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Original article

Coronal trunk imbalance in idiopathic scoliosis: Does gravity line localisation confirm the physical findings?

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ABSTRACT

Background: Adolescent idiopathic scoliosis (AIS) can require surgical procedures that have major consequences. Coronal imbalance as assessed clinically using a plumb line is a key criterion for selecting patients to surgery. Nevertheless, the reference standard for assessing postural balance of the trunk is gravity line localisation within a validated frame of reference. Recent studies have established that the gravity line can be localised after body contour reconstruction from biplanar radiographs. The objective of this study was to validate a gravity line localisation method based on biplanar radiographs in a population with AIS then to validate gravity line position versus plumb line position.

Hypothesis: Plumb line and gravity line assessments of coronal balance correlate with each other.

Material and methods: A gravity line localisation method based on biplanar radiography was validated in 14 patients with AIS versus force platform as the method of reference. Normal plumb line and gravity line positions were determined in 27 asymptomatic adolescents using biplanar radiography. The results of the two methods were then compared in 53 patients with AIS.

Results: The reliability of gravity line localisation in the coronal plane based on biplanar radiography was 2.4 mm (95% confidence interval). The distance between the gravity line and the middle of the line connecting the centres of the two femoral heads (HA) showed a strongly significant association with plumb line position computed as the distance from the vertical line through the middle of T1 and the centre of the S1 endplate (T1V/S): $r = 0.71, p < 0.0001$. Of the 20 patients with plumb line results indicating coronal imbalance, 11 (55%) had a normal gravity line-to-HA distance. Of the 33 patients with normal plumb line results, 7 (21%) had an abnormal gravity line-to-HA distance.

Conclusion: The results of this study validate gravity line determination from biplanar radiographs in a population with AIS. Plumb line position correlated significantly with gravity line position but was less accurate for guiding surgical decisions.

Level of evidence: IV, retrospective study.

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1. Introduction

Adolescent idiopathic scoliosis (AIS) is a common condition that affects about 3% of all adolescents [1]. Early detection followed by appropriate treatment decreases the need for surgery and the risk of complications in adulthood (e.g., low back pain, degenerative disc disease, and respiratory insufficiency). The main criterion used

to determine whether surgery is appropriate in a patient with AIS is Cobb's angle (usually with a cut-off of 40°) [1]. Coronal trunk imbalance as assessed using the plumb line method is associated with curve progression, even in adults, and may therefore support surgical treatment [2,3]. In recent studies of overall trunk posture, a force platform was used to localise the gravity line [4–6]. Gravity line position correlated with quality of life and self-esteem in a population of adults with scoliosis [7]. Gravity line position can also be determined by body contour reconstruction from low-dose biplanar radiographs, as recently reported in healthy individuals [8,9].

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The decision to perform scoliosis surgery can have major anatomic, functional, and psychological consequences. Complications are dominated by mechanical and infectious events and still occur in as many as 6% of patients [10]. Surgical decisions must therefore be based on objective criteria assessed using reliable tools that are accurate and impose as few constraints as possible on the patient and surgeon. Objectively and accurately assessing coronal trunk balance by gravity line localisation based on biplanar radiographs may hold promise as an aid to treatment decision-making.

The objective of this study was to validate a gravity line localisation method based on biplanar radiographs in a population with AIS then to validate gravity line position versus plumb line position as a measure of coronal trunk balance. In addition, gravity line position was evaluated in each of the anatomic types of scoliosis present in our population. The working hypothesis was that plumb line and gravity line assessments of coronal balance correlated with each other.

2. Material and methods

The gravity line localisation method was validated in 14 prospectively recruited patients receiving follow-up for AIS. The patients were all under 18 years of age. Our institutional review board approved the study, and informed consent to study participation was obtained from the patients and/or parents.

Biplanar radiographs were obtained using the EOS system (EOS-Imaging, Paris, France), with the patient standing on a force platform (Wii Balance Board, Nintendo France, Cergy-Pontoise, France) according to a previously validated protocol [11]. The gravity line of reference was determined based on the mean position of the reaction forces from the force platform during image acquisition. Body contour reconstruction was performed using a method previously validated in healthy individuals [9]. For body contour reconstruction, the contour of a 3D template was back-projected onto the antero-posterior and lateral radiographic views. An operator could adjust the back-projected contour to match the body contour of the patient (Fig. 1). The biplanar radiograph gravity line was defined as the vertical line through the whole-body centre of mass (WBCM) and was compared to the reference gravity line identified by the force platform. The masses obtained using the two methods were also compared.

