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Age- and gender-related changes in pediatric thoracic vertebral morphology

James R. Peters, BS[a], Charanya Chandrasekaran, BS[a], Lucy F. Robinson, PhD[b], Sabah E. Servaes, MD[c], Robert M. Campbell, Jr., MD[d], Sriram Balasubramanian, PhD[a,*]

[a]*School of Biomedical Engineering, Science and Health Systems, Drexel University, 3141 Chestnut St, Bossone 718, Philadelphia, PA 19104, USA*
[b]*Department of Epidemiology and Biostatistics, School of Public Health, Drexel University, Nesbitt Hall, 3215 Market St. Philadelphia, PA 19104, USA*
[c]*Department of Radiology, The Children's Hospital of Philadelphia, 34th St and Civic Center Boulevard, Philadelphia, PA 19104, USA*
[d]*Division of Orthopaedic Surgery, The Children's Hospital of Philadelphia, 34th St and Civic Center Boulevard, Philadelphia, PA 19104, USA*

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Abstract

BACKGROUND CONTEXT: Although it is well known that the growth of thoracic spine changes significantly with age, gender, and vertebral level in the skeletally normal pediatric population, there have been very few studies attempting to comprehensively quantify such variations. Biomechanical and computational models of the growing thoracic spine have provided insight into safety and efficacy of surgical and noninvasive treatments for spinal deformity. However, many of these models only consider growth of the vertebral body and pedicles and assume a consistent growth rate for these structures across thoracic levels.

PURPOSE: To enhance the understanding of age-, gender-, and level-related growth dynamics of the pediatric thoracic spine by comprehensively quantifying the thoracic vertebral morphology for subjects between 1 and 19 years.

STUDY DESIGN: A retrospective computed tomography (CT) image analysis study.

METHODS: Retrospectively obtained chest CT scans from 100 skeletally normal pediatric subjects (45 males and 55 females between the ages 1 and 19 years) were digitally reconstructed using medical imaging software. Surface point clouds of thoracic vertebrae were extracted and 26 vertebral geometry parameters were measured using 25 semiautomatically identified surface landmarks and anatomical slices from each thoracic vertebra (T1–T12). Data were assessed for normality, symmetry, and age-, gender-, and level-related differences in geometric measures and growth. Linear regression was performed to estimate of the rates of variation with age for each measurement.

RESULTS: Asymmetries (bilateral, superior-inferior, and anteroposterior) were observed in vertebral body heights, end plate widths and depths, and interfacet widths. Within genders, significant interlevel differences were observed for all geometric measures, and significant differences in the rates of growth were found across thoracic levels for most parameters. Significant differences were observed between genders for pedicle, spinous process, and facet measurements. Growth rates of the pedicles and vertebral bodies were also found to vary significantly between genders.

CONCLUSIONS: The rates of growth for most thoracic vertebral structures varied between genders and across vertebral levels. These growth rates followed trends similar to those of their associated vertebral dimensions and this indicates that, across levels and between genders, larger vertebral structures grow at faster rates, whereas smaller structures grow at a slower rate. Such

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* Corresponding author. School of Biomedical Engineering, Science and Health Systems, Drexel University, 3141 Chestnut St, Bossone 718, Philadelphia, PA 19104, USA. Tel.: (1) 215-571-3738; fax: (1) 215-895-4983.

E-mail address: sri.bala@drexel.edu (S. Balasubramanian)

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level- and gender-specific information could be used to inform clinical decisions about spinal deformity treatment and adapted for use in biomechanical and computational modeling of thoracic growth and growth modulation.

Keywords: Pediatric; Spine; Morphology; Vertebra; Growth; Thoracic

Introduction

For the skeletally normal pediatric population, it is known that growth of the spine varies with age and gender and that such variations in spinal growth may influence the progression of spinal deformities, confounding treatment outcomes [1–8]. Growth sparing spine instrumentation, in contrast to fusion-based techniques, guides the growth of the spine through periodic distraction and is the preferred treatment method for correcting thoracic spinal deformity in pediatric subjects. This preference can be attributed to a combination of effeteness and the instrumentation's preservation of subjects' mobility, the natural anatomy [9–12]. Current trends indicate that the future direction for spine deformity correction will rely on growth modification. This will require the study and characterization of normal growth to inform more effective growth modification strategies and enable better device design. Because of the lack of pediatric cadaveric material, current growth sparing spine instrumentations are commonly evaluated using biomechanical and computational models, which often make the assumptions of scaled material properties and a non-growing thoracic geometry [13–29].

