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Height of girls with adolescent idiopathic scoliosis

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Abstract In a Finnish population, the standing height of 1500 consecutive female patients aged 9–24 years (mean 13.9 years) with untreated idiopathic scoliosis of at least 10° in their lateral curves was compared with the standing height of average girls. The mean magnitude of the major curves was 29.4° (range 10°–80°), and that of the minor curves 20.3° (range 0°–66°). A formula for the height loss caused by the lateral curves, and that caused by thoracic kyphosis, was derived. The corrected height of the girls with idiopathic scoliosis was highly significantly ($P < 0.001$) greater than the height of

average girls at the age of 11–15, and this high level of significance was present at the age of 11–13, even without correcting for the height loss caused by scoliosis. After maturation, the girls with idiopathic scoliosis were not significantly taller than average girls. On average, the magnitude of thoracic kyphosis did not affect the height of patients with scoliosis as compared with the height of normal girls of the same age.

Keywords Adolescent idiopathic scoliosis · Girls · Height · Height correction · Menarche

Introduction

Growth is one of the most important factors associated with the progression of adolescent idiopathic scoliosis [3, 17]. Therefore, the height gain of individuals in different age groups is of special interest for understanding the progression of scoliosis. There are studies which show that girls with adolescent idiopathic scoliosis are taller in younger age groups than average girls of the same age [4, 10, 15, 16, 18]. Moreover, according to some studies, girls with idiopathic scoliosis are taller than average normal girls after maturity as well [6, 16]. Environmental factors may have an effect on the prevalence of adolescent idiopathic scoliosis. Ryan and Nachevson [12] found that scoliosis was more frequent in higher socio-economic groups than in lower groups. In Norway, Skogland and Miller [13] found a prevalence of scoliosis with a curve magnitude of more than 10° of 0.5% in Lapps. The equivalent figure for non-Lapps was 1.3%. Their observations were based on 21,130 chest radiographs (minifilms). In Japan,

Ohtsuka et al. [11] reported a significantly higher incidence of scoliosis (curves over 20°) in Tokyo than in its surroundings for girls in the age range of 12–14.

The aim of this study was to compare the standing height of girls with adolescent idiopathic scoliosis in different age groups with average girls of the same age, and determine whether, after maturation, girls with idiopathic scoliosis are taller than normal girls of the same age. As lateral curves result in loss of spine height, and the straightening due to thoracic kyphosis may result in gains in spine height [1], a formula for the correction of height loss due to the lateral curves was established, and the effect of thoracic kyphosis on height examined.

Materials and methods

The study consists of 1500 girls aged 9–24 with untreated idiopathic scoliosis of at least 10° of magnitude in their lateral curves, and without any other disease except for lumbar spondylolysis and spondylolisthesis. However patients with spondyloptosis were excluded from the study. Selection was made on the basis of consec-

