

Normal human spine growth and prediction of final spine height:

Results of a longitudinal cohort of children followed through growth completion

James O. Sanders, MD - University of Rochester

Lauren Karbach, MD – University of Rochester

Thomas Osinski, BS – University of Rochester

Raymond Liu, MD – Case Western University

Xiang Liu, MA – University of Rochester

Xing Qiu , PhD – University of Rochester

Daniel Cooperman, MD – Yale University

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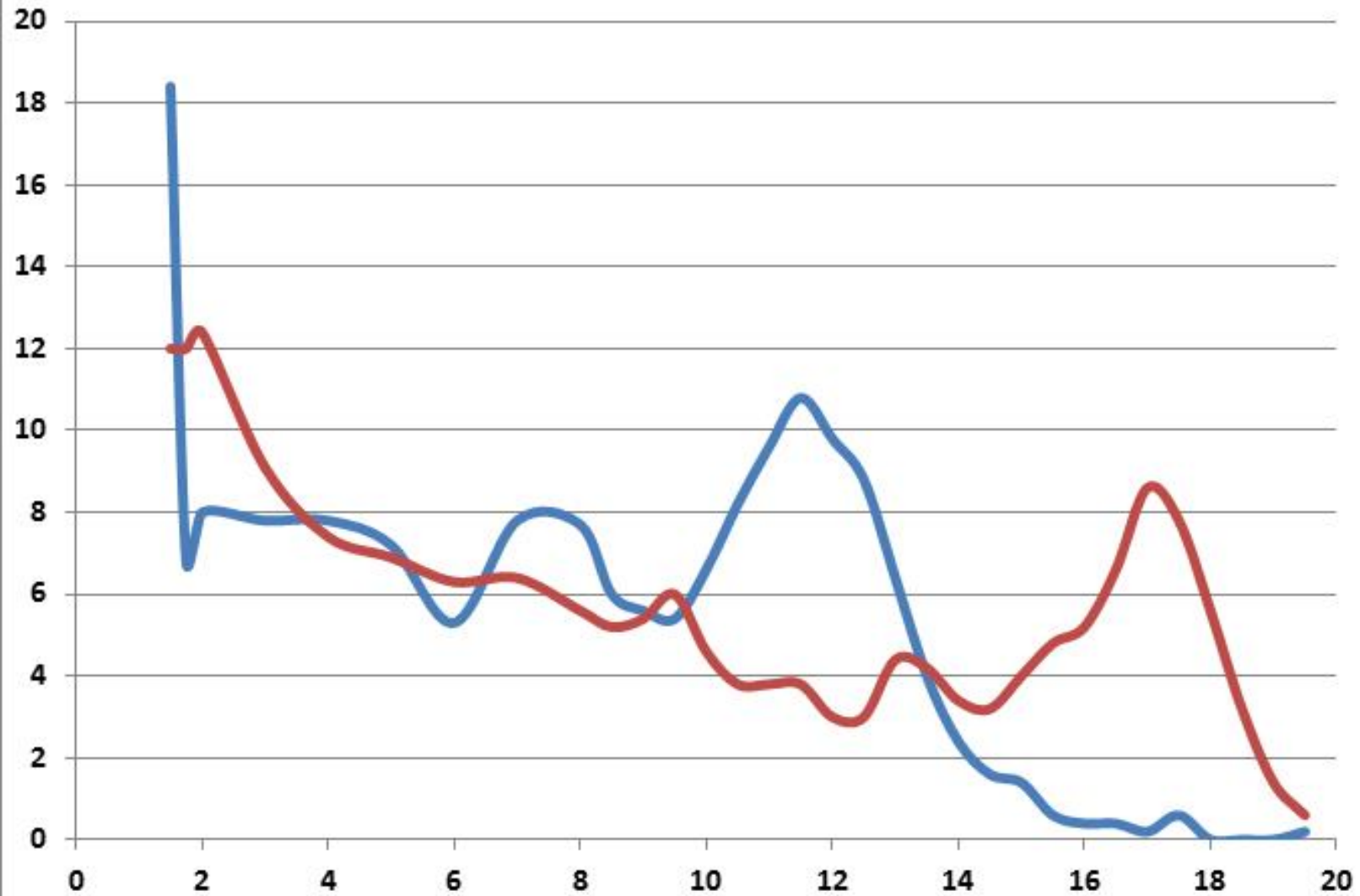
Why Does Longitudinal Matter?

- To date, our primary sources of spinal growth information have come from cross sectional data using small samples of normal children.
- Cross sectional studies blunt the marked changes occurring during the adolescent growth spurt.