Thorough quantitative evaluations of adult thoracic vertebral morphology report detailed geometric measures of the end plates, vertebral bodies, pedicles, spinal canals,

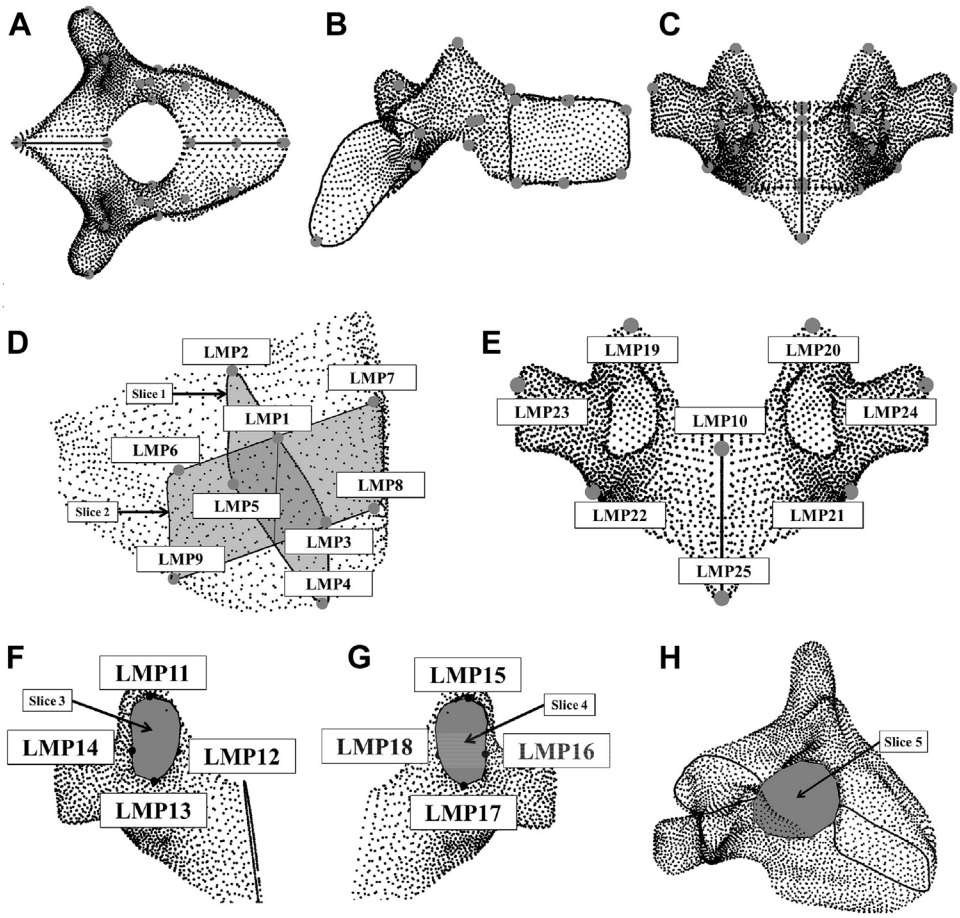

Fig. 1. All LMPs displayed in (A) x-y (transverse) plane, (B) x-z (sagittal) plane, and (C) y-z (coronal) plane. (D) Vertebral body LMPs 1 to 9 and anatomical slices (Slice 1–2). (E) Spinal canal (LMP10), facet (LMPs 19–22), and transverse and spinous process LMPs (23–25). (F) Right pedicle LMPs (11–14) and anatomical slice (Slice 3). (G) Left pedicle LMPs (15–18) and anatomical slice (Slice 4). (H) Spinal canal anatomical slice (Slice 5). LMP, landmark point.