Stature and growth compensation for spinal curvature.

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Abstract: Spinal curvatures alter measured stature and may influence the evaluation of skeletal maturity and growth based on stature measurements. Methods: A dataset of calibrated measurements of vertebral positions of 407 radiographs in the frontal plane, together with clinically measured Cobb angles was used to determine the difference between spinal length and spinal height ('height loss') as a function of Cobb angles for radiographs indicating both single (N=182) and double (N=225) curves. Results: An apparently quadratic relationship: Height loss (mm) = 1.0 + 0.066*Cobb + 0.0084*Cobb*Cobb was found between height loss and each patient's mean Cobb angle for double curves. There was close agreement of the regression coefficients for single and double curves, and the present findings were very similar to the relationship reported by Ylikoski (Eur Spine J, 2003, 12:288-291). The relationships differed substantially from those proposed by Bjure (Clin Orthop, 1973 93:44-52) and by Brookenthal (SRS Exhibit 15, 2002). Discussion and Conclusions: The findings of the present study indicate that height loss (in mm) occurring with a 10 degrees increase in mean Cobb angle (for two curves) would be 1.1 + 0.16 times the mean Cobb angle (in degrees). For example, for a Cobb angle change from 30 to 40 degrees, the expected height loss would be 1.1 + 35*0.16 mm = 6.7 mm. This assumes that height loss occurs only as a result of altered curvature, without alteration in disc height associated with an increase in scoliosis.

Keywords: Stature; Height loss; Skeletal maturity; Spinal length; Radiography

Introduction

A spine of a given length will have a lesser vertical height when curved - hence scoliosis is associated with loss of stature ('height loss'). This height loss may be of concern to patients with scoliosis. Also, it may confound evaluation of growth and maturity that involve standing or sitting height measurements. In principle, if the shape of the spine with scoliosis is known, the relationship between spinal height and curvature can be evaluated geometrically. Such an analysis must assume that the total length of the spine is unaltered by the curvature - that is the height of vertebrae and discs at their centers is unaffected. A simplified analysis of this kind was reported by Brookenthal [3], assuming a circular geometry of the scoliosis curve. Other previous studies have been empirical, employing measurements of patients with scoliosis [1,2]. The present study sought to confirm the previously reports of height loss, and to determine whether the relationship of height loss to Cobb angle differed for single and double curves.

Methods

A dataset of measurement of 407 calibrated stereo-radiographs or patients with a diagnosis of idiopathic adolescent or juvenile idiopathic scoliosis was used to analyze the relationship between Cobb angle, spinal length and spinal height. Data were included in the present study for patients between 9 and 20 years old, before any surgery, but some patients were listed in the database as undergoing brace treatment. The radiographs were made between the years 1981–1986 in a study of three-dimensional spinal shape. [4]. The Cobb angle had been recorded in the database from measurements made by a scoliosis surgeon, and in each case measurements were identified as from single, double or triple curve deformities. Only single (N=182 radiographs) and double curve (N=205 radiographs) data were analyzed here.

The database included the three-dimensional coordinates of landmarks on each the vertebrae from T1 to L5. The height of each vertebra and disc was determined as the Pythagorean distance between the 3-D coordinates of the corresponding endplate centers. All vertebral landmarks from T1 to L5 had been measured, but the vertebrae and discs above T5 were omitted from this study because they were frequently unclear on the original films as a result of exposure or projectional problems. Spinal length was defined as the sum of the heights of all vertebrae and discs from T5 to L5 in the frontal plane. The spinal height was defined as the vertical distance from T5 to L5 in the frontal plane. Height loss was defined as the difference between spinal length and spinal height.

The patients had been radiographed in a controlled standing posture, with supports contacting the anterior superior iliac spines and clavicles, with arms to the sides, to minimize patient motion during radiography. There were 2 radiographic projections made with a 3 m film-to-focus distance, using 36-in (914 mm) cassettes, with low-dose intensifying screen and film combinations. Posteroanterior and oblique views were made. The oblique view used an x-ray tube either at 20° on the patient's right side or 15° above the horizontal. For each stereo reconstruction of the spine, vertebral landmarks (vertebral endplates and bases of pedicles) had been previously identified, marked, and digitized from each radiograph according to the methods described [4] to obtain the 3-D coordinates of each landmark.

The relationship between height loss and Cobb angle was determined by regression analysis, separately for single and double curves. In the case of double curves, the spinal deformity was quantified by the average of the two Cobb angles.

Results

The relationship between height loss and Cobb angle was observed to be non-linear (Figure 1). Quadratic regression analysis of the supposed relationship between height loss and the mean Cobb angle in the form

Height loss = C + B*Cobb + A*Cobb^2 was employed, generating parameter values listed in Table 1. A similar analysis was employed by Ylikoski [1], which generated a relationship similar to that found for double curves in the present study (Figure 1).

Table 1: Parameter values in quadratic regression analysis curve fit to the observed relationships between height loss and mean Cobb Angle.