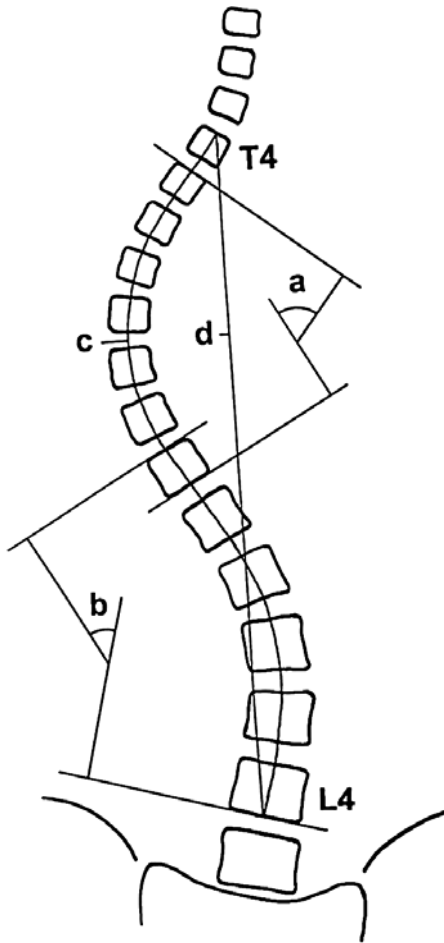
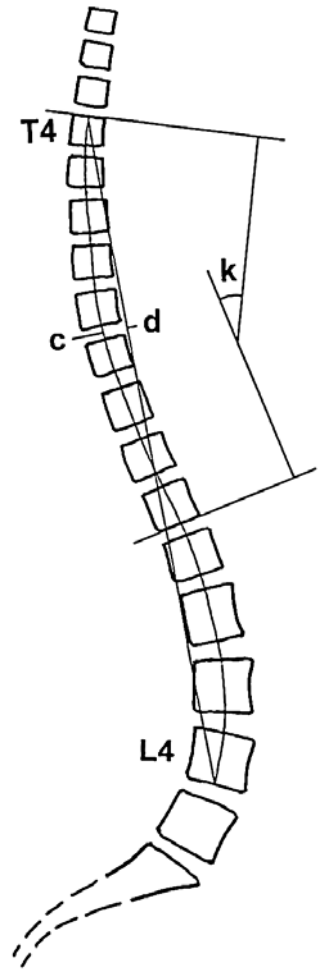


Fig. 1 Measurement method for the height loss between T4 and L4 caused by lateral curves. *a* and *b* are the respective angles of the major and minor curves; *c* is the curved distance from the upper endplate of T4 to the lower endplate of L4 according to the midpoints of intervertebral discs; and *d* is the straight distance from the upper endplate of T4 to the lower endplate of L4

utive patients fulfilling the above criteria who were referred to Orton Orthopaedic Hospital, in Helsinki, because of scoliosis between the years 1987 and 1997. The author measured the subjects' lateral and sagittal curves from full-length standing posteroanterior (PA) and lateral radiographs by Cobb's method.

To get a formula for the correction of height loss caused by lateral curves, the distance from the upper endplate of T4 to the lower endplate of L4 was measured twice on PA radiographs of 130 patients, once by a flexible wire according to the midpoints of the intervertebral discs, and again using the direct distance (Fig. 1). To obtain the formula, the magnitudes of the major and minor lateral curves were added together. The magnitude of thoracic kyphosis was measured from T4 to the lower end vertebra of the kyphosis, which in most cases was T12. To get a formula for correction of the height loss caused by thoracic kyphosis, the distance from the upper endplate of T4 to the lower endplate of L4 was measured twice on lateral radiographs of 30 patients, first using a flexible wire according to the midpoints of the intervertebral discs, and then by direct distance (Fig. 2). The magnitude of 29° was considered as a reference when correcting for the height loss or gain caused by the thoracic kyphosis, as this was the mean magnitude of thoracic kyphosis in normal girls with a mean age of 13.8, as

Fig. 2 Measurement method for the height loss between T4 and L4 caused by thoracic kyphosis. *k* is the angle of thoracic kyphosis; *c* is the curved distance from the upper endplate of T4 to the lower endplate of L4 according to the midpoints of intervertebral discs; and *d* is the straight distance from the upper endplate of T4 to the lower endplate of L4



measured by pantogram in the study of Nissinen et al. [9]. If the kyphosis was more than 29° , the correction was added to their height, and if the kyphosis was less than 29° , the correction was subtracted from their height. The standing heights and time of menarche for each subject were obtained from their clinical data. The control material of Sorva et al. [14] was used to compare the height of the girls with scoliosis with that of average Finnish girls.

Statistical significances were tested by the two-way Student's *t*-test. $P < 0.05$ was regarded as significant.

