

Coupled Symmetry and Pattern of Rib Growth in the Growing Human

Richard M. Schwend MD

John Schmidt PhD

Laurel Blakemore MD

Julie Reigut MS

Behrooz Akbarnia MD



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Introduction

- There is substantial information on the changes of the **rib cage** during childhood and asymmetry of the thorax in children with scoliosis.
- Virtually no normative data on the growth of **ribs** throughout childhood and adolescence.



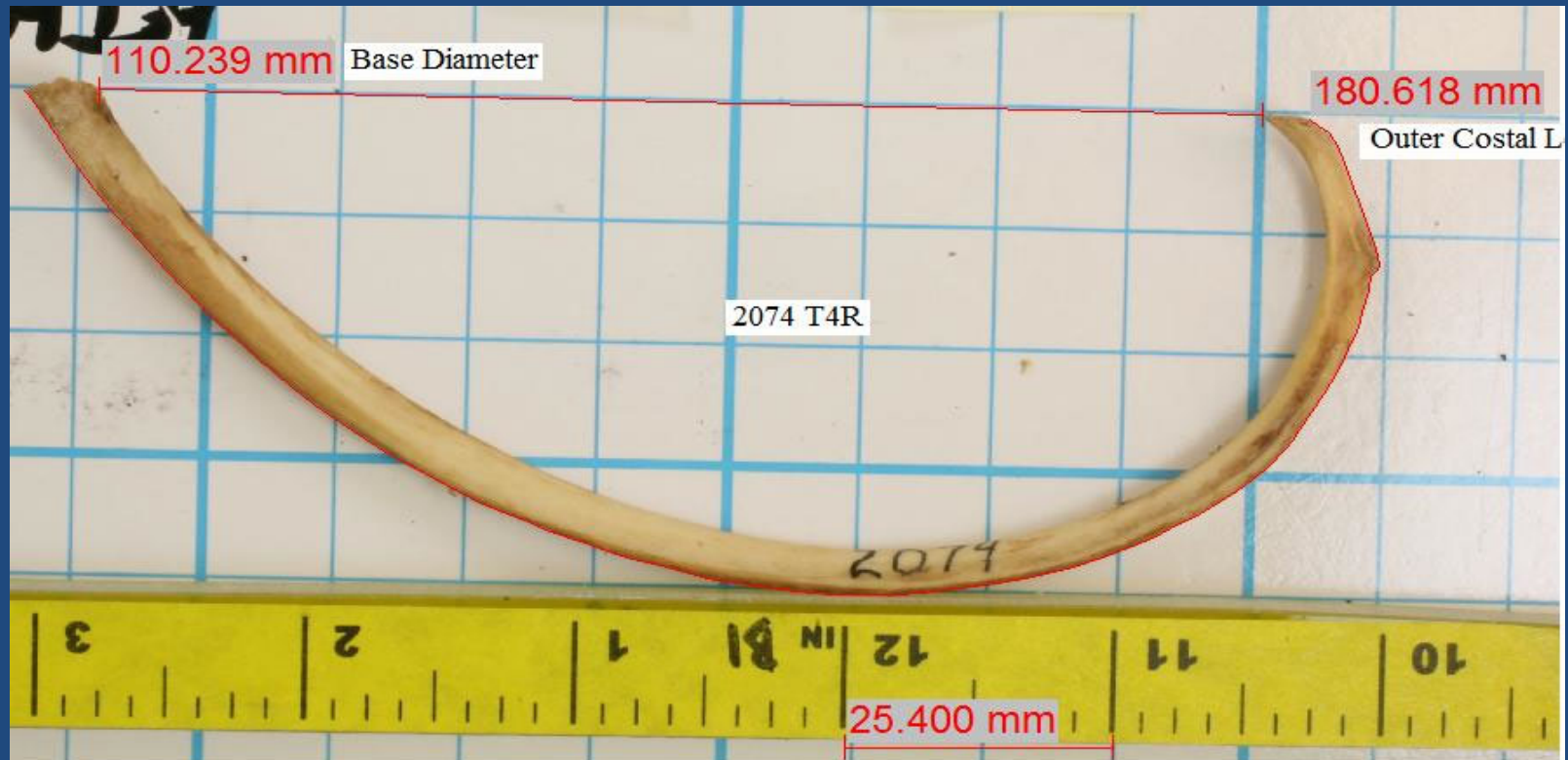
Methods

- The Hamann-Todd Osteological Collection provided the bones of 32 specimens aged 1-18 years.