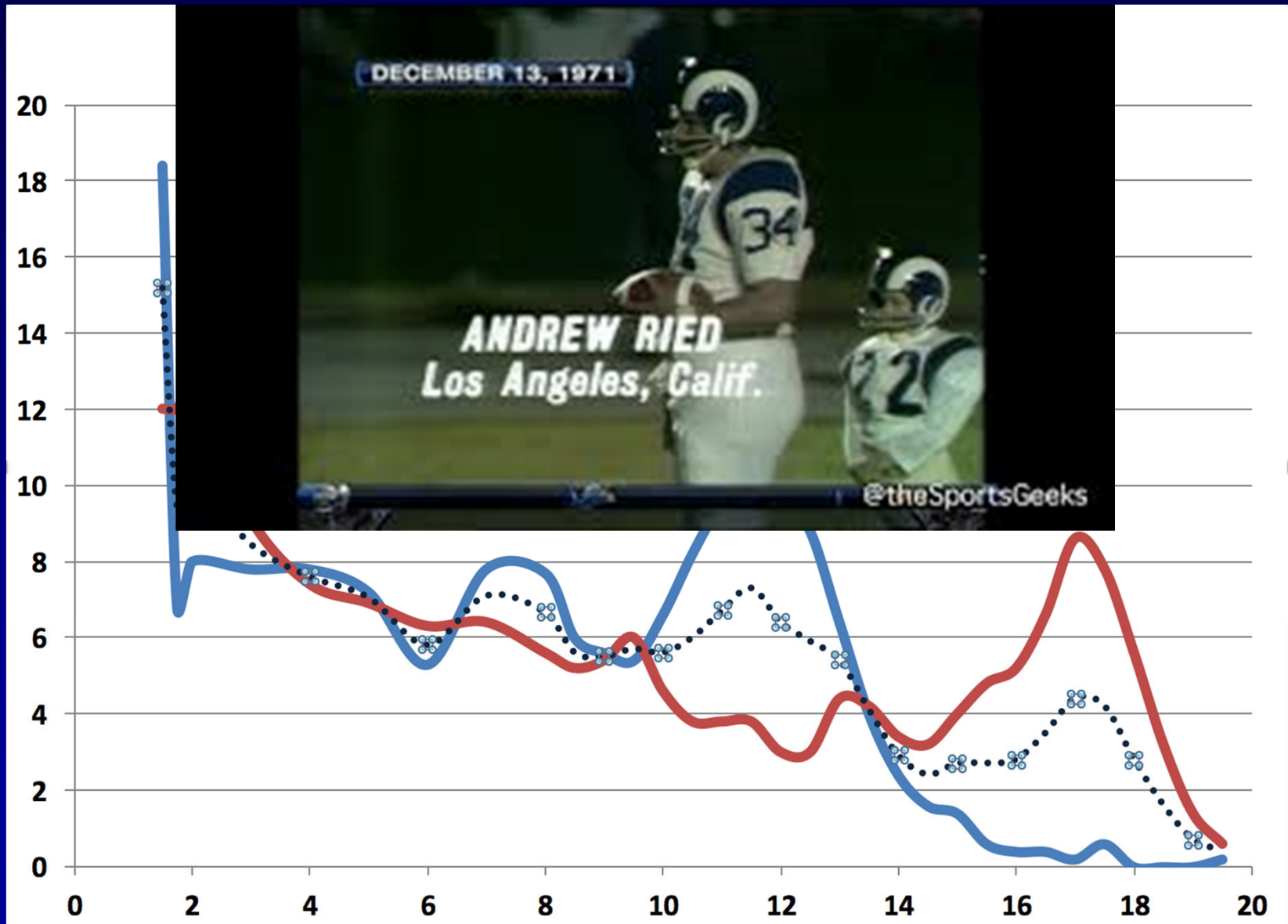
Growth Studies:	Cross Sectional	Longitudinal
Data Collection	Straight forward Can be done quickly Relatively inexpensive	Challenging Takes decades Expensive
Statistical Analysis	Routine techniques	Specialized expertise
Missing data	Not problematic	Advanced techniques required
Utility	Good for broad information Blunts individual patterns	Needed for subject specific information

Longitudinal:

2 Boys' Height Velocities

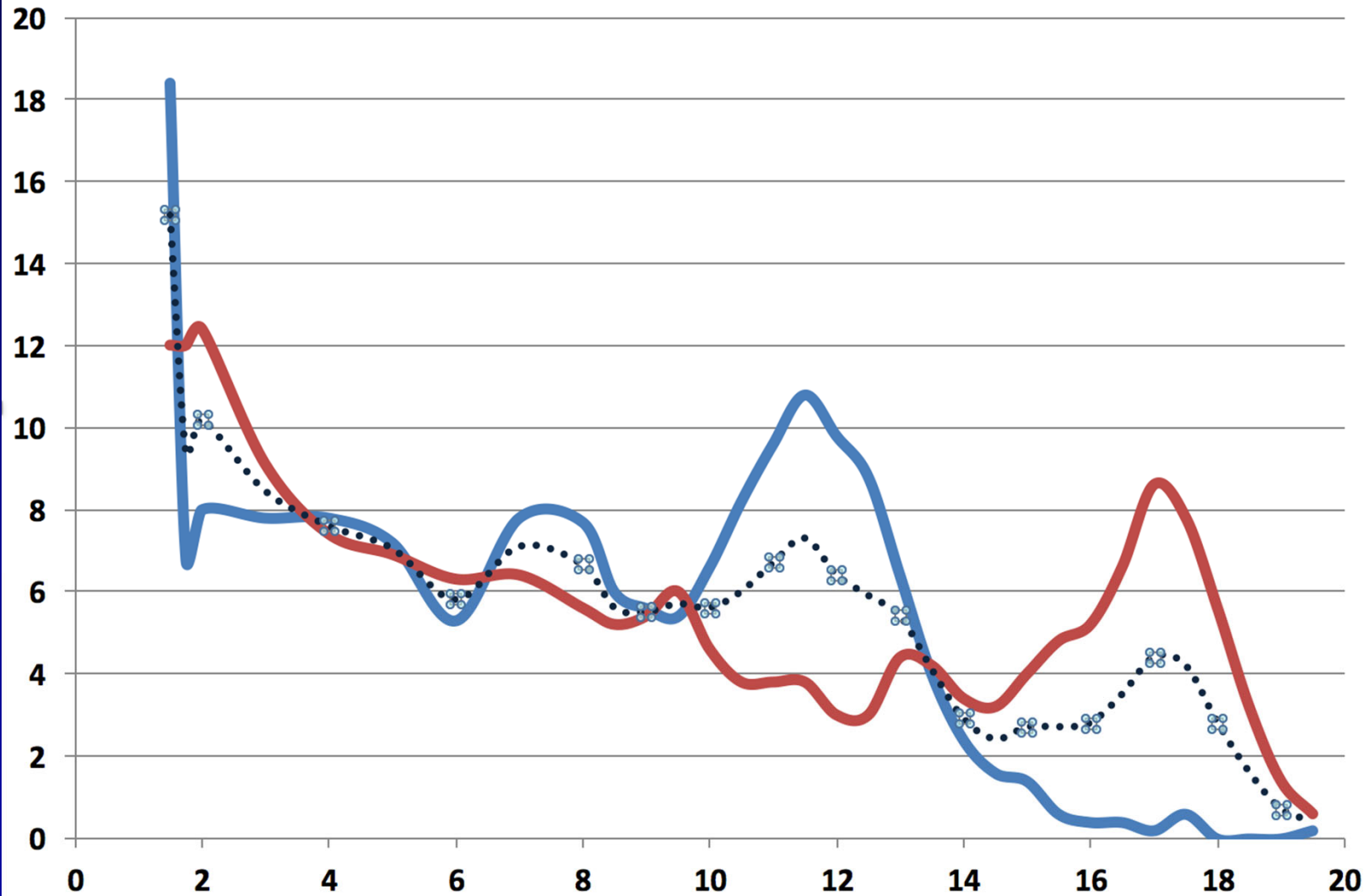


Cross Sectional:



Cross Sectional:

2 Boys' Height Velocities



T. Wingate Todd, MD



- Funded by Brush and Bolton Foundations, started the largest and most complete extant collection of skeletal radiographs following a longitudinal cohort of children through their growth.
- Healthy Cleveland Children 1929-1942
- Examined q3mo till 1yr old, q6mo till 5yrs then annually near birthday.
- Each visit had:
 - Radiographs of left hand, elbow, hip, shoulder, knee, foot
 - Anthropometrics – height, weight, segment measurements

POSNA Sponsored Study

- POSNA 2009 Huene Award to use Todd's (Bolton-Brush) data and identify subjects who had clearly completed their growth (<1 cm/yr)
- Hypothesis that skeletal maturation and anthropometrics would be much better correlated with the PHV than chronological age.

