Original Article

On the linear sizes of vertebrae and intervertebral discs of children in the beginning of puberty

ABSTRACT

Study Design: We collected experimental data concerning vertebrae sizes and performed an investigation of these data for different patient ages by methods of mathematical statistics.

Purpose: The standard dimensions of vertebrae and intervertebral discs are of major importance for obtaining a comprehensive understanding of spine diseases and their successful treatment. The purpose is to study these sizes for children at the age of 9–14 years.

Overview of Literature: Unfortunately, this issue is poorly presented in the corresponding literature. There are no systematic results. Only particular cases are presented.

Materials and Methods: Experimental is based on the: results of X-ray investigations of children spines. Theoretical background is given by methods of mathematical statistics.

Results: Systematic description of vertebrae sizes for children of age 9–14 is given. This specific age interval is the most common period of initiation of various pathological deformations of human spine.

Conclusions: The acquired data both reflect the process of spine growth and can serve for building correct mathematical models of a healthful or diseased spine.

Keywords: Scoliosis, spine, vertebrae

INTRODUCTION

Pathological deformations of a human spine can be regarded as stable deviations of its shape from the normal state. Like any disease, this deviation begins from minimal changes in the homeostasis. On the one hand, this preclinical stage is the most subtle to diagnose, but on the other hand, the most opportune for the treatment or prevention of the disease. This is also true for idiopathic scoliosis.

Based on the broad information on the anatomic and functional properties of the human spine, repeatedly confirmed under various clinical studies,[1-7] a mathematical modeling problem was formulated.[8] Attempts at solving this problem described[9-12] the process of formation of a three-dimensional deformation of the two-column human spine in the framework of theoretical mechanics. The modeling revealed a strict sequence of stages of deformation identical to the observed clinical picture.

However, the models developed suffer from lack of concrete numerical values of the linear dimensions of the components of a spine, which prevents from applying them further to obtain the precise conditions of the transition from a normal to a scoliotic spine.

To address this issue, we analyzed X-ray images of children's spines at different ages to reveal the real values of these parameters and their growth rates.

Mikhail Dudin, Yuri Baloshin[1], Igor Popov[1], Nikita Lisitsa[1], Stepan Bober

Center for Rehabilitation for Children's Orthopaedic Diseases, [1]Department of Higher Mathematics, ITMO University, Kronverkskiy, St. Petersburg, Russia

Address for correspondence: Prof. Igor Popov, Department of Higher Mathematics, ITMO University, Kronverkskiy, 49, St. Petersburg 197101, Russia. E-mail: popov1955@gmail.com

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MATERIALS AND METHODS

It is hard to measure the linear dimensions of spine components directly due to its anatomic complexity. One of the available methods consists in examining X-ray images of the spine of patients of the Center for Rehabilitation for Children's Orthopedic Diseases "Ogonek" (Saint Petersburg). Two groups of patients were considered: one with spinal compression fracture and the other with flat back posture and with idiopathic lordoscoliosis of the first degree with deformation angle 5°–7°.

Compressed vertebrae were ignored in the measurements. Furthermore, the low deformation magnitude in the second group when measured in the axial projection does not affect the observed linear dimensions of the vertebrae.

A total of 497 X-ray images were used. The detailed information on the numbers of images is presented in Table 1.

Each image was processed to measure only the distinctly seen dimensions, mainly the vertebrae C_7–L_5. The measured parameters were as follows:

- Width of vertebrae bodies (wb)
- Anterior–posterior size of vertebrae (aps)
- Vertebrae height (vh)
- Intervertebral discs height (hd).

These parameters are depicted on Figure 1.

The obtained data arrays are plotted in Figures 2-5.

RESULTS

The mean values of linear dimensions of vertebrae for different ages were obtained through the method of polynomial regression.[13] As a result, we obtained the averaged form of a linear dependency of vertebrae height and anterior–posterior size and an averaged quadratic dependency of vertebrae width and intervertebral discs height from the vertebra index. The vertebrae indices increase from top to bottom of the spine, vertebra Th_1 having index #6, while vertebra L_5 having index #23. The numerical formulas of these dependencies are presented in Table 2 ("N" is the vertebra index).