	C	B	A
Patients with single curves	1.55	-0.0471	0.009
Patients with double curves	1.0	0.066	0.0084
Ylikoski	0	0.012	0.0096

Note: Ylikoski gives values for total Cobb angle (of two curves), here divided by two (i.e. corresponding to average Cobb angle).

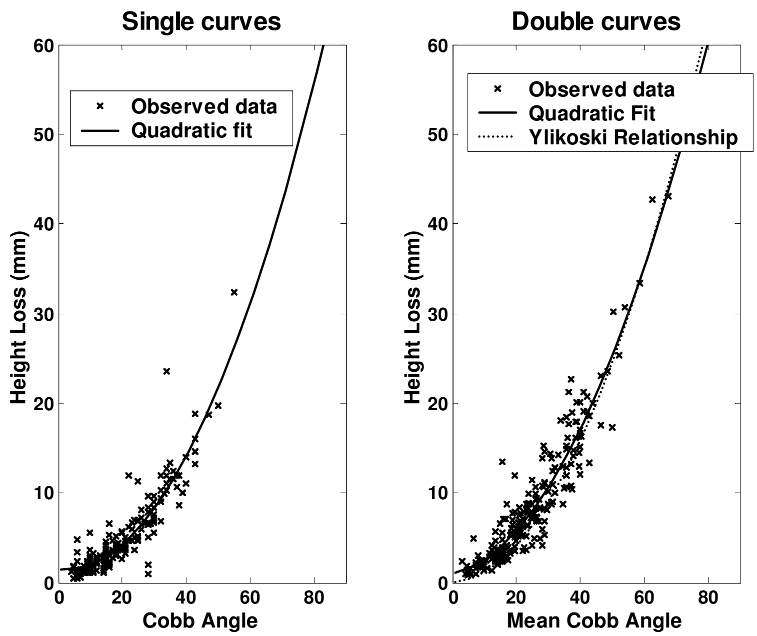

Figure 1: (Left): Observed relationship between Height loss and Cobb angle for single curves. (Right): Observed relationship between Height loss and mean (of two) Cobb angles for double curves. The relationship given by Ylikoski [1] is also plotted in the right panel graph.

Discussion and Conclusions

There was close agreement of the regression coefficients for single and double curves and with the relationship reported by Ylikoski [1],. The relationships differed substantially from those proposed by Bjure and Nachemson [2] and by Brookenthal [3].

Based on the findings for double curves in the present study, the height loss for an increment of Cobb angle can be estimated by taking the first derivative of the quadratic relationship - i.e. increase in height loss per increase in Cobb angle = 0.066 + 2*0.0084*Cobb. Thus for example, for a ten-degree Cobb angle change from 30 to 40 degrees, the expected additional height loss would be 0.66+ 35*0.168 mm = 6.5 mm. Annual spinal growth was reported to be about 15 mm per year at age 11 years, and about 5 mm per year at age 16 years [5], hence a progressive scoliosis can confound measurements of the rate of spinal growth.

The relationships found between height loss and Cobb angle differed substantially from those proposed by Bjure and Nachemson [2] (who assumed a logarithmic relationship) and by Brookenthal [3] (who assumed a circular geometry of the scoliosis curve). The Bjure and Nachemson relationship would predict a height loss of about 8 mm in the absence of scoliosis and would over-estimate the height loss for small curves. The Brookenthal relationship indicated height loss about 60% of that observed in the present study.

The findings in this study were very similar to those of Ylikoski [1] who reported height loss in 130 radiographs. Ylikoski considered that all patients had two curves, and reported the relationship between height loss and the total of the two Cobb angles. The present study (that analyzed single and double curves separately) indicated a lesser height loss in patients with single curves. This is probably a result of the height loss in compensatory curves that had not been included in the analysis, thus a more accurate indication of the height loss would be obtained by averaging the Cobb angle of both curves, whether or not both were considered structural.

This study examined measurements of radiographs of patients having differing degrees of scoliosis with some patients recorded more than once (combined longitudinal and cross-sectional database, but analyzed as if each observation was independent). No longitudinal studies of height loss were found through a search of the literature.

This study was two-dimensional, in that all measurements of spinal height and length were made in a frontal plane projection of the spine, despite the original data being three-dimensional. This was because only the scoliosis (lateral curvature) deformity was included, and the possible contributions of differing kyphosis or lordosis were not included. Ylikoski reported a linear relationship between kyphosis and height loss (about 15 mm loss for a 50 degrees kyphosis).

The present study assumes that spinal height loss occurs only as a result of altered curvature, without alteration in disc height associated with an increase in scoliosis. A longitudinal study would have advantages over this cross sectional study, since it could take into account any loss of discs height occurring in progressive scoliosis. In addition, only spinal height loss was considered, while the relationship between total height (stature) of a patient and the sitting height may differ during the course of adolescent growth [6].

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