6226 individual photographs of all vertebral bodies and ribs were obtained from these specimens.
Over 32,000 separate measurements

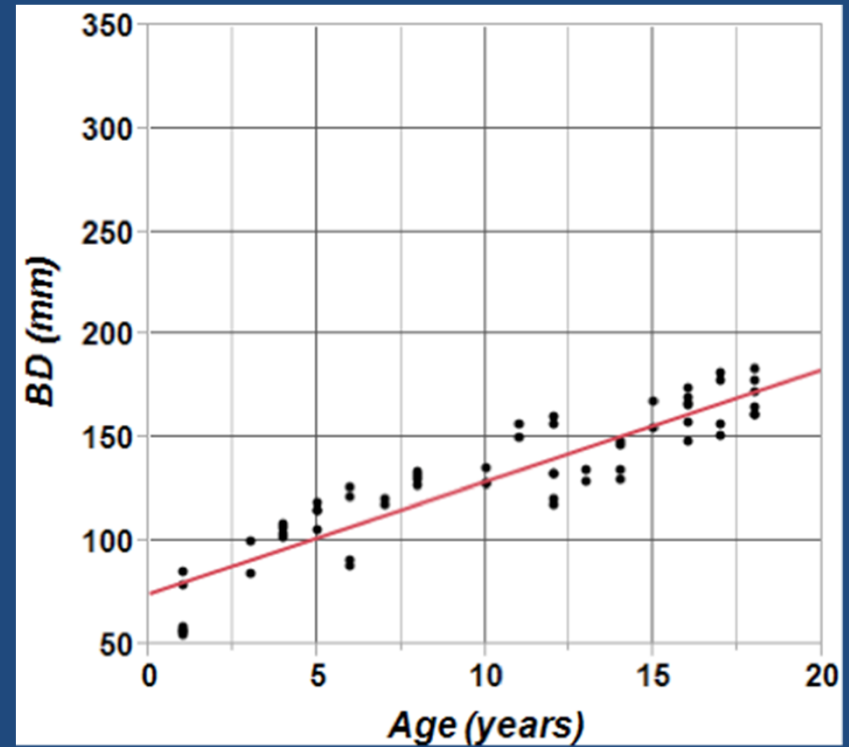
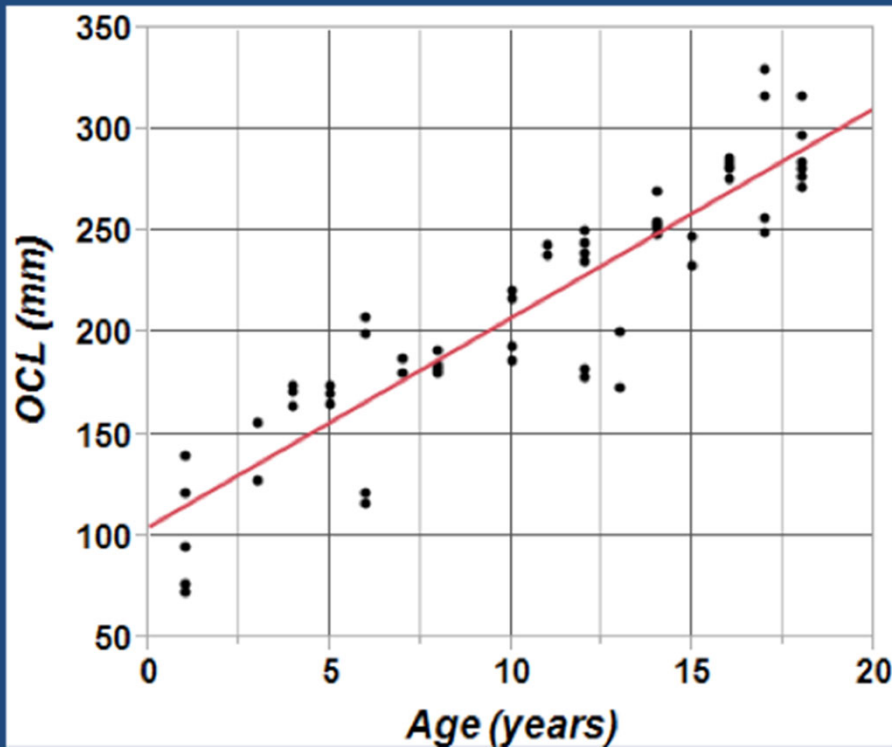


Quantitative measurements were taken with image analysis software. (Scandium Image Analysis Software Olympus, Soft Imaging Solutions)

Results of two of the measurements, the Outer Costal Length (OCL) and the Base Diameter (BD), are presented.