These dependencies are plotted graphically in Figures 6-9.

Table 1: The numbers of x-ray images for different ages

	9 years	10 years	11 years	12 years	13 years	14 years	Total
AP	40	50	52	38	56	22	258
Lateral	50	45	76	44	4	20	239
Total	90	95	128	82	60	42	497

AP - Anterior-Posterior

DISCUSSION

The initial data for the study come from X-ray investigations of children spines. It allows one to find only geometric characteristics of vertebrae and intervertebral discs. Other, mechanical, parameters of the biomechanical system which are needed for creation of a mathematical model should be determined by other experimental methods. Systematic description of vertebrae sizes for children of age 9–14 is given. This specific age interval is the most common period of initiation of various pathological deformations of the human spine. These

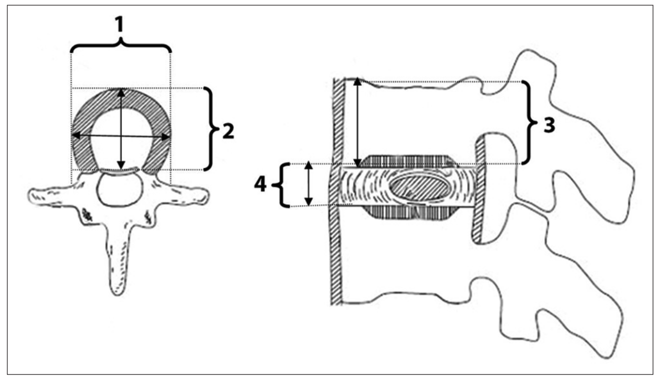

Figure 1: 1 – The measured vertebrae parameters, 2 – Width of vertebrae bodies (wb), 3 – Anterior–posterior size of vertebrae (aps), 4 – vertebrae height (vh), and 5 – intervertebral discs height (hd)

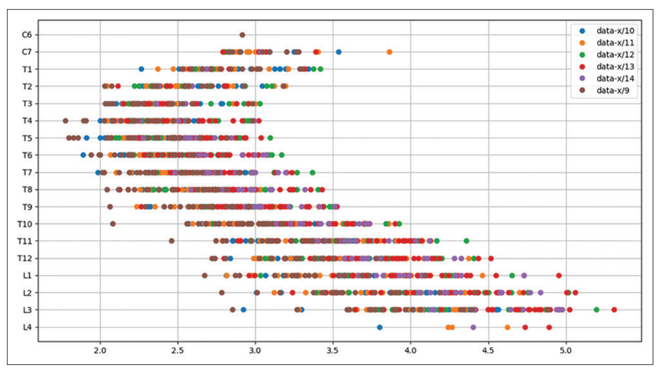

Figure 2: Width of vertebrae bodies (wb), cm (initial data array)

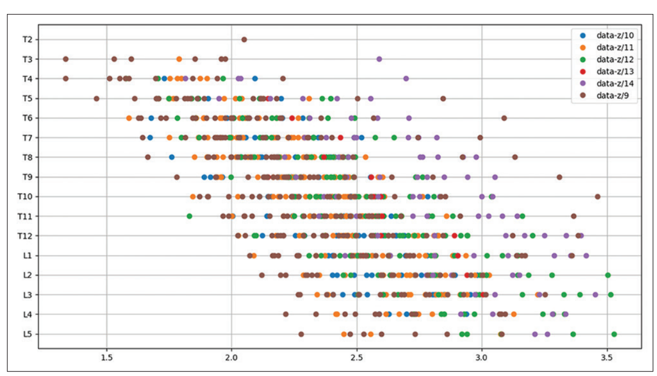

Figure 3: Anterior–posterior size of vertebrae (aps), cm (initial data array)

