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Clinical Study

Three-dimensional vertebral wedging and pelvic asymmetries in the early stages of adolescent idiopathic scoliosis

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Abstract

BACKGROUND CONTEXT: Scoliosis is a three-dimensional (3D) deformation of the spine and the pelvis. Although the relation between the pelvic asymmetries and scoliosis progression was proposed by several authors, it has not been documented over time in adolescent idiopathic scoliosis (AIS).

PURPOSE: The objective was to determine whether vertebral wedging and pelvic asymmetries progress in the early stages of AIS before any orthopedic treatment.

STUDY DESIGN: The study design included an observational cohort study.

PATIENT SAMPLE: Nineteen AIS girls participated in this study.

OUTCOME MEASURES: The outcome measures were pelvic and spine geometries from simultaneous biplanar radiographs.

METHODS: At the diagnosis, the girls (12.6±1.3 years) had a Cobb angle of 13.9°±6.0°. At the end of their observation period (11 months on average), the scoliosis progressed to 20.5°±5.5°. Bone 3D geometry was reconstructed from biplanar radiographs. Sagittal and frontal wedgings were calculated for five vertebral levels, namely, at the apex and at the two vertebral bodies above and below it. The pelvic geometry was described using five 3D homologous right-left lengths to estimate pelvic asymmetries. Paired *t* tests were performed on vertebral wedging and pelvic asymmetries to assess their progression between the two evaluations. Principal component (PC) analyses were applied to determine whether vertebral wedging or pelvic asymmetries were predominant at each evaluation.

RESULTS: Vertebral wedging was present at the diagnosis (1.76°–5.92°) and generally did not progress until brace prescription. The mean difference between the right and left pelvic normalized lengths was 1.4% and 2.4% for the initial and final evaluations, respectively. Results revealed the width of the right pelvis to be superior by 3%, and this asymmetry progressed to 4.0%. Principal component analysis revealed that initial vertebral wedging was present in seven out of eight parameters of the first three PCs, whereas at the final examination, vertebral wedging and pelvic asymmetries were evenly present.

CONCLUSIONS: Our study confirms the presence of vertebral wedging at the early stages of scoliosis. This is the first to document the association between spinal and pelvic deformities over time. Pelvic asymmetries could be responsible for trunk muscle imbalances and lead to reduced neuromuscular control reported in AIS patients. These results could influence body brace fitting.

Keywords: Vertebral wedging; Pelvic asymmetries; Scoliosis; Adolescent idiopathic scoliosis; 3D reconstruction modeling; Biomechanics

FDA device/drug status: Not applicable.

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EVIDENCE & METHODS

Context
An association between pelvic asymmetry, vertebral wedging and adolescent idiopathic scoliosis (AIS) has been proposed in the past. Observational cohort studies have not thoroughly investigated this phenomenon, however. The authors performed an observational cohort study involving 19 females with AIS.

Contribution
This investigation identified that vertebral wedging was already present at the time of the initial diagnosis. The authors maintain that their work is the first to document temporal associations between pelvic and spinal deformities.

Implications
This work raises some interesting questions regarding the pathophysiology of AIS and the influence of pelvic and spinal deformities on the progression of this condition. That being said, the sample under study was small, with only 19 patients, and the period of follow-up was relatively short. These factors may impair the capacity for broad clinical application of this study's findings.

—The Editors

Introduction

Scoliosis is a three-dimensional (3D) deformation of the spine [1], because of vertebral wedging and rib cage distortion [2], resulting in serious morphologic changes in the trunk. Vertebral wedging is a progressive deformation of the vertebral bodies into an irregular hexahedron (ie, a deformed cube). It is associated with axial rotation [3] and scoliosis progression [4]. This abnormal bone growth is not limited to the spine; it has been observed in the upper limbs [5] and face [6] of subjects with adolescent idiopathic scoliosis (AIS). Pelvic abnormalities were also reported [7], and their relation to the progression of scoliosis was proposed by several authors [8–10]. The link between vertebral wedging and pelvic abnormalities has yet to be established in progressive AIS.

Monitoring of 3D deformation and its progression are based on biplanar radiographs. Although 3D reconstructions of the whole spine are performed since the 1970s [11], these are usually obtained by rotating or asking the patient to turn 90° for sequential posteroanterior and lateral radiographs. Changes in body postures between radiographic exposures could lead to substantial errors in estimating vertebral and pelvic morphologies. To partially overcome this limitation, Delorme et al. [12] developed a 3D geometrical modeling technique. A set of high-resolution anatomic points obtained from serial computed tomography scan reconstructions of dry bone specimens called primitives are deformed to fit 3D radiographic data of the whole spine and pelvis. Using this method, the authors reported an accuracy of 3.3 mm, which was described as acceptable for clinical studies. This was an important step in reducing measurement errors from sequential posteroanterior and lateral spinal radiographs. In more recent literature, the EOS X-ray imaging system (Biospace Med, Paris, France) offers simultaneous posteroanterior and lateral radiographs during full weight-bearing standing [13]. It not only produces high-quality radiographic images but also generates less radiation than standard imaging techniques [14]. Clinical studies with regard to this novel technology remain limited. Recently, the EOS system was used by Scherrer et al. [15] to document 3D vertebral wedging, but pelvis abnormal growth and its relation to scoliosis progression in a longitudinal study are yet to be addressed.

Only a few studies reported wedging in mild scoliotic girls before any orthopedic treatment [15,16]. The latter included a single evaluation of the patient before orthopedic treatment rather than implementing consecutive observations to quantify the progression of the deformities. The patients were commonly evaluated once rather than over observation period before any treatment prescribed by an orthopedic surgeon. Furthermore, most studies quantified vertebral wedging from measurements taken on a posterior-anterior spinal radiograph only [17–22]. This could be misleading because projected values of 3D vertebral body deformations often lie in a plane oblique to the frontal plane.

Pelvic abnormalities were reported by Duval-Beaupere et al. [7], and several authors proposed that these are consequential to abnormal bone growth [23,24]. This supports the concept that the pelvis behaves as a vertebra [25]; however, its link with spinal deformity remains unclear. In preoperative AIS, Qiu et al. [26] concluded that differences between the right and left pelvic dimensions were because of horizontal rotations, measured from standing posteroanterior radiographs rather than developmental asymmetry or distortion of the pelvis. This observation is in agreement with the findings of Gum et al. [8] where AIS patients had a significant transverse plane pelvic rotation. These studies relied on the use of planar radiography or supine CT scans that could induce large variability. Both frontal and sagittal plane projections of the 3D shape of the pelvis and its spatial orientation could be misleading [27,28]. Stylianides et al. [24] are among the first to report 3D iliac crest asymmetries in able-bodied girls and in untreated AIS with moderate and severe scoliosis from cutaneous measurements using a 3D electromagnetic pointer. To our knowledge, no one has described the 3D morphology of the pelvis from bony landmarks on the ilium and pubis in AIS. Furthermore, the mechanism of this concomitant distortion of the pelvis and vertebral wedging remains unclear.

Skeletal deformity of the spine is associated with pelvic misalignment and morphologic asymmetry in patients with