Methods – Part 1

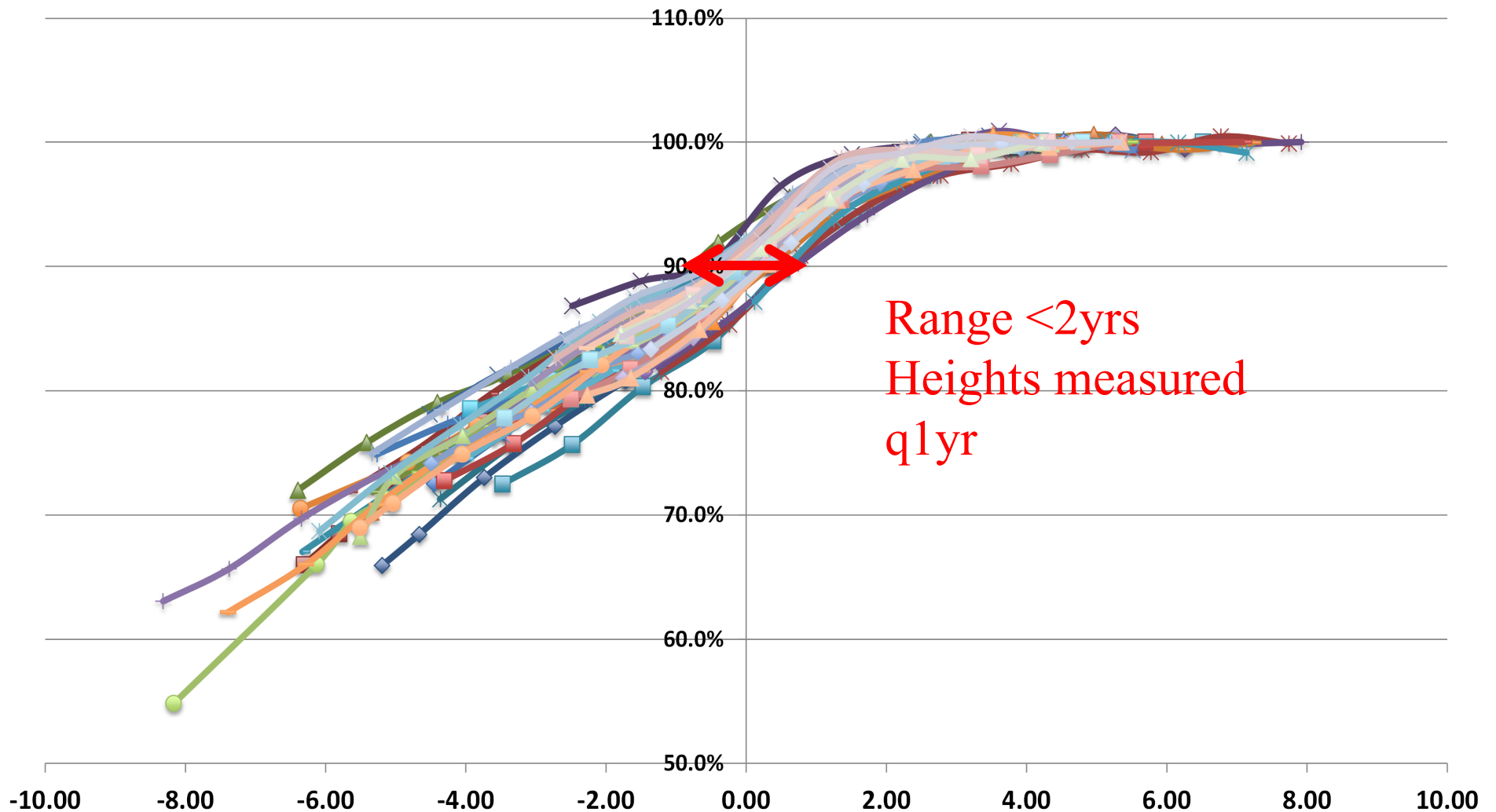
- Identified subjects clearly completing their growth (<1 cm/year at the final visit).
- Estimated the timing of their individual peak height velocity (PHV) using 1st derivative of cubic spline curve fitting.
- The timing before and after the PHV in years was compared to the percentage of final height.

Results (Basic):

- 54 subjects had completed their growth at the study terminus (35 f, 19m).
- Age at first data:
 - Girls 2 to 10yrs
 - Boys from 7.5 to 11yrs
- PHV timing
 - Girls 9.7 to 13.4yrs average 11.3 years
 - Boys 11.7 to 14.3yrs average 13.0 years.
- Final heights
 - Girls 151 to 175cm (average 163.4 cm)
 - Boys 169 to 183.9cm (average 177 cm)

