Age-related changes in geometric characteristics of the pediatric thoracic cage

Center for Child Injury Prevention Studies
The Children's Hospital of Philadelphia® RESEARCH INSTITUTE

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Background

- Pediatric anthropomorphic test devices (ATD) and computational models are currently used to evaluate automotive restraint systems for child occupants.
- The geometric and structural biofidelity of the thorax governs how the restraint system interacts with the child.
- Pediatric ATD thorax design is based on external thoracic anthropometry data measured from real children with limited data on pediatric skeletal thoracic geometry.
- A comprehensive data-driven approach is needed to generate age-specific thoracic geometric guidelines in order to develop the next generation of pediatric ATDs.

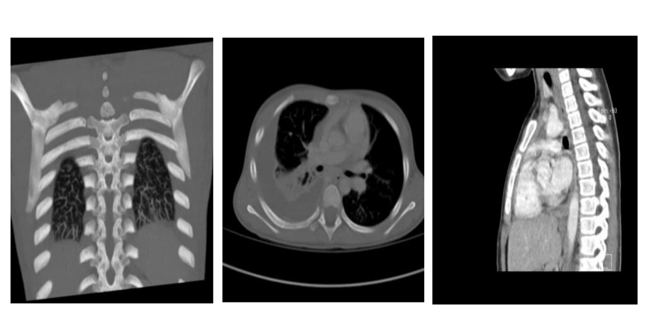
Objective

To quantify the three-dimensional structural characteristics (example: bony geometry) of the pediatric thoracic cage for male subjects ages 1, 3, 6, 10 and 18 years.

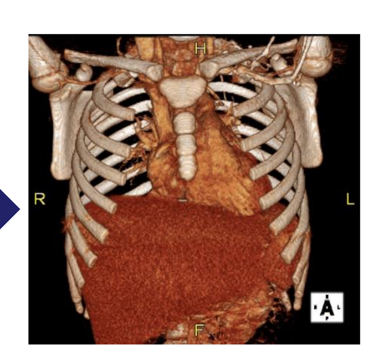
Methods

- With CHOP – Institutional Review Board (IRB) approval, Computed Tomography (CT) scans were obtained from 1, 3, 6, 10 and 18 year old male subjects (5 subjects per age group).
- Anatomical landmarks on the thoracic cage, such as costochondral junction, tubercle, external surface of the rib shaft, etc., were digitized (1) using Analyze software (Mayo Clinic, Rochester, MN) at Drexel University.
- A custom MATLAB (The MathWorks Inc., Natick, MA) code was created to compute the geometrical characteristics based on the Cartesian coordinates of these points. Parameters were computed from 10 to 90% of the rib length (the tubercle is at 0%, the costochondral junction is at 100%).
- Key computed parameters include normalized rib length, lateral rib angle, apparent curvature of the ribs and longitudinal twist of the ribs (2,3).

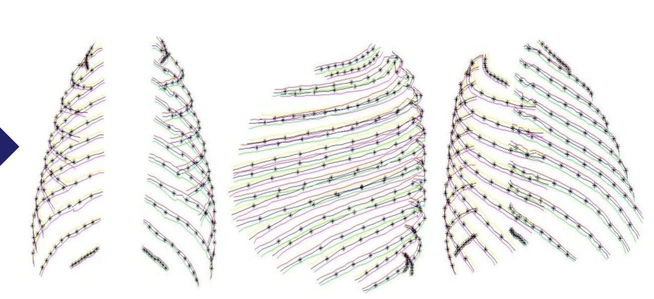
CHOP IRB Approval



CT scans of thorax

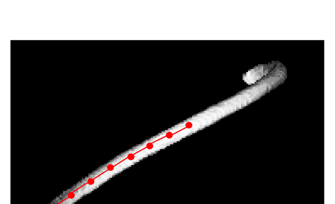


3D reconstruction

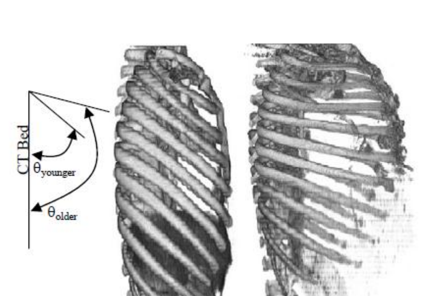


Digitized point cloud

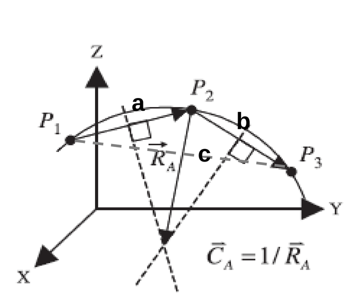
Custom MATLAB Code: Compute geometric parameters



