Measuring spinal growth in EOS:  
*What are the goals and what does it tell us*

James O. Sanders, MD  
Frank C. Wilson, Distinguished Professor  
Chair Orthopaedics University of North Carolina at Chapel Hill
Three of the most important tools in measuring child health

- Stadiometer
- Scale
- Growth Charts
Height Measurements are Only as Accurate as the Technique

Technique for measuring erect height (Herpenden Stadiometer)

- Child should be fully erect.
- Head in the Frankfurt plane.
- Back of the head, thoracic spine, buttocks, heel should touch the vertical axis of the stadiometer.
- Should be measured in triplicate and the mean should be recorded.
Stunting

- Not etiology specific
- A generalized measure of health
There are Functional Alternatives to Height Measurement when Needed

- sitting height
- arm span
- upper arm length
- ulnar length
Disease Specific Growth Charts

- Use with caution
  - Often small numbers, retrospective
  - Measurements not standardized
  - Unsure of nutritional or health status
  - No adjustment for racial or other characteristics
Disease Specific Growth Charts

- Trisomy 21 (Down syndrome) (Cronk, 1988)
- Prader-Willi syndrome (Holm, 1995)
- Williams syndrome (Morris, 1988)
- Cornelia deLange syndrome (Kline, 1993)
- Turner syndrome (Ranke, 1983; Lyon, 1985)
- Rubinstein-Taybi syndrome (Reference)
- Marfan syndrome (Pyeritz, 1983; Pyeritz, 1985)
- Achondroplasia (Horton, 1978)
Actual Growth - Berkeley Series

Boys and Girls

- Infantile Phase
- Childhood Phase
- Adolescent Phase
Childhood Growth

- Children tend to grow in a specific percentile (canalization).
- Growth is slower than infancy and relatively linear.

![Berkley Boys and Girls Growth Chart](chart.png)
Spine Growth in Childhood

- Relatively linear and same for both sexes.
- T1-S1:
  - Our Data: 1.5 cm/year
  - DiMeglio: 1.2 cm/year
Parent, Beauséjour, El-Hawary, Sanders, Yaszay, Akbarnia

Centile curves of 3D True Spinal Length in children 3 to 11

True spine 3D length = T1-S1 height x 1.026
Spinal growth (T1-S1) is very rapid during the growth spurt.

<table>
<thead>
<tr>
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<th>Girls</th>
<th>Boys</th>
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<tbody>
<tr>
<td>Childhood</td>
<td>1.5cm/year</td>
<td>1.5cm/year</td>
</tr>
<tr>
<td>Growth Spurt</td>
<td>2.5cm/year</td>
<td>2.5cm/year</td>
</tr>
<tr>
<td>Terminal Growth</td>
<td>0.4cm/year</td>
<td>0.4cm/year</td>
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</tbody>
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Growth Remaining (Multipliers) to Skeletal Maturity

• The relationship between growth remaining and skeletal maturity is tight during the growth spurt
Early onset scoliosis can create:

- A deformed breathing apparatus
  - Short
  - Twisted
  - Mechanically constricted
- A mismatch between respiratory ability and physiological demand.
- Poor health
What should we follow?

• Height - readily available.
• Effected by:
  – spinal deformity
  – underlying disorder
• Does provide an overall metric:
  – vs. age in preadolescent children
  – vs. PGA in adolescence
Spine Specific Measures

- T1-S1
- T1-T12
- Ratios
• Most curves effect both thoracic and lumbar spine
• T1-S1 is a global measure
• How much do we really care about the lumbar spine?
Crowding from Lumbar Spine

McCarthy
It takes very severe lumbar spine shortening to cause thoracic crowding and pulmonary dysfunction.

In general, it is the thoracic dimension (excluding crowding) that matters.
- May be reflective of pulmonary volume
- Correlates with FVC in a cohort with largely congenital scoliosis (20/28)
- All severe curves fused *in situ*
As noted by CJ

- Not all patients with short chests do poorly
Does this boy with cleidocranial dysostosis need T1-12 of 22cm to function well?
Ultimately, chest growth should match the remainder of the body.

A mouse does not need a human sized chest.
Spondylothoracic Dysplasia
(Ramirez)
Severe Restrictive Respiratory Pattern

- Average spirometric values 27.9% FVC
- 29.5% predicted FEV1
- 0.92 FEV1/ FVC ratio
- Clinically stable restrictive disease with an adequate quality of life not requiring supplemental oxygen in adults
- “It is surprising how well our older patients have done clinically with severe restrictive lung disease secondary to a decreased thoracic height.”
Ratios

- Ratios may be more reflective of patient size and pulmonary need than absolute measurements.
- Much like BMI is a better measure of cachexia or obesity than weight alone.
Pelvic Width to Height (Emans, Johnston):
The Orthopedic Concept

- The chest is a box with the spine creating the vertical component.
- All current EOS devices work to make a static box bigger.
- Does not account for the dynamic nature of breathing.
We need a paradigm change for EOS

- It’s not just a bigger box.
- It’s dynamic expansion and contraction with a bigger box—a larger, more effective bellows.
How do we get there?

• T1-S1
  – Relate to age in childhood
  – Relate to PHV during adolescence
  – Not as important as chest growth for lung function

• Use PSSG data to correlate mature PFT with T1-T12 ratios to:
  – BMI
  – Height
  – Pelvic width

• Think more about chest dynamics rather than purely a bigger box.