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Case Series

The Development of Thoracic Vertebral Sagittal Morphology During Childhood

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Abstract

Study design: This is a cross-sectional descriptive study objectives to describe normal development of thoracic vertebrae during childhood and document contribution of individual vertebral shape to the sagittal alignment.
Summary of Background Data: Sagittal spinal alignment changes during growth. The changes in sagittal alignment during adolescent growth spurt as well as the individual shapes of thoracic vertebrae have been implicated as factors for the development of adolescent idiopathic scoliosis (AIS). The contribution of individual vertebral shape to the sagittal alignment and the changes in the vertebral shape with growth is not known.
Methods: Sagittal computed tomographic (CT) scans of thoracic vertebrae were examined in children without any evidence of spinal deformity. Vertical distances between the endplates at the most anterior and most posterior sides of vertebral body were measured as anterior vertebral height (aVH) and posterior vertebral height (pVH), respectively.
Results: There were a total of 133 CT scans done on 71 male and 62 female children. The children were grouped as follows: Group I (0–2 years of age), Group II (3–6 years of age), Group III (7–9 years of age), Group IV (10–12 years of age), and Group V (13–16 years of age). A-P ratios of vertebral heights were grouped as T1–T5, T6–T8, and T9–T12. Measurements demonstrated that the anterior and posterior heights in each vertebra grew longitudinally and consistently with increasing age. The aVH/pVH ratio of each individual vertebra showed no significant difference according to age. Measurements of thoracic vertebrae on sagittal spinal CT images did not show any differences in the relative growth and heights of the anterior versus posterior walls of the vertebral bodies in any of the segments in any age or age group.
Conclusions: The sagittal alignment changes during growth are likely related to maintenance of sagittal balance rather than the shapes of individual vertebrae.
Level of Evidence: Level II.

Keywords: Spine growth; Thoracic spine; Pediatric spine; Idiopathic scoliosis; Early onset scoliosis

Introduction

There is a continuous change in the sagittal alignment of the human spine from birth until the adult spinal contour develops. The global spinal kyphosis of the newborn changes with growth such that the thoracic kyphosis increases while cervical and lumbar lordoses develop [1,2]. Failure to achieve a normal thoracic kyphosis (hypokyphosis) has been suggested to be an inciting factor for the development of adolescent idiopathic scoliosis (AIS) [3]. During the natural development of the human spine, the least magnitude of kyphosis is observed between 10 and 12 years of age, and this period corresponds to the same ages as the clinical presentation of AIS [1,3]. Knowledge of normal sagittal alignment and proportions of individual vertebrae and discs are important in order to identify the pathologic processes that take place during the development of spinal deformity.

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The normal growth patterns of individual thoracic vertebrae have not been reported. Therefore, the aim of this study is to provide cross-sectional chronologic data on the evolution of thoracic vertebral body heights in children with no evidence of spinal deformity.

Methods

Following the approval by the Institutional Review Board (IRB), in collaboration with the pediatrics department spinal computed tomographic (CT) films of children who underwent imaging for reasons unrelated to the spine were collected between the years 2010 and 2013. Scanning protocols were adjusted for clinical indication and patient weight and automatic exposure control system was used in all patients. Scanning range was between the apex of the lungs and lung bases. Axial overlapping thin slices were used to create the sagittal reformations. Incomplete CT scans of the thoracic spine and children with spinal cord or column abnormalities were excluded. A total of 150 children without known vertebral pathology who underwent thoracic CT met the initial inclusion criteria. Patients had a wide range of diagnosis, mainly asthma and pneumonia; none of them had any neuromuscular disease. To standardize the size and growth of the children, patients between 0 and 2 years who are falling off from the third percentile according to World Health Organization (WHO) charts and patients between 2 and 16 years who are less than the third percentile according to Centers for Disease Control and Prevention (CDC) charts were excluded from study. Three patients were sporadically diagnosed with scoliosis in coronal scout views and were excluded. CT images of 133 children satisfied all of the inclusion criteria.