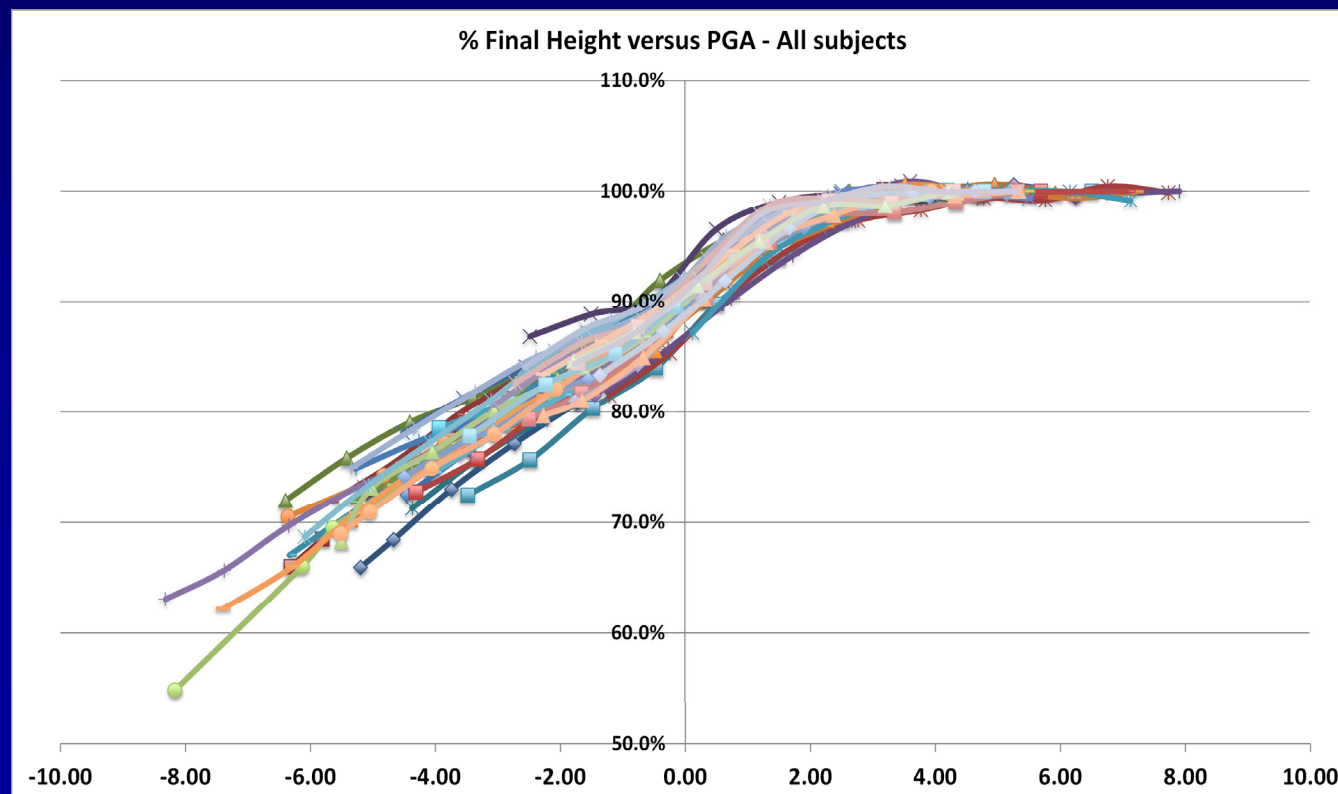
Plotted PHV vs. %Final Ht (reciprocal of multiplier)

% Final Height versus PGA - All subjects



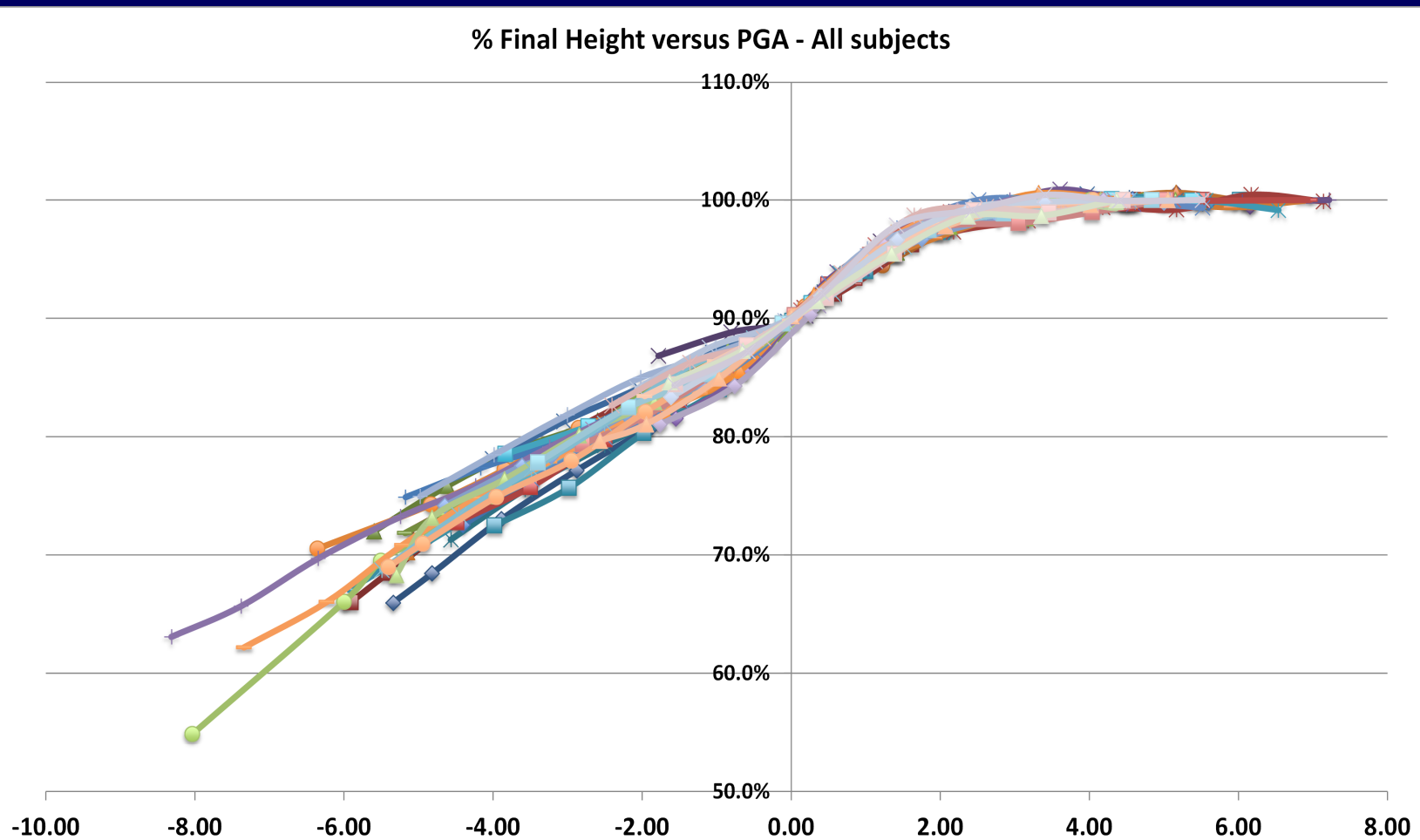
Clearly, the various curves are similar

- PHV averaged 90% of final height with ranges within our measurement residuals
- The curves look like they are just phase shifted



