GLOBAL SAGITTAL ANGLE (GSA): A NOVEL PARAMETERS TO ADDRESS SAGITTAL ALIGNMENT AND COMPENSATORY MECHANISMS IN THE BODY

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**Introduction: History**

- **Conus of economy:**
  - “where the body can stay balanced with the minimum of muscle action”
  - Jean Dubousset, 1972
  - Anterior/posterior deviation recruits muscle expenditure

- **Spino-pelvic mismatch concept:**
  - Pelvic incidence minus lumbar lordosis measures
  - Spinal alignment is governed by the pelvic morphology
  - Frank J. Schwab, 2009

*Truncal anterior shift*
**INTRODUCTION: BEYOND THE SPINE, CONSEQUENCES OF MALALIGNMENT**

**Hip level:**

- **Pelvic tilt:**
  - Compensation for spinal malalignment:
    - Duval-Beaupere, 1992
  - Correlated with clinical outcome scores
    - Virginie Lafage, 2009

**Knee level:**

- **Knee flexion:**
  - Compensatory mechanism for spinal malalignment:
    - Cedric Barrey and Ibrahim Obeid 2011

\[\text{Pelvic tilt + knee flexion = pelvic posterior shift}\]
Observations of full body images:
- Anterior shift of the trunk
- Posterior shift of the pelvis

Objective of the study:
- One measure to quantify the real deformity while respecting these two phenomena.
Retrospective single center review of patients underwent full body stereoradiography Time for enrollment:
- 2012-2013

Inclusion Criteria:
- Patients with the following diagnosis:
  - ASD, AIS, DDD, degenerative spondylolisthesis, lower back pain
  - Completed Oswestry disability index (ODI) questionnaire

Exclusion Criteria:
- Diagnoses of neoplasm, ankylosing spondylitis, DISH, fracture
**Methodology: Radiographic Measurements**

- **SRS-Schwab sagittal modifiers:**
  - Pelvic incidence (PI) minus Lumbar lordosis (LL)
  - Pelvic retroversion measured by pelvic tilt angle (PT)
  - Sagittal Vertical Axis (SVA)
  - T1 pelvic angle (TPA)

- **Cranio-cervical**
  - C2-C7 cervical curvature
  - C2-C7 SVA
  - Chin-brow vertical axis: CBVA
  - MacGregor Slope (McGS)
  - Slope of the line of Sight (SLS)

- **Knee flexion angle (KA):**
  - Angle between the mechanical axis of the femur and the mechanical axis of the tibia

- **Ankle flexion angle (AA):**
  - Angle between the mechanical axis of the tibia and the vertical

- **Pelvic posterior shift (P. Sh.):**
  - Horizontal offset from the S1 plumbline to the anterior cortex of the distal tibia
The angle between the line from the knee to the middle of C7 vertebra and the line between this point and posterior superior corner of S1

- Knee point; the midpoint between the two distal femoral condyles

- Analysis:
  - Pearson correlation:
    - GSA vs. radiographic parameters
    - Radiographic parameters vs. ODI
  - Regression analysis to investigate the relationship between GSA and deformity/compensation
Patients population:
- 80 patients, 76.3% females
- Mean age: 51.6±18.6 y/o
- Body mass index: 27.5 kg/m²

Cohort sagittal profile:
- GSA: 4.7, [-3.7-25.2°]
- Variable deformity profiles PT, PI, PI-LL, SVA

“Normative value”
- Based on SRS- Schwab classification subset of patients with minimal to no spinal malalignment

GSA = -1.3 ± 1.35°
○ GSA correlates with

○ Spino-pelvic parameters
  ○ PI-LL, SVA, TPA, PT

○ Lower limbs
  ○ Knee, Ankle, pelvic shift

○ Cranio-cervical:
  ○ CBVA, CC, cSVA

○ ODI
  ○ Better than SVA
  ○ Clinical relevance.

<table>
<thead>
<tr>
<th>Variable</th>
<th>GSA</th>
<th>SVA</th>
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</thead>
<tbody>
<tr>
<td>ODI</td>
<td>0.408</td>
<td>0.395</td>
</tr>
<tr>
<td>CBVA</td>
<td>-0.327</td>
<td>-0.269</td>
</tr>
<tr>
<td>SLS</td>
<td>-0.342</td>
<td>-0.287</td>
</tr>
<tr>
<td>McGS</td>
<td>-0.302</td>
<td>-0.269</td>
</tr>
<tr>
<td>C2-C7 CC</td>
<td>-0.446</td>
<td>-0.463</td>
</tr>
<tr>
<td>cSVA</td>
<td>0.418</td>
<td>0.394</td>
</tr>
<tr>
<td>SVA</td>
<td>0.965</td>
<td>-</td>
</tr>
<tr>
<td>PT</td>
<td>0.483</td>
<td>0.404</td>
</tr>
<tr>
<td>PI-LL</td>
<td>0.761</td>
<td>0.750</td>
</tr>
<tr>
<td>KA</td>
<td>0.775</td>
<td>0.63</td>
</tr>
<tr>
<td>AA</td>
<td>0.534</td>
<td>0.368</td>
</tr>
<tr>
<td>P.Sh</td>
<td>0.899</td>
<td>0.841</td>
</tr>
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</table>

p < 0.05 for all correlations
GSA IS SENSITIVE TO PELVIC TILT AND/OR KNEE FLEXION

- Lack of pelvic compensation leads to more disability
  - Lafage 2009

- In this study, Regression analysis:

<table>
<thead>
<tr>
<th>Dependent</th>
<th>Standardized Coefficients</th>
<th>R</th>
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<tbody>
<tr>
<td></td>
<td>TPA</td>
<td>PT</td>
</tr>
<tr>
<td>GSA</td>
<td>+1.722</td>
<td>-1.032</td>
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<tr>
<td>ODI</td>
<td>+0.769</td>
<td>-0.546</td>
</tr>
</tbody>
</table>

GSA and ODI increases with increase deformity “TPA” and concurrent decrease in compensation “PT”

Less disabled

More disabled
Conclusions

- Full body alignment evaluation is necessary to globally understand regional deformities
  - Big picture

- GSA is a relevant measure for the true sagittal deformity
  - Correlation with HRQOL
  - Correlation with head to feet sagittal parameters

- Future work: evaluate improvement in GSA pre to post deformity treatment
Bassel G. Diebo, Vincent Challier, Shaleen Vira, Matthew Spiegel, Bradley Harris, Renaud Lafage, Barthelemy Liabaud, Jensen Henry:
- Nothing to disclose

Virginie Lafage
- (a) SRS, NIH, DePuy
- (b) DePuy Spine, Johnson and Johnson
- (b) Medicrea
- (b) (c) Nemaris

Frank J. Schwab:
- (a,b) DePuy Spine, Johnson and Johnson;
- (a,b,d) Medtronic;
- (a,b) Biomet
- (a,b,d) K2M
- (b,d) Medicrea
- (a,b) Nuvasive
- (c) Nemaris

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