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Influence of structural pelvic disorders during standing and walking in adolescents with idiopathic scoliosis

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Abstract

BACKGROUND CONTEXT: In adolescents with idiopathic scoliosis (AIS), several studies have shown that the pelvis is structurally changed by the spinal disorder. In fact, a significant correlation has been observed between the three-dimensional changes in the lumbar curve and the reduction in pelvic displacement in the three spatial planes during gait. However, the impact of this pelvic disorder on the walking mechanism has not been established.

PURPOSE: To quantitatively evaluate the influence of scoliosis on the three-dimensional (3D) pelvic position during bipedal standing, on the 3D pelvic displacement during gait, and on the walking mechanics in adolescents with idiopathic lumbar and thoraco-lumbar scoliosis.

STUDY DESIGN/SETTING: Paired sample matched for age and gender.

PATIENT SAMPLE: Twenty-four subjects, 12 healthy adolescents matched for age and gender with 12 adolescents with lumbar or thoraco-lumbar idiopathic scoliosis.

OUTCOME MEASURES: A test battery including clinical examination, radiological assessment, static 3D pelvic examination in bipedal position, and instrumented gait analysis. The statistical analysis was performed by a paired *t* test to evaluate the differences on nominally recorded data between control subjects and patients and a signed rank test for ordinal data.

METHODS: The spine and pelvis were assessed by X-ray, clinical examination, and 3D analysis with the Elite system V5, in the standing position. The gait was assessed by instrumented analysis, including synchronous kinematic, dynamic, and electromyographic (EMG) recordings.

RESULTS: Our results showed that radiological measurements of the pelvis were significantly different between patients and control subjects. However, 3D pelvic kinematics were not significantly different between AIS patients and normal subjects during standing and walking. We observed an increase in the muscular external work, a reduction in the efficiency of the locomotor mechanism, and a prolonged duration of activation of the lumbar muscles, ie, erector spinae and quadratum lumborum, in AIS patients.

CONCLUSIONS: The scoliosis affected the structural bones of the pelvis with no effect on the 3D pelvis position during standing. During walking, normal 3D pelvic displacements could be explained by the prolonged duration of activation of the erector spinae and quadratum lumborum muscles bilaterally allowing the equilibrium of the pelvis to be maintained. This excessive muscular activity caused a failure of the locomotor mechanism as shown by an increase in the muscular external work.

Keywords: Gait; Idiopathic scoliosis; Pelvic displacement; Mechanical work

Introduction

Idiopathic scoliosis in adolescents (AIS) is the most common deformity seen in spine clinics for adolescents. As superimposed growth changes take place during adolescence, some instances of nonstructural scoliosis progress to a structural deformity including wedging and rotation of the

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vertebral bone. Moreover, severe spinal structural scoliosis can affect the structural bones of the pelvis [1–4]. Saji et al. [5] showed that in patients with scoliosis, the femoral neck-shaft angle was significantly greater than in normal subjects and more open on the concave side of the spinal curve. Several authors [3–5] have demonstrated that the pelvis is structurally changed by the structural spinal change. In fact, they showed a correlation between the changes in the lumbar curve and the rotation of pelvic displacement during gait in AIS patients [6,7]. However, the impact of this structural pelvic disorder on the efficiency of the locomotor mechanism has not yet been studied. By studying the energy changes of the center of the body of mass, it is possible to gain further insight into the mechanisms of pathological walking and whether or not the efficiency of the locomotor mechanism is preserved in AIS patients.

The aim of our study, therefore, was to assess the impact of the structural pelvic disorder secondary to scoliosis on the three-dimensional (3D) pelvic (1) position during bipedal standing, (2) displacements during gait, and (3) efficiency of the locomotor mechanism in adolescents with idiopathic lumbar and thoraco-lumbar scoliosis.

Materials and methods

Subjects

Twelve adolescents with idiopathic scoliosis and 12 control subjects were included in this study. All the patients were recruited from the Scoliosis Center at the Orthopedic and Traumatology Service of the University Clinic Saint-Luc in Brussels. The inclusion criteria for patients were X-ray evidence of progressive idiopathic scoliosis with a lumbar or thoraco-lumbar curve and no previous conservative or surgical treatment for the scoliosis as described by Stagnara [8]. We considered the curves as progressive when the modification of curve along 1 year was greater than 10 degrees [9]. Exclusion criteria were previous orthopedic surgery, central or peripheral neurological disorders, or other spinal disorder. In the patient group, the mean (±SD) age was 13.2 (±.8) years, the mean height was 1.56 (±.11) m, and the mean weight was 41.2 (±8) kg.

Twelve healthy subjects matched in age, height, and weight were recruited. The inclusion criteria for healthy subjects were an age between 12 and 14 years, a normal X-ray of the spine, no previous spinal disorders, no previous orthopedic surgery, and no central or peripheral neurological disorders. Their mean (±SD) age was 12.9 (±.9) years, mean height 1.58 (±.11) m, and the mean weight 46.4 (±9) kg.

Both groups underwent a "test battery" including clinical examination, radiological assessment, static 3D pelvic examination in bipedal position, and instrumented gait analysis. All participants and their parents gave informed consent and were recruited on a volunteer basis to participate in this study.

Assessment

X-ray assessment

A full spine X-ray based on standard anteroposterior (AP) pelvic films, from the top of the skull to the bottom of the sacrum, was performed in the frontal and sagittal planes in the bipedal standing position by means of Stagnara's criteria [8,10]. The deformity of scoliotic thoracic and lumbar curves was measured by the Cobb technique [11]. The apical lumbar rotation [12] and the Risser index were also calculated. The pelvic difference was calculated as the difference between the thickness of both iliac crests in the frontal plane. The angle subtended by the upper border of the sacrum and the horizontal reference level indicated the degree of pelvic tilt [1]. The pelvic balance was calculated as the distance between the vertical center sacral line and the C7 vertical line [13].

Clinical examination

Quadratus lumborum, erector spinae, gluteus maximus, gluteus medius, and the abdominal muscles were assessed bilaterally and scored according to the Medical Research Council criteria, ie, 0=no muscular contraction to 5=normal muscular strength. The muscular testing was assessed according to Kendall et al. [14]. Neuromuscular examination included assessment of the patellar, abdominal, and plantar skin reflexes. This neuromuscular examination allowed neuromuscular disease to be excluded. The same physiotherapist performed the clinical examination in all cases.

Instrumented assessment: static and gait analysis

The static 3D position of the pelvis was assessed by 3D analysis with Elite system V5 (BTS, Milan, Italy) at 50 counts per second (cps). Four infrared cameras measured the coordinates in the three spatial planes of three reflective markers positioned on specific pelvic anatomical landmarks (two iliac crests and sacrum) to compute the angular displacement of the pelvis based on Euler angles and Newtonian mechanics [15].

The gait was objectively and quantitatively assessed by instrumented analysis, including synchronous kinematic, dynamic, and electromyographic (EMG) recordings. Subjects were instructed to walk alone on the measurement field (10 m long) with no assisting device and at a comfortable pace.

Foot-switch soles, attached under the feet of the patient, were recorded at 1000 cps (Elite V5; BTS). These data were necessary to compute the global kinematic parameters: walking speed, step length, and step frequency. These parameters allowed a global assessment of gait quality and constituted temporal marks necessary for the analysis of all other variables. Segmental kinematic data were measured with the Elite system V5 at 50 cps as described below and evaluated for the following parameters: maximum pelvis upward and downward position, maximum anterior and posterior pelvic