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Position of the major curve influences asymmetrical trunk kinematics during gait in adolescent idiopathic scoliosis

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ABSTRACT

Background and purpose: Adolescent idiopathic scoliosis (AIS) is a structural, lateral curvature with rotation of the spine that develops around puberty. The influence of this spinal deformity on three-dimensional trunk movements during gait has not yet been elucidated. The aim of this study was to determine the influence of spinal curve pattern (single thoracic curve vs. single lumbar curve) on trunk kinematics during gait.
Methods: Twenty-two patients with a single thoracic curve (Lenke type 1) and 17 patients with a single lumbar curve (Lenke type 5) were included in this study. Trunk symmetry in the sagittal, coronal, and transverse planes during gait was evaluated using an optoelectronic motion capture system.
Results: In the type 1 group, the trunk was significantly rotated towards the concave side in the transverse plane during gait (mean difference of transverse rotation angle between concave side load and the convex side load, $8.8 \pm 0.6^{\circ}$, $p < 0.01$). In the type 5 group, the trunk was significantly rotated towards the convex side in the coronal plane throughout the stance phase of gait (mean difference of coronal inclination angle, $1.9 \pm 0.3^{\circ}$, $p < 0.05$).
Conclusions: The AIS patients with a single thoracic curve showed asymmetrical trunk movement in the transverse plane, and patients with a single lumbar curve showed asymmetrical trunk movement in the coronal plane. These results indicate that the spinal curve pattern influenced trunk kinematics, and suggest that the global postural control strategy of patients with AIS differs according to the curve pattern.

1. Introduction

Adolescent idiopathic scoliosis (AIS) is a structural, lateral curvature with rotation of the spine that develops in otherwise healthy children around puberty. Current epidemiological studies estimate that 1–3% of the at-risk population (females aged 10–16 years) will develop some degree of spinal curvature [1]. AIS impacts negatively on self-image, increases degeneration of the spine, induces back pain, and causes deterioration of the respiratory and circulatory systems [2] as the spinal deformities become severe.

Additionally, the deformed spine has been reported to affect pelvic and lower limb kinematics during gait. Masso et al. [3] used an optical measurement system to conduct the first dynamic motion analysis of the gait of patients with AIS, and other authors have subsequently used optical measurement systems and force plates to study the effects of spinal deformity on gait and trunk motion in patients with AIS from kinematic and mechanical points of view [4–19]. However, the majority of these papers have investigated pelvic motion, lower limb kinematics, gait speed, or ground reaction forces during gait, and few papers have reported the relation between trunk kinematics and spinal deformity. Kramers de-Quervain et al. [8] demonstrated that the trunk showed rotational deviation to the concave side during gait. Recently, Yang et al. [18] reported asymmetrical trunk kinematics during gait in patients with mild-to-moderate AIS (Cobb's angle $<34^{\circ}$). However, these reports included patients with a variety of curve patterns and did not clearly elucidate the effects of the curve

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pattern on the trunk kinematics. Since mobility of the thoracic spine and lumbar spine differs, the trunk kinematics of the thoracic scoliosis may differ from that of lumbar scoliosis.

In this study, AIS patients with two distinct curve patterns (thoracic single curve and lumbar single curve) were selected, and the three-dimensional trunk movements during gait were quantified for each curve pattern. We hypothesized that the position of the curve would affect trunk kinematics during gait in patients with AIS.

2. Methods

2.1. Study population

A total of 122 preoperative patients with AIS were scheduled for gait analysis and posterior correction and fusion surgery at our hospital between December 2011 and June 2014. Among them, patients with either of two distinct curve types were selected and invited to participate in the study: 22 patients with the single major curve at the thoracic area (Lenke type 1 A or B [20]) and 17 patients with the single major curve at the lumbar area (Lenke type 5) (Fig. 1). Patients with a double major curve or triple major curve were excluded. In the type 1 group, the convexity of the thoracic curve was located on the right side in all patients. In the type 5 group, the convexity of the lumbar curve was located on the left side in all patients.

All subjects were female. The mean age at measurement was 15.5 years (range, 13–26 years) in the type 1 group and 16.0 years (range, 12–21 years) in the type 5 group (Table 1). The mean body weight was 45.8 kg (range, 39.0–63.2 kg) in the type 1 group and 50.0 kg (range, 34.0–57.5 kg) in the type 5 group. The mean height was 157 cm (range, 148–172 cm) in the type 1 group and 155 cm (range, 148–173 cm) in the type 5 group. None of the patients reported back pain or low back pain, and none were neurologically disturbed.