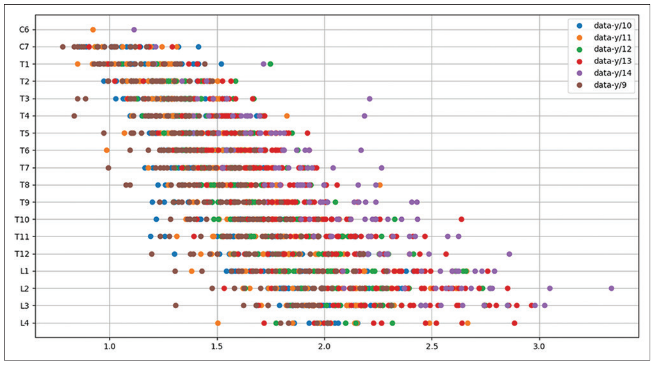

Figure 4: Vertebrae height (vh), cm (initial data array)

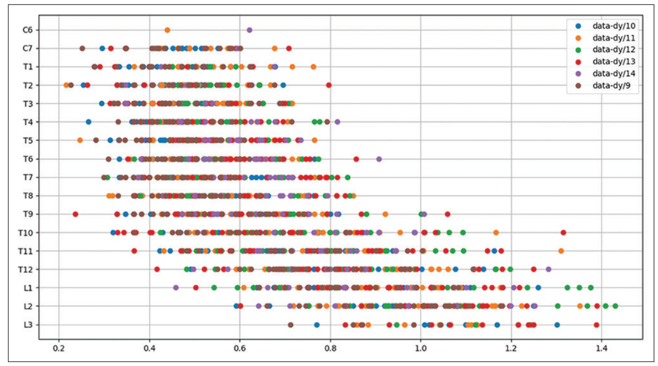

Figure 5: Intervertebral discs height (hd), cm (initial data array)

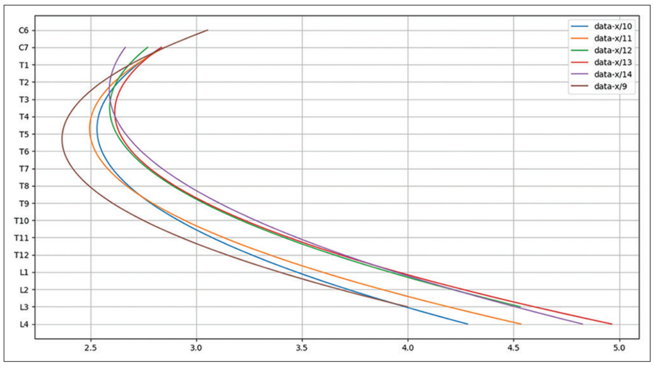

Figure 6: Width of vertebrae bodies (wb), cm (quadratic regression)

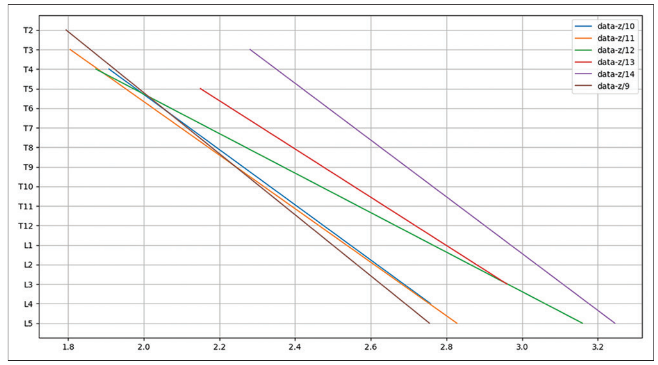

Figure 7: Anterior–posterior size of vertebrae (aps), cm (linear regression)