Results

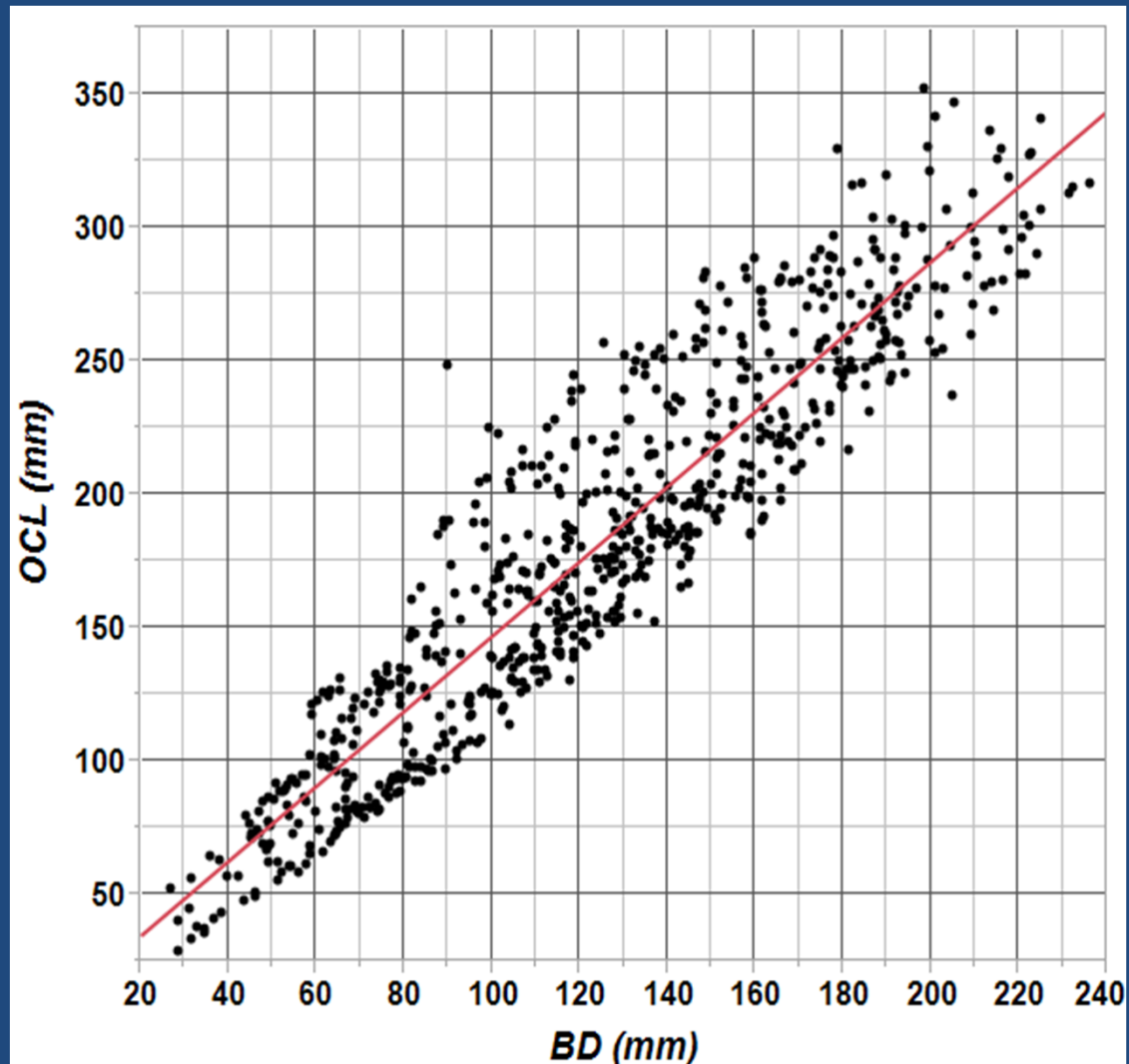
- With the exception of the ribs at T12, both the OCL and the BD showed a linear, statistically significant growth with age for all ribs, and the linear relationship between the BD and OCD correlated across all ages, indicating that the ribs changed their dimensions in unison.



Rib 4

-Outer Costal Length (OCL) and Base Diameter (BD) were plotted against age. This example shows results for rib 4. Regression lines had correlation coefficients (r^2) of 0.840.

-For rib 4 OCL changed (slope of the line) at a rate of 10.3 mm/year and BD increased at rate of 5.4 mm/year. All of the measurements for ribs 1 through 12 were similar and showed this general linear increase with age.