2.2. Equipment for three-dimensional trunk kinematics analysis

An optoelectronic motion capture system (Oqus, Qualysis, 8 cameras, 120 Hz, Gothenburg, Sweden) was used to measure trunk kinematics and was synchronized with two force plates embedded in the floor (sampling frequency 600 Hz, Type 4060-10, Bertec, Columbus, OH, USA). Thirty-one reflective markers were affixed to the surface of the subjects' trunks and limbs at the following sites to create anatomical indices: trunk (bilateral acromion, C7 and T10 spinous processes), upper extremity (bilateral epicondyles of the humerus and wrist), pelvis (outermost borders of both wings of the ilium and S1 spinous process), and lower extremity (bilateral greater trochanters of the femur, anterior surface of the thigh, medial and lateral side of the knee joint, anterior surface of the lower leg, medial and lateral side of the ankle joint, posterior surface of the calcaneal bone, and heads of the first and fifth metatarsal bones).

Table 1
Demographic data for the 39 patients with AIS.

Patients	Lenke type 1 n = 22	Lenke type 5 n = 17	p-value
Age	15.5 ± 5.0	16.0 ± 2.8	p > 0.05
Height (cm)	157 ± 6.0	155 ± 8.0	p > 0.05
Weight (kg)	45.8 ± 6.2	50.0 ± 6.4	p > 0.05
Radiographic parameters			
Cobb angles (degrees)	51.7 ± 9.4	51.7 ± 10.9	p = 0.53
Flexibility (%)	47.9 ± 18.5	62.4 ± 16.0	p < 0.02
Sagittal balance (mm)	−22.8 ± 21.4	−18.4 ± 22.5	p = 0.81
Coronal balance (mm)	5.3 ± 11.7	−27.2 ± 17.9	p = 0.07

2.3. Measurement of trunk kinematics during standing and gait

Trunk kinematics were evaluated using the data from eight body surface markers; those affixed to the two acromion processes, C7 and S1 spinous processes, bilateral greater trochanters of the femurs, and the outermost borders of both wings of the ilium. Trunk kinematics were calculated using Visual 3D software (C-Motion, Inc., Rockville, MD, USA) as follows. First, the axis of coordinates on the pelvis was determined using the marker on the S1 spinous process (Fig. 2). Then, the sagittal trunk inclination angle (SA) was defined as the angle in the sagittal plane between the vertical axis and a line connecting the markers on the C7 and S1 spinous processes. The coronal trunk inclination angle (CA) was defined as the angle in the coronal plane between the vertical axis and a line connecting the markers on the C7 and S1 spinous processes. Trunk rotation angle (TA) was defined as the angle in the transverse plane between the line connecting markers on the two acromion processes and the axis of coordinates in the transverse plane.

First, trunk position in all planes was measured for 5 sec while subjects stood with both upper limbs hanging downwards. And the maximum TA to each right side and left side during standing was

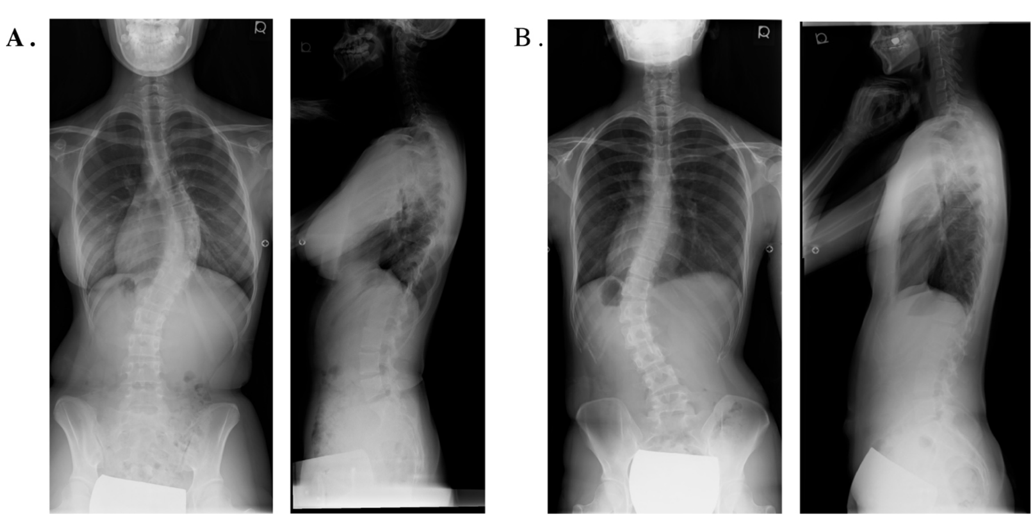

Fig. 1. Typical radiographic images of AIS patients with a single curve. A: Single thoracic major curve (Lenke type 1), B: Single lumbar major curve (Lenke type 5).