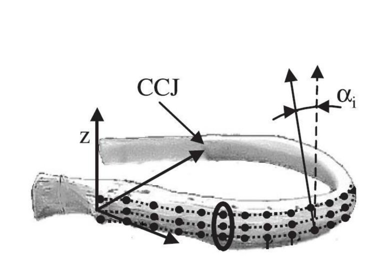
Rib Length (2)



Lateral Rib Angle (3)



Apparent Curvature (2)



Longitudinal Twist (2)

Results

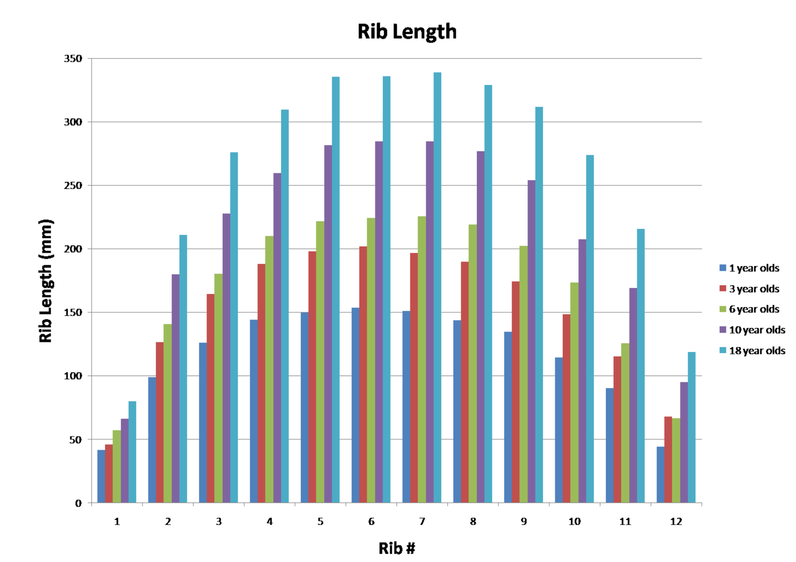


Figure 1: Average rib length for all age groups.

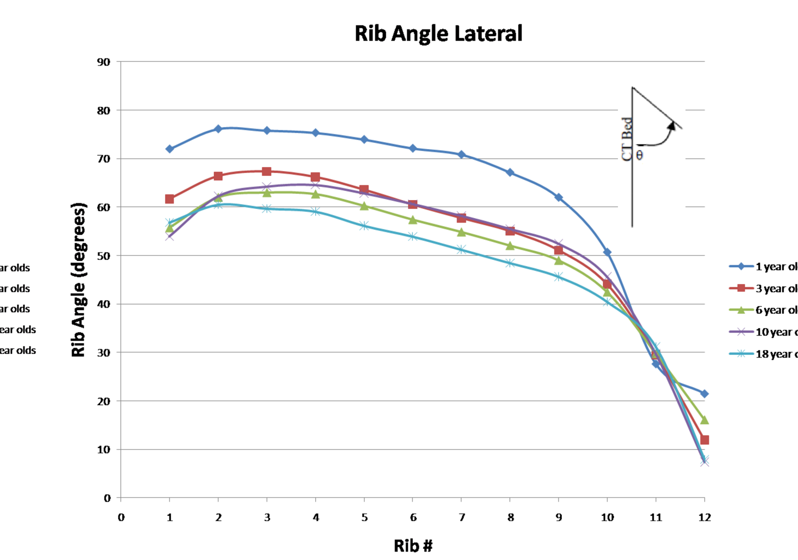


Figure 2: Average rib angle for all age groups measured from vertical.