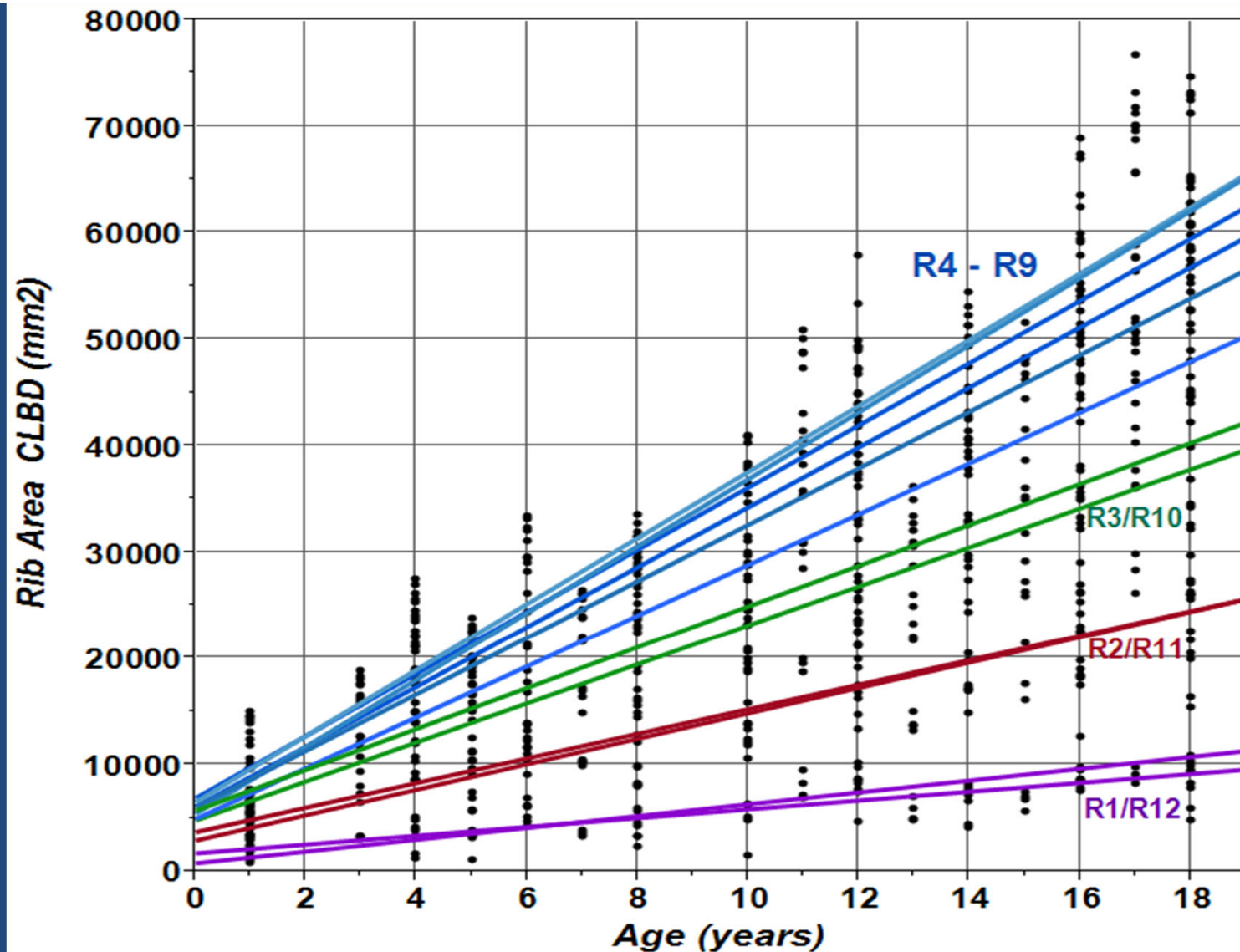
Linear relations between the rib BD and the OCL. These measurements Correlated across all ages, indicating that ribs change their dimensions in unison

$$\text{OCL (mm)} = 6.6 + 1.4 \times \text{BD (mm)} \quad r^2 = 0.860 \quad N = 714$$

Rib No	b Start Length (mm)	m Growth Rate (mm/yr)	r² Correlation Coefficient	n Sample Size
1	56.7	4.1	0.761	60
2	86.9	7.5	0.823	61
3	99.5	9.4	0.869	62
4	105.0	10.3	0.823	62
5	112.0	11.0	0.864	62
6	114.2	10.7	0.854	60
7	113.9	10.6	0.821	60
8	109.6	10.5	0.885	59
9	106.4	9.4	0.842	60
10	94.5	8.1	0.823	59
11	69.9	6.1	0.760	59
12	39.0	4.0	0.575	50

Results

- The BD x OCL product indicates that the ribs grow through coupled symmetry, in which ribs in the upper and lower thorax start at the same size and grow at the same rate within the pair; ribs 1 and 12, 2 and 11, 3 and 10.
- Each rib pair grows at a significantly different rate from the other pairs.