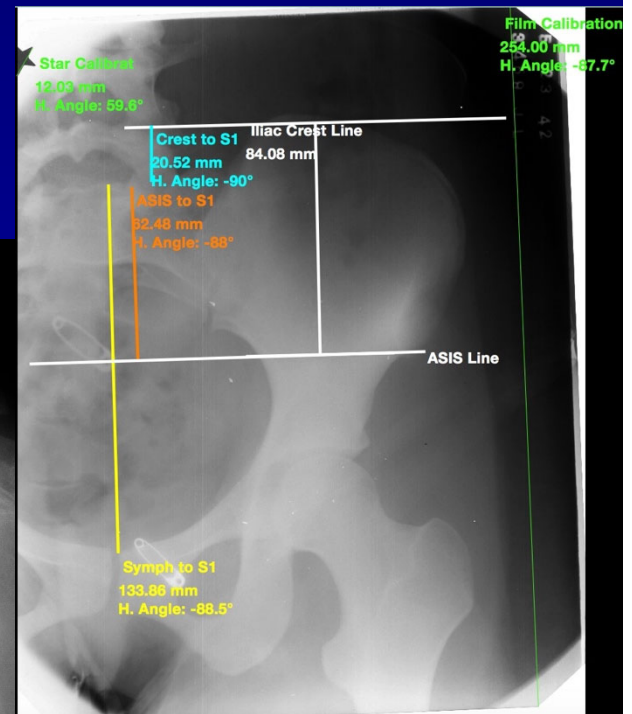
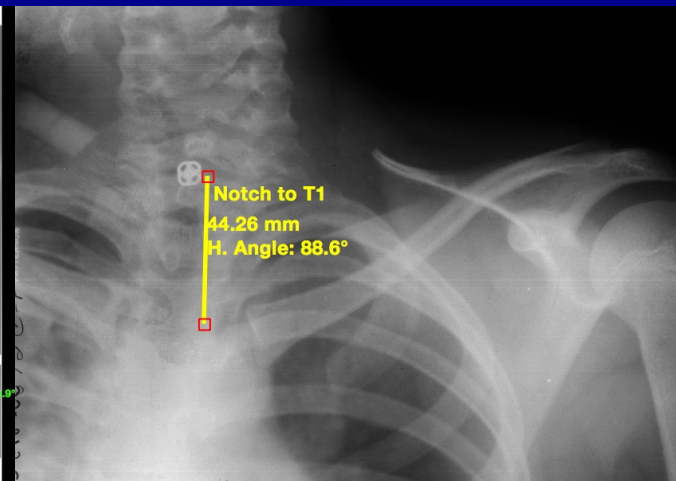
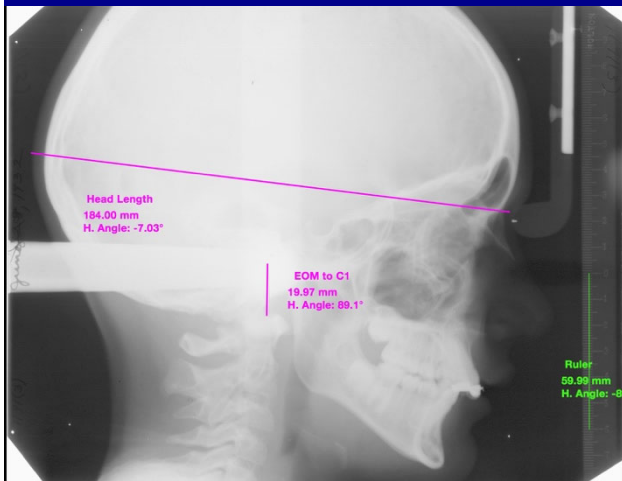
Finding 1: 90% final growth corresponds to the PHV

and growth standardized by it is very consistent across all children of both sexes

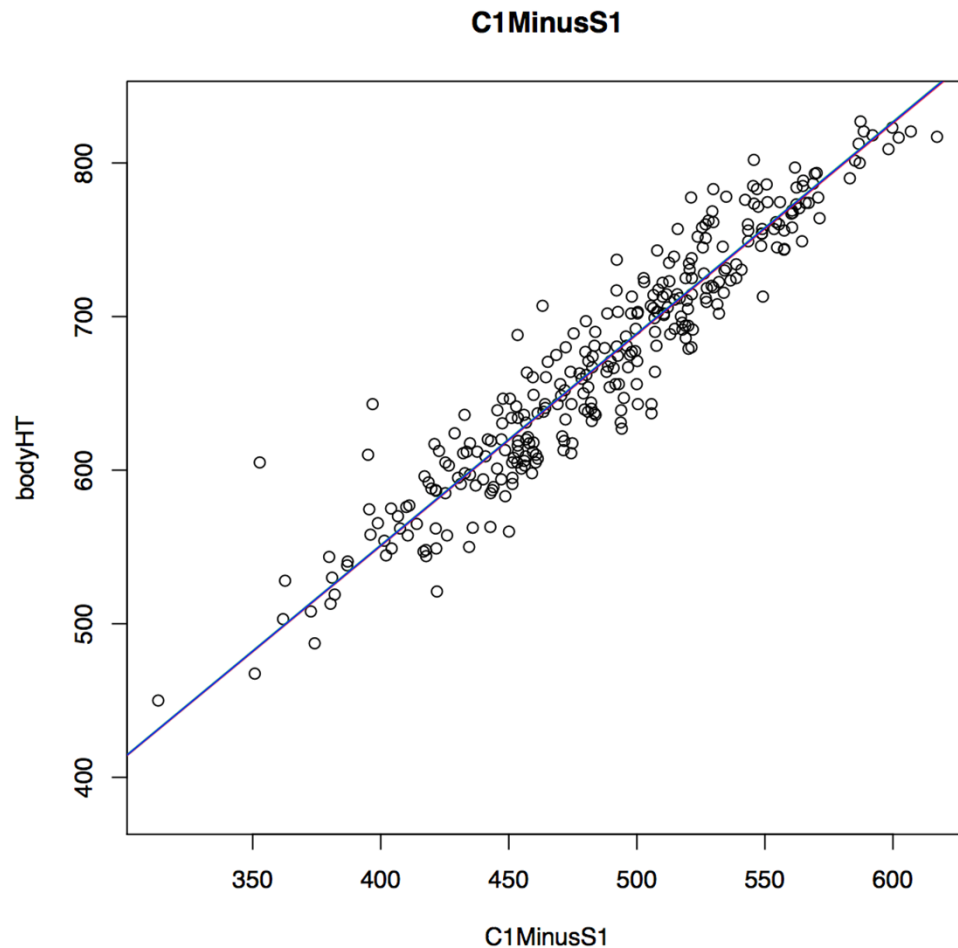


Methods – Part 2

- Compared anthropometrics with concurrent x-rays to identify the heights of S1, T1, and C1.
- Compared these to percentage of sitting height minus the head height.
- Used these values to calculate multipliers for spinal growth.