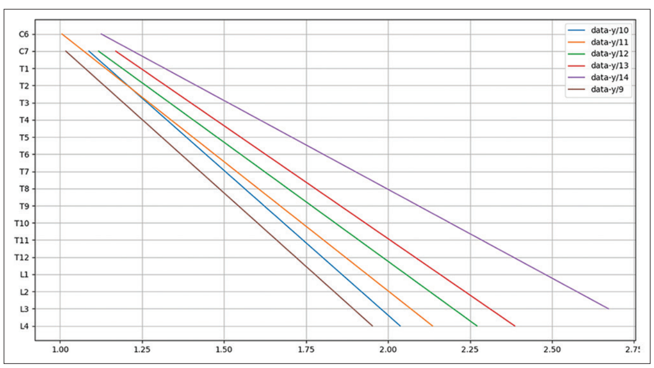

Figure 8: Vertebrae height (vh), cm (linear regression)

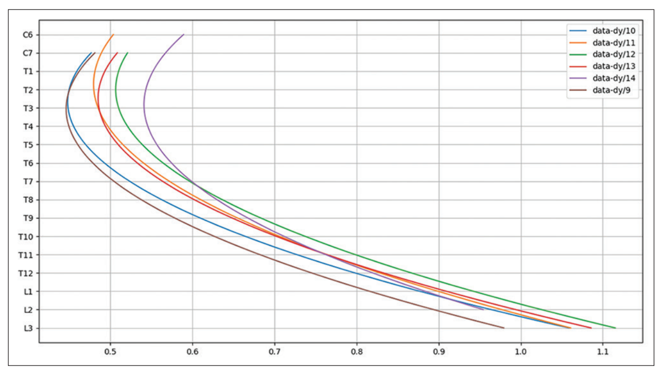

Figure 9: Intervertebral discs height (hd), cm (quadratic regression)

Table 2: Vertebrae height, anterior-posterior size, vertebrae width and intervertebral discs height for different children ages

	Width (wb), cm	Height (vh), cm	AP size (aps), cm	hd, cm
9 years	$0.017 \cdot N^2 - 0.392 \cdot N + 4.58$	$0.058 \cdot N + 0.67$	$0.064 \cdot N + 1.28$	$0.0037 \cdot N^2 - 0.067 \cdot N + 0.75$
10 years	$0.014 \cdot N^2 - 0.294 \cdot N + 4.10$	$0.059 \cdot N + 0.73$	$0.070 \cdot N + 1.20$	$0.0040 \cdot N^2 - 0.069 \cdot N + 0.75$
11 years	$0.016 \cdot N^2 - 0.342 \cdot N + 4.32$	$0.066 \cdot N + 0.67$	$0.073 \cdot N + 1.15$	$0.0033 \cdot N^2 - 0.051 \cdot N + 0.67$
12 years	$0.015 \cdot N^2 - 0.278 \cdot N + 3.91$	$0.072 \cdot N + 0.68$	$0.099 \cdot N + 0.88$	$0.0036 \cdot N^2 - 0.058 \cdot N + 0.74$
13 years	$0.016 \cdot N^2 - 0.305 \cdot N + 4.10$	$0.076 \cdot N + 0.71$	$0.081 \cdot N + 1.26$	$0.0038 \cdot N^2 - 0.065 \cdot N + 0.76$
14 years	$0.012 \cdot N^2 - 0.208 \cdot N + 3.47$	$0.097 \cdot N + 0.64$	$0.069 \cdot N + 1.66$	$0.0033 \cdot N^2 - 0.058 \cdot N + 0.80$

AP - Anterior-Posterior; wb - Width of vertebrae bodies; vh - Vertebrae height; aps - AP size of vertebrae; hd - Intervertebral discs height

data are necessary, for example, for so-called two-column model of spine explaining the scoliosis reasons and evolution (e.g.,).[3,8,9,11]

CONCLUSIONS

This work revealed simple yet informative approximations of the values of linear sizes of the components of the spine for children in the first half of puberty. These values can be used as a reference for building dynamic mathematical models of a normal spine, as well as models of its pathological deformations.

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Conflicts of interest

There are no conflicts of interest.

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