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Differences in early sagittal plane alignment between thoracic and lumbar adolescent idiopathic scoliosis

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Abstract

BACKGROUND CONTEXT: It has previously been shown that rotational stability of spinal segments is reduced by posteriorly directed shear loads that are the result of gravity and muscle tone. Posterior shear loads act on those segments of the spine that are posteriorly inclined, as determined by each individual's inherited sagittal spinal profile. Accordingly, it can be inferred that certain sagittal spinal profiles are more prone to develop a rotational deformity that may lead to idiopathic scoliosis; and lumbar scoliosis, on one end of the spectrum, develops from a different sagittal spinal profile than thoracic scoliosis on the other end.

PURPOSE: To examine the role of sagittal spinopelvic alignment in the etiopathogenesis of different types of idiopathic scoliosis.

STUDY DESIGN/SETTING: Multicenter retrospective analysis of lateral radiographs of patients with small thoracic and lumbar adolescent idiopathic scoliotic curves.

PATIENTS SAMPLE: We included 192 adolescent idiopathic scoliosis patients with either a thoracic (n=128) or lumbar (n=64) structural curve with a Cobb angle of less than 20° were studied. Children with other spinal pathology or with more severe idiopathic scoliosis were excluded, because this disturbs their original sagittal profile. Subjects who underwent scoliosis screening and had a normal spine were included in the control cohort (n=95).

OUTCOME MEASURES: Thoracic kyphosis, lumbar lordosis, T9 sagittal offset, C7 and T4 sagittal plumb lines, pelvic incidence, pelvic tilt, and sacral slope, as well as parameters describing orientation in space of each individual vertebra between C7 and L5 and length of the posteriorly inclined segment.

METHODS: On standardized lateral radiographs of the spine, a systematic, semi-automatic measurement of the different sagittal spinopelvic parameters was performed for each subject using in-house developed computer software.

RESULTS: Early thoracic scoliosis showed a significantly different sagittal plane from lumbar scoliosis. Furthermore, both scoliotic curve patterns were different from controls, but in a different sense. Thoracic kyphosis was significantly decreased in thoracic scoliosis compared with both lumbar scoliosis patients and controls. For thoracic scoliosis, a significantly longer posteriorly inclined segment, and steeper posterior inclination of C7–T8 was observed compared with both lumbar

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scoliosis and controls. In lumbar scoliosis, the posteriorly inclined segment was shorter and located lower in the spine, and T12–L4 was more posteriorly inclined than in the thoracic group. The lumbar scoliosis cohort had a posteriorly inclined segment of the same length as controls, but T12–L2 showed steeper posterior inclination. Lumbar lordosis, pelvic incidence, pelvic tilt, and sacral slope, however, were similar for the two scoliotic subgroups as well as the controls.

CONCLUSIONS: This study demonstrates that even at an early stage in the condition, the sagittal profile of thoracic adolescent idiopathic scoliosis differs significantly from lumbar scoliosis, and both types of scoliosis differ from controls, but in different aspects. This supports the theory that differences in underlying sagittal profile play a role in the development of different types of idiopathic scoliosis.

Keywords: Sagittal spinopelvic alignment; Vertebral inclination; Posteriorly directed shear loads; Etiopathogenesis; Adolescent idiopathic scoliosis

Introduction

Adolescent idiopathic scoliosis (AIS) is a complex, three-dimensional rotatory deformity of the spine [1]. It has previously been shown that the human spine, in a rotational sense, is a much less stable construct than any other spine in nature, because rotational stiffness of spinal segments is decreased by posteriorly directed shear loads [2,3]. These posteriorly directed shear loads are the result of gravity and muscle tone; they are unique for bipedal man and act on all posteriorly inclined segments of the spine as determined by each individual's unique sagittal profile (Fig. 1). Accordingly, it can be inferred that the area of the spine in which a rotational deformity has a chance to develop is based on differences in the sagittal profile. In other words, scoliosis can be expected to develop on a different sagittal profile than a nonscoliotic spine, and lumbar scoliosis can be expected to develop on a different sagittal profile than thoracic scoliosis. To investigate this, sagittal profile differences must be determined at a very early stage of the condition, because more advanced scoliosis, by nature of its three-dimensional deformity, in itself causes changes in the sagittal alignment of the spine.

In this retrospective, multicenter study, the sagittal spinopelvic alignment of small thoracic scoliosis was compared with similar lumbar curves. Furthermore, sagittal profiles of both curve types were compared with controls without scoliosis.

Subjects and methods

Population

After obtaining institutional review board approval, all patients between 10 and 16 years old with the ICD-9-code for idiopathic scoliosis who had had standard posteroanterior and lateral radiographic evaluations of the spine in one of two major scoliosis centers (Nemours, Alfred I duPont Hospital for Children, Wilmington, DE, USA; University Medical Center Utrecht, Utrecht, The Netherlands) between January 2006 and December 2011 were enrolled in this study. A flow chart for inclusion and exclusion is shown in Fig. 2. Only patients with either a single thoracic or a single lumbar coronal curve of less than 20° were included in this study. All children with radiographs of poor quality, radiographs from outside facilities or on which the whole spine from C7 to S1 and both femoral heads were not clearly identifiable were excluded.

A control cohort was created by selection of all children who had undergone standard radiographic screening for scoliosis because of school nurse or general practitioner referrals or the initiative of the parents, but had no scoliosis documented clinically or radiographically. Exclusion criteria for this group of children were the same. Demographics were collected for all included subjects and compared between the cohorts.

Radiography

In both centers, as recommended by the Scoliosis Research Society, plain full-length radiographs were made in an upright standing position, with anterior superior iliac spines and hips parallel to the cassette and the beam aimed at T10. [4] General Electric AL01F (General Electric, Schenectady, NY, USA), Philips Digital Diagnost (Philips B.V., Best, The Netherlands) and Siemens VERTIX (Siemens, Erlangen, Germany) were used for digital radiography. Lateral radiographs were made with the patient in a position as similar as possible to the anteroposterior (AP) radiograph, with the beam 90° to that used for AP radiography, with anterior superior iliac spines and hips perpendicular to the film and with the right side of the patient to the cassette. Subjects were instructed to look straight forward and to stand in a relaxed manner with arms flexed forward at 45°, hands supported on poles in one center, or fingertips on zygomatic bones in the other center, to maintain a neutral sagittal stance.

Measurement of spinopelvic parameters

Similar to a previous study [5], two trained observers (a resident in orthopedic surgery and an orthopedic research student) used in-house developed software to measure a number of sagittal spinopelvic parameters semiautomatically, namely, thoracic kyphosis, lumbar lordosis, T9