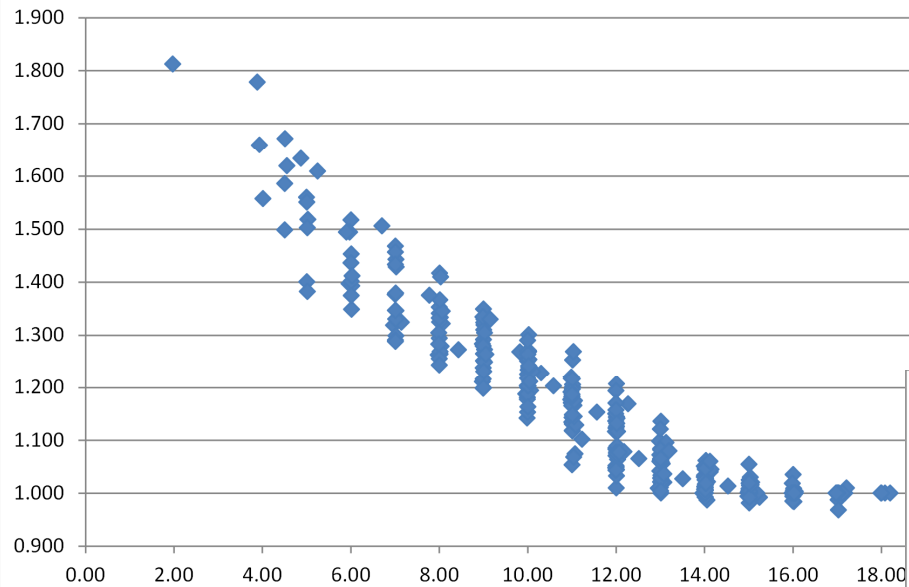


Finding 2: C1-S1 Length is a consistent proportion of Sitting height minus Head height.

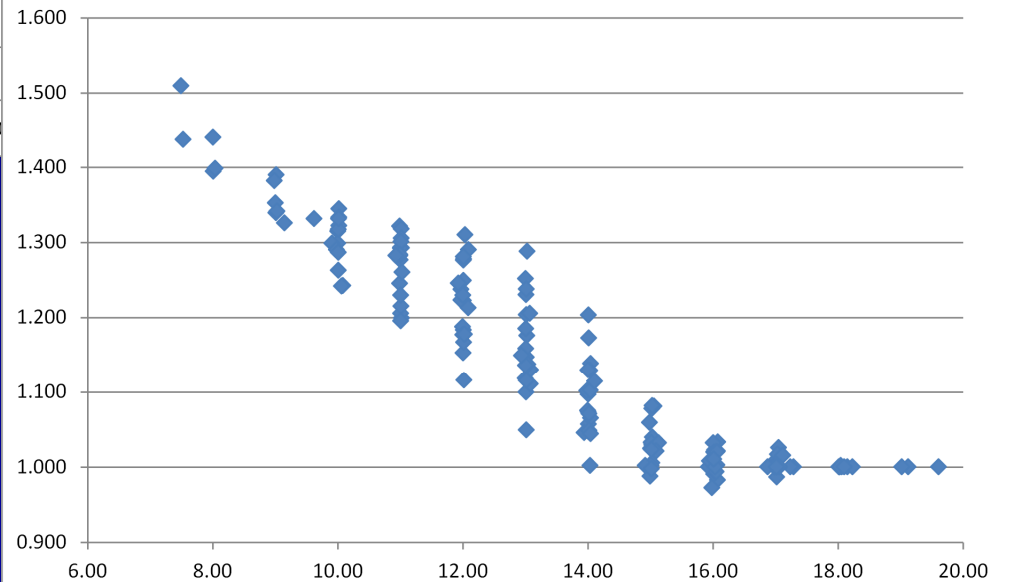


Finding 3: Multiplier vs Age have wide distributions.