The Projected area of the ribs by age. The regression line for each rib is shown. Ribs 1 and 12 (purple) increased in projected area the least amount. Ribs 2 and 11 (red) were nearly superimposed and increased in area faster than ribs 1 and 12. Ribs in the middle thorax (blue) increased the fastest.

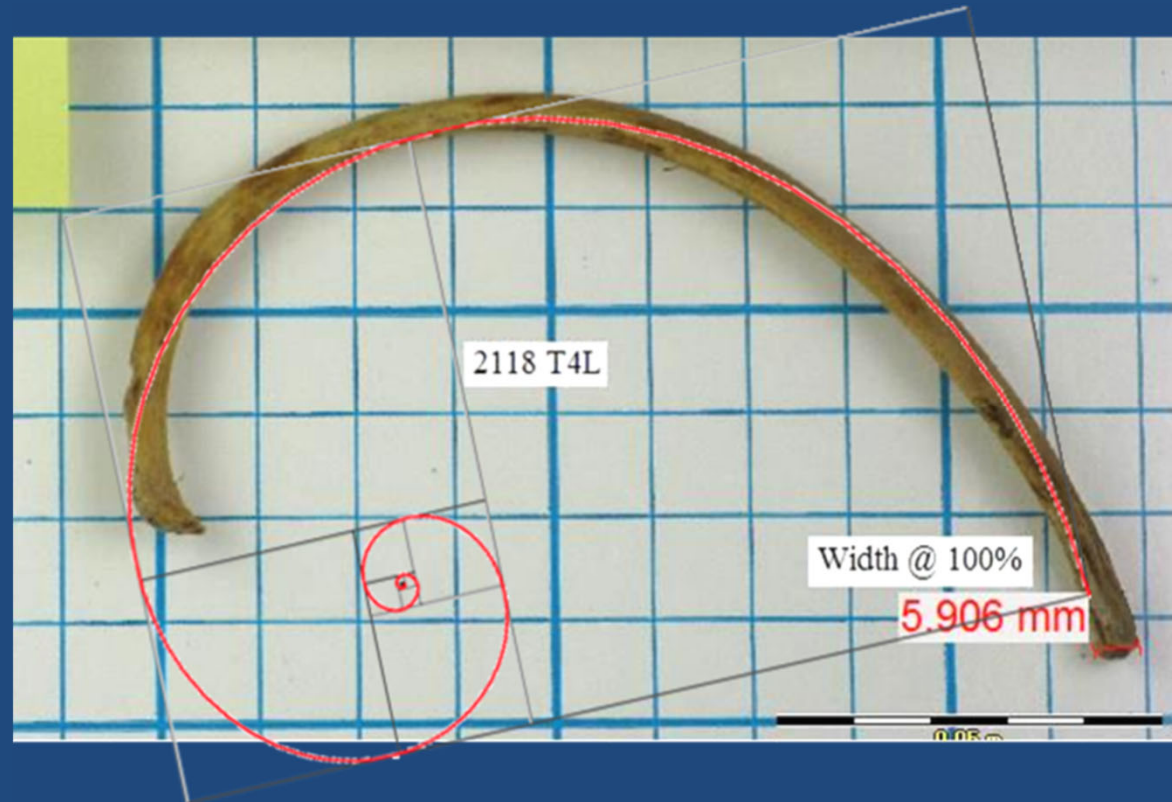
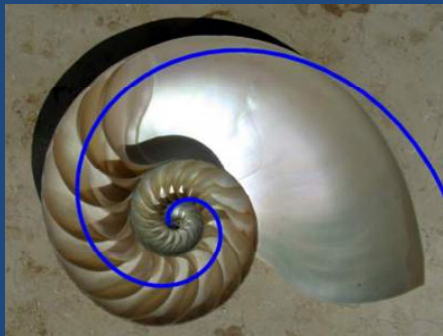
Results

- Measurements of BD and OCL from a specimen with scoliosis from the collection compared to these normative values were greatly different.



Results

- Elliptical or golden spiral (within 8% error)
- Similar to a nautilus shell, rib growth is primarily at the sternal end of the rib spiral.



Conclusions

- We believe that this is the first report of the change in length and shape of normal ribs, measured directly from the human specimens in a wide age range of children who did not have scoliosis.

Significance

- This data adds to the understanding of normal rib growth and provides a framework for determining the difference between ribs from normal children and those with scoliosis.

Special Thanks

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