Sagittal reformations of thoracic vertebrae were examined and measurements were made on the Picture Archiving and Communication System (PACS) (General Electric Health Systems Centricity™) by one senior orthopedic resident and one spine surgeon, who are coauthors of this study. The sagittal CT cut with the widest canal diameter was identified and the measurements were performed on this image. In order to measure the anterior and posterior vertebral heights, two lines passing tangential to the most cranial and most caudal part of individual vertebrae were drawn as the proximal and distal endplates. Vertical distances between two lines at the most anterior and most posterior sides of the vertebral body were measured as the anterior vertebral height (aVH) and the posterior vertebral height (pVH), respectively.

The absolute values of aVH and pVH according to age, as well as the ratios of aVH to pVH (aVH/pVH), were recorded for each thoracic level.

Statistical analysis was performed with SPSS statistical software (SPSS Inc., Chicago, IL). The mean and standard deviations were calculated for all measurements. Kruskal-Wallis test was used to analyze the correlation between age groups and the anterior and posterior vertebral height ratios. The level of significance was set at $p < .001$.

The inter- and intrarater measurement reliability were tested by remeasuring 30 CT scans in a blinded fashion. Intraclass correlation (ICC) analysis revealed that there are almost perfect agreements for interrater (minimum-maximum ICC[3, 1] is 0.842–0.995) and intrarater evaluations (minimum-maximum ICC[1, 1] is 0.812–0.996). ICC(3, 1) and ICC(1, 1) values for all vertebras were higher than 0.8.

Results

There were a total of 133 CT scans done on 71 male and 62 female children. Age groups and thoracic spinal

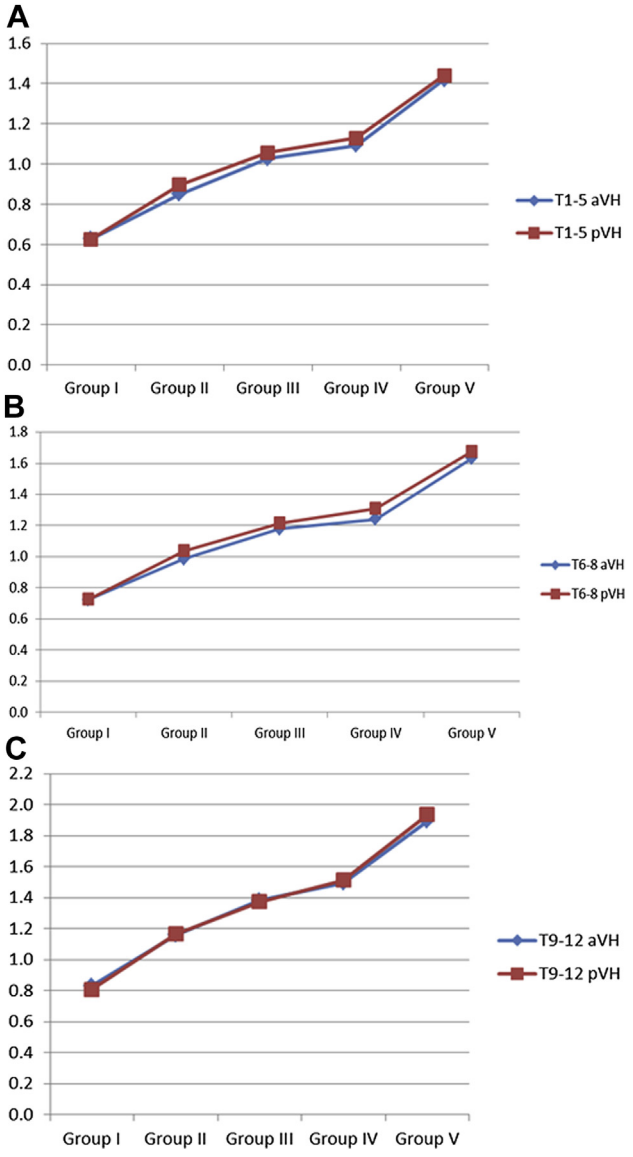

Fig. In all segmental groups, the growth of the anterior and posterior aspects of the vertebral bodies increased consistently and longitudinally. Longitudinal growth data of the (A) T1–T5 segmental group; (B) T6–T8 segmental group; and (C) T9–12 segmental group. The x-axis denotes the age groups and the y-axis denotes the vertebral height in centimeters.