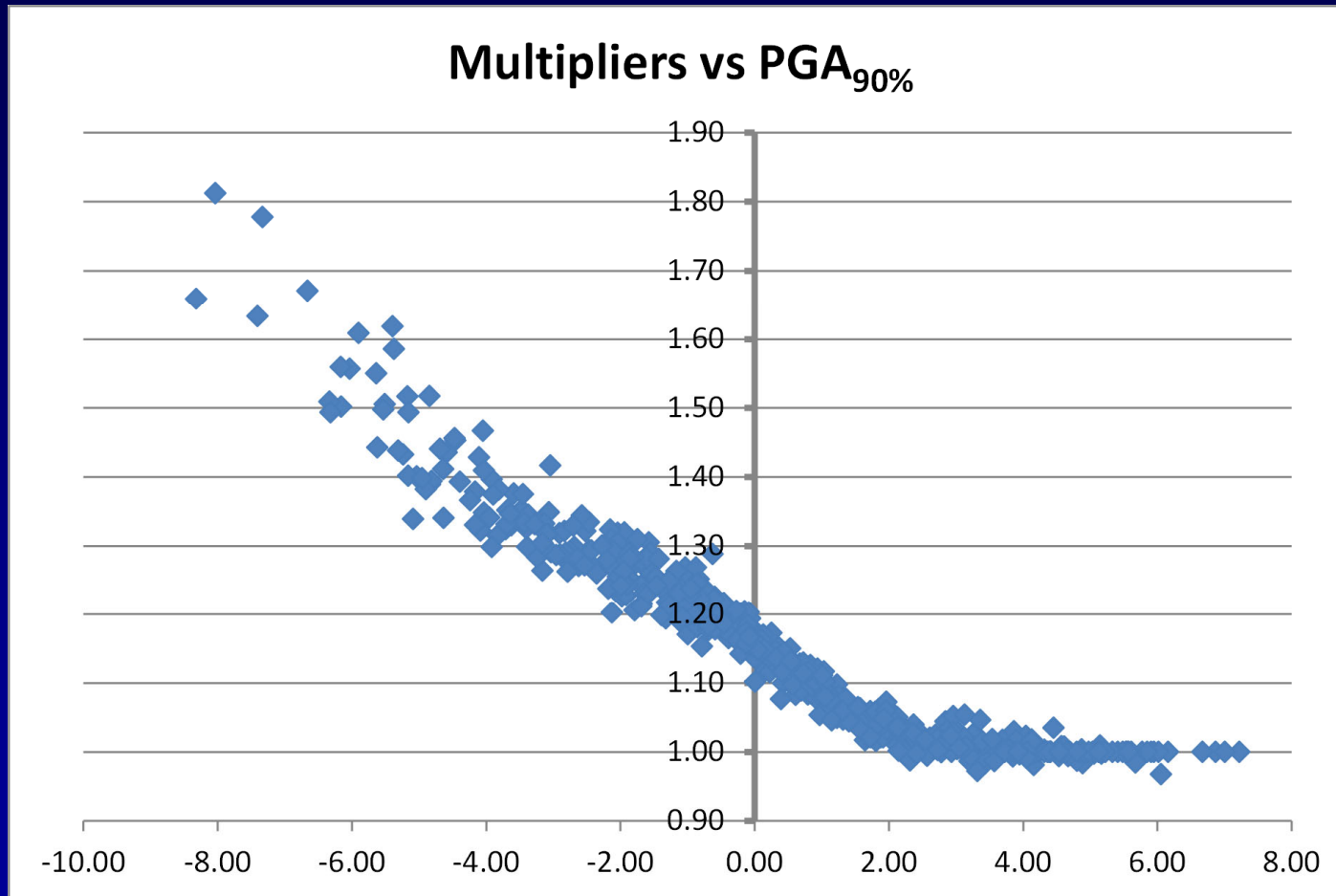
Multipliers vs Age Girls



Multipliers vs Age Boys

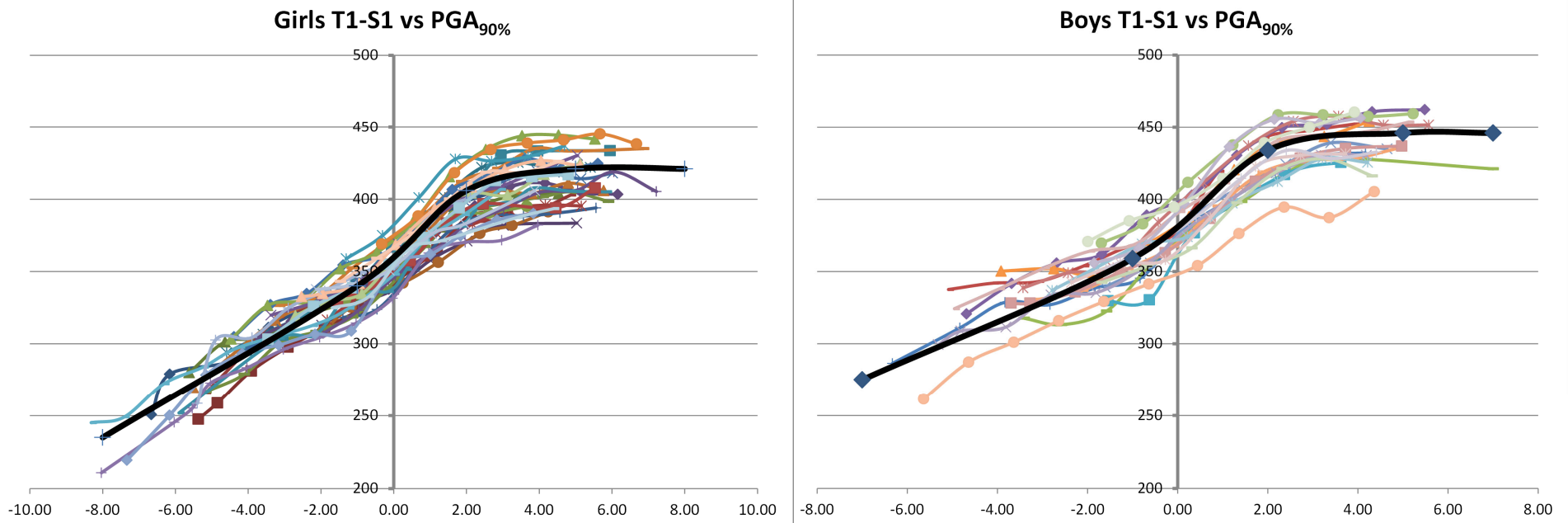


Finding 4: Multipliers standardized to the PHV have very tight distributions.