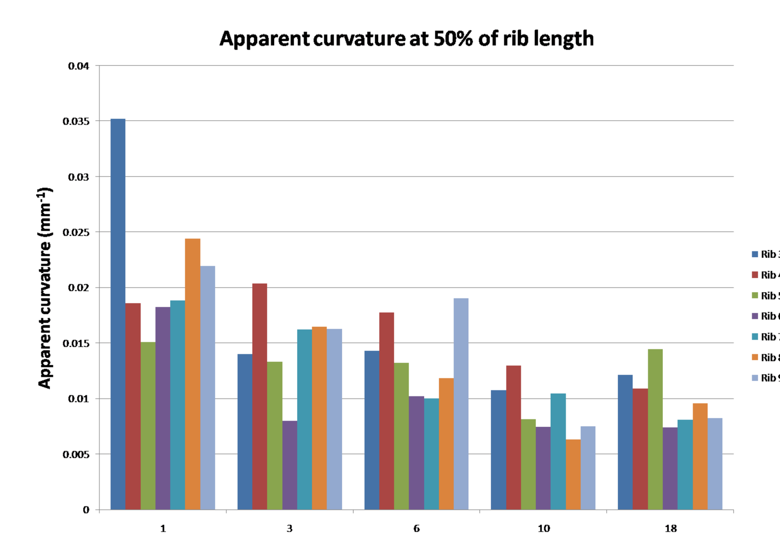


Figure 3: Average apparent curvature for ribs 3-9 for all age groups at 50% of rib length.

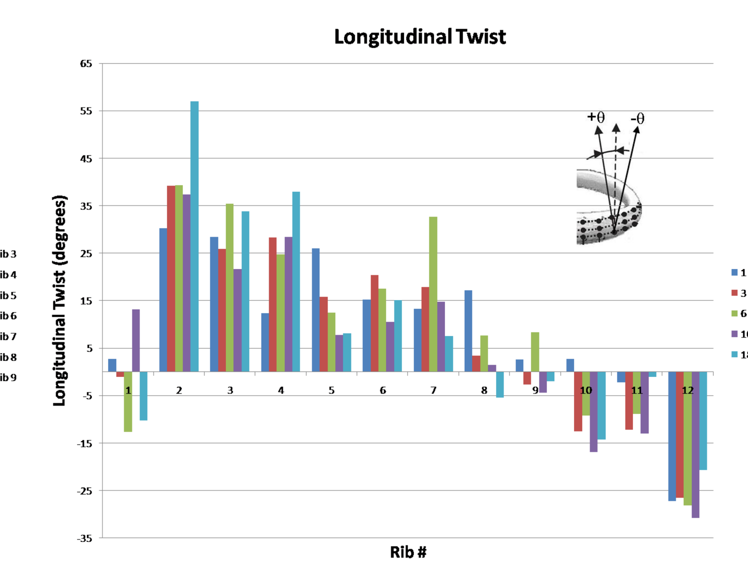


Figure 4: Average longitudinal twist for all age groups. The average difference between longitudinal twist at the 90% and 10% site is shown.

- Rib length is significantly different across all age groups for ribs 1-12, however no significant differences are observed in any age group for ribs 1-12 when rib length is normalized by standing height (Figure 1).
- Average lateral rib angle shows a decreasing trend (i.e. become more vertical) with increasing rib number and increasing age (Figure 2). One year olds are significantly different from all other age groups for ribs 1-8.
- Apparent curvature shows a decreasing trend with increasing age (Figure 3). One year olds are significantly different from all other age groups for ribs 5-9.
- Ribs 2-7 twist inward and ribs 10-12 twist outward for all age groups (Figure 4). No significant differences were found across age groups at any rib level. Maximum twist was observed in rib 2.

Conclusions

- Age-specific geometric differences were observed in pediatric thoracic cage structure.
- Future work to compare ATD thorax shapes to corresponding human ages.

References

1. Gayzik, F.S., Yu, M.M., Danelson, K.A., Slice, D.E., Stitzel, J.D. (2008) *Quantification of age related shape change of the human rib cage through geometric morphometrics.* Journal of Biomechanics, 41: 1545-1554.
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