Correlations between plumb line position and gravity line position were then assessed in 27 apparently healthy individuals (controls) defined as having only minimal spinal deformity with a Cobb's angle of less than 10° and in 53 patients with documented AIS and a Cobb's angle greater than 10° . Individuals with congenital spinal abnormalities or other types of spinal deformity (e.g., spondylolisthesis) were excluded. Standing whole-body biplanar radiographs were acquired in each study participant according to the same protocol [12].

A patient-specific 3D model of the entire spine (from the dens to S1), pelvis, and body contour was obtained using previously reported reconstruction methods [8,13,14] (Fig. 1). The normal range for plumb line position was defined based on the distance on the antero-posterior view in the control group between the vertical line through the centre of T1 and the centre of the S1 endplate (T1V/S) (Fig. 2). Coronal trunk imbalance in the patients was then defined as a T1V/S value above the 95th centile in the control group. Cobb's angle and the T1V/S distance were determined using the 3D reconstructions. In all patients, the gravity line was defined as the vertical line through the WBCM [8]. In each patient, the distances separating the gravity line in the coronal plane from the middle of the line connecting the centres of the two femoral heads HA (GL/HA) and the dens (GL/D) were compared to the T1V/S distance (Fig. 2). In the groups of patients with and without coronal trunk

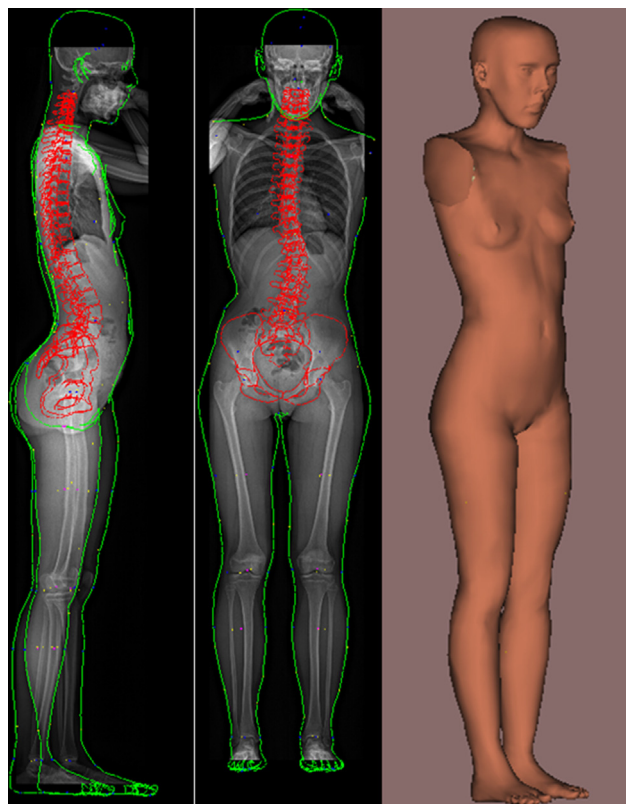


Fig. 1. 3D reconstruction of the spine and body contour.

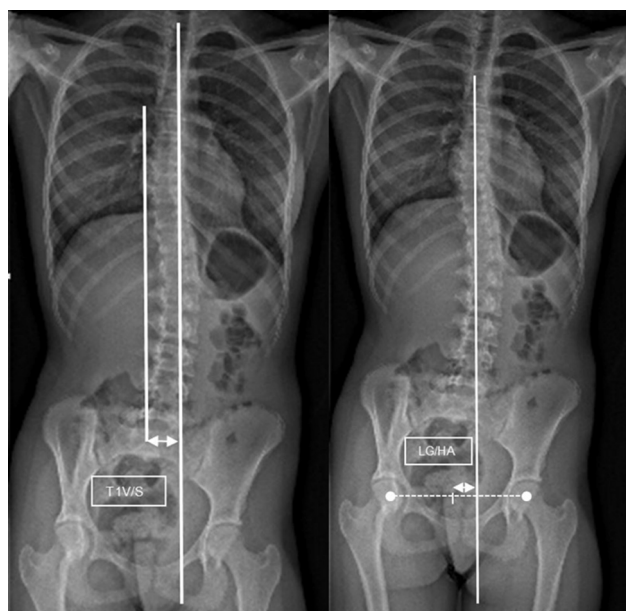


Fig. 2. Plumb line position (T1V/S) and gravity line position (GL/HA). T1V/S, distance between the vertical through the middle of T1 and the midpoint of the S1 endplate; GL, gravity line localised using biplanar radiographs; HA, midpoint of the line connecting the femoral heads; GL/HA, distance between the gravity line and HA.

imbalance and in the control group, we also assessed head position in the coronal plane as the position of the dens relative to the gravity line and the angle between the dens-HA line and the vertical from the dens [8].

Statistics: The statistical analysis was performed using SPSS V23.0 (IBM, Armonk, NY, USA). Values of p smaller than 0.05 were

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