And are FAR better than age derived multipliers

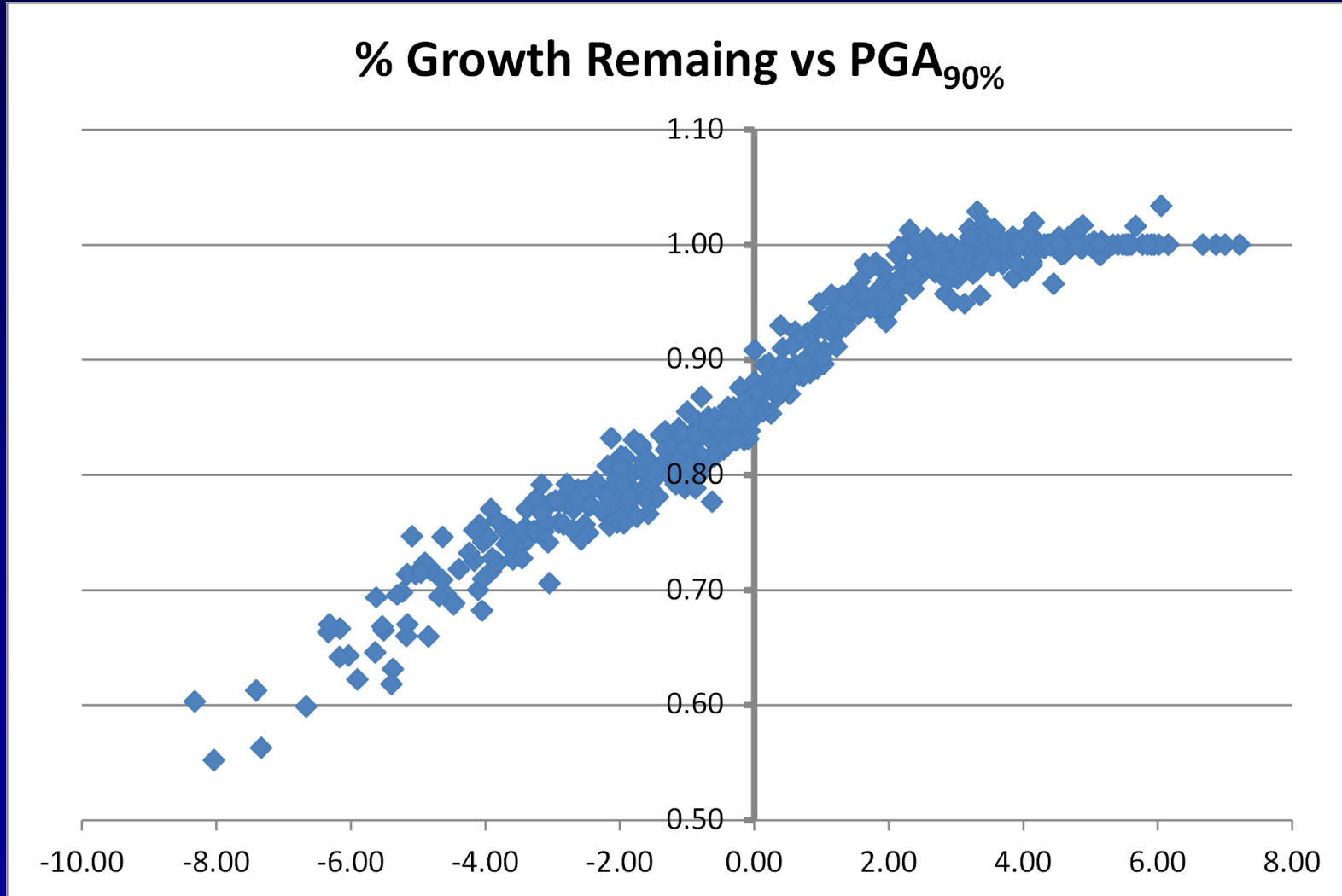
Finding 5: Spinal growth (T1-S1) is very rapid during the growth spurt.



	Girls	Boys
Childhood	1.5cm/year	1.5cm/year
Growth Spurt	2.5cm/year	2.5cm/year
Terminal Growth	0.4cm/year	0.4cm/year

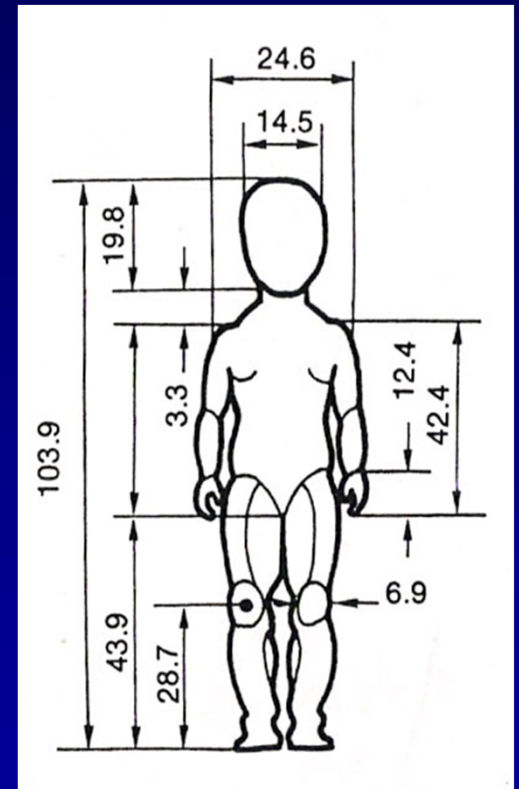
Higher than reported with prior cross sectional studies

Finding 6: When final height is 90% final, the spine is only 85% final



Finding 7 and 8:

- Head height changes little from mid childhood to maturity
- The Proportion of cervical to thoracic and lumbar spine does not change during the same age range
 - C-Spine represents 24% of C1-S1 length
 - Multipliers are the same for C-Spine, TL-Spine and CTL-Spine



Limitations

- This is 2D, not 3D data – does not account for the sagittal plane.
- Have only localized C1, T1, S1 and does give information on individual FSUs or lumbar/thoracic segments
- This can be supplemented with high quality cross sectional data.
- Multipliers still need to be identified for younger children.

Summary - Longitudinal Growth

Data is Important

1. 90% final growth corresponds to the PHV and is a better standardizer of growth than age or estimated PHV timing.
2. C1-S1 Length is a consistent proportion of Sitting height – Head height.
3. Age based multipliers of spinal growth remaining have wide distributions.
4. Multipliers standardized to the PHV have very tight distributions and are far better than age based multipliers.

Summary (cont)

5. Spinal growth is very rapid during the growth spurt and higher than shown in prior reported studies.
6. When final height is 90% final, the spine is only 85% final
7. Head height does not change much from mid childhood to maturity
8. The Proportion of cervical to thoracic and lumbar spine does not change through the same age range

Summary

- We now have useful multipliers of spinal growth from mid childhood through adolescence.
 - Predict correction with growth modification
 - Predict final spine length with fusion
 - Comparison with normal for growing rods
- Timing relative to the growth spurt and not by age is what counts.
- Growth of the spine is more rapid during the growth spurt than previously found.
- We can use these same methods to look at spinal growth in younger children.

Implications

- We now have reasonable multipliers of spinal growth from mid childhood through adolescence.
- Can calculate spinal correction with growth modification or spinal length potential for gain chest volume.
- Because all longitudinal growth is physal from long bones or spine end plates, it is highly likely that physal appearance is very reflective of the spinal growth and spinal height multipliers - more to come.
- We can use these same methods to look at spinal growth in younger children.

Thank you!

