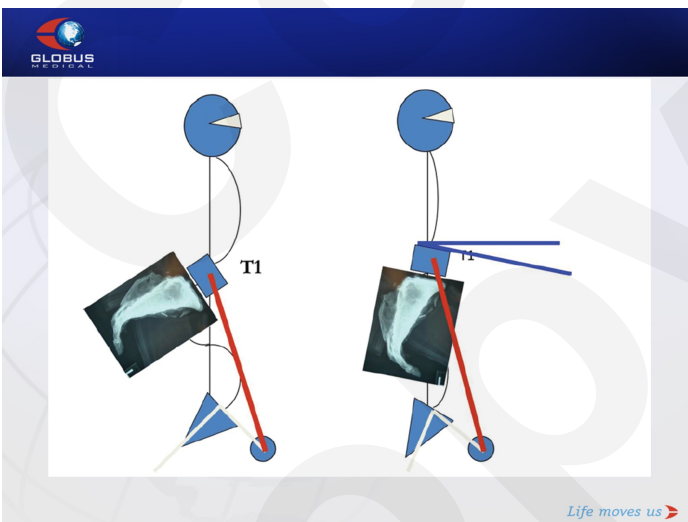


FIG. 10. The spine functions as a global unit so that cervical alignment parameters influence, and are influenced by, parameters in the lower regions. CL = cervical lordosis, COG = center of gravity, FS = femoral shaft, PI = pelvic incidence, PT = pelvic tilt, SS = sacral slope.

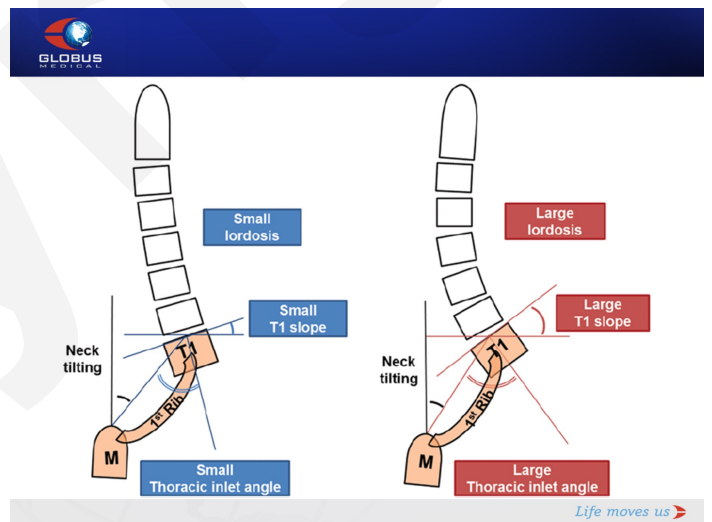
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Classification of the Normal Variation in the Sagittal Alignment of the Human Lumbar Spine and Pelvis in the Standing Position

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Johanes Dimnet, PhD‡

- Stagnara et al. 1982 “the span of possible values of maximum kyphosis and lordosis in subjects with no spinal disease is considerable ...It is therefore unreasonable to speak of normal kyphotic or lordotic curves.”

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