Results

The mean age of the patients was 13.9 years (SD 1.9, range 9–24 years); the mean magnitude of the major curves was 29.4° (SD 11.2, range 10° – 80°), and that of the minor curves 20.3° (SD 9.9, range 0° – 66°). A total of 1329 patients had standing full-length lateral radiographs, from which the measured thoracic kyphosis was on average 31.5° (SD 11.8 $^\circ$). A total of 1361 patients had either standing full-length or standing or supine lumbar lateral radiographs, from which it was possible to detect a lumbar vertebral spondylolysis and spondylolisthesis. The mean magnitude of spondylolisthesis for the 123 patients who

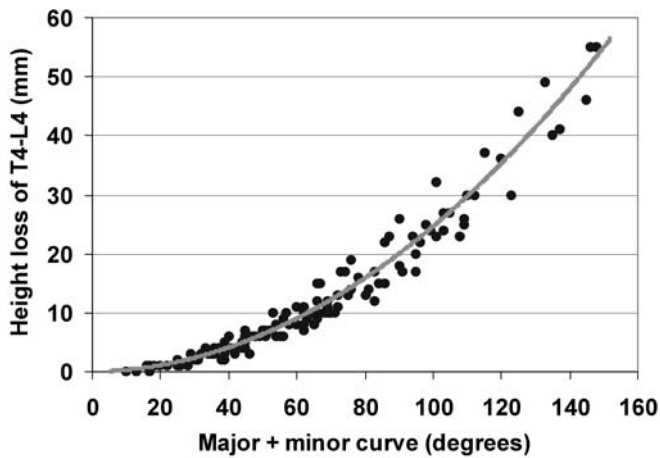


Fig. 3 Relation between lateral curves and the height loss between T4 and L4 in 130 patients. Height loss (mm) = $0.0062 * x + 0.0024 * x^2$ (where x = major plus minor curve, in degrees)

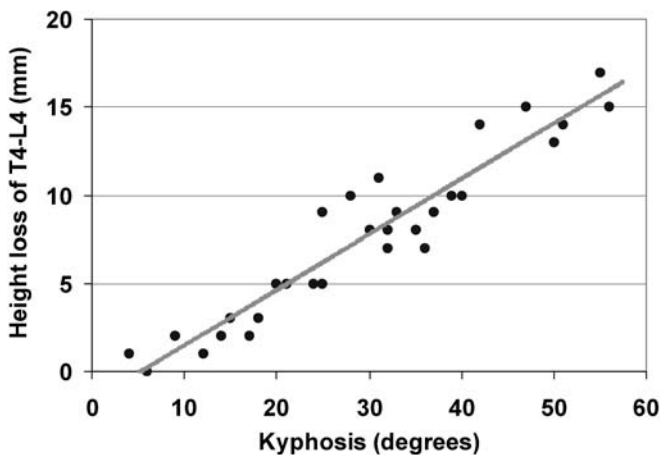


Fig. 4 Relation between thoracic kyphosis and the height loss between T4 and L4 in 30 patients. Height loss (mm) = $-1.68 + 0.315 * x$ (where x = thoracic kyphosis in degrees)

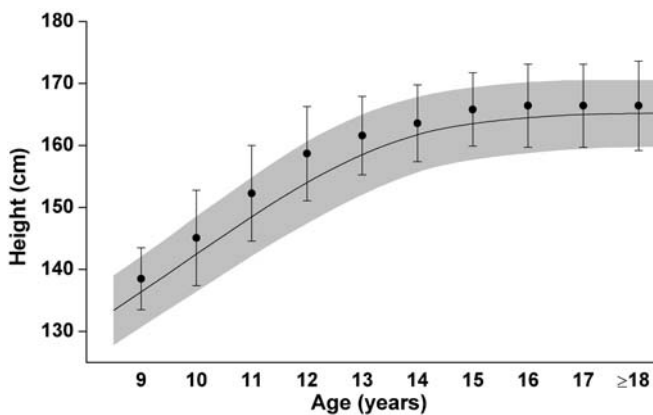


Fig. 5 Corrected standing height in different age groups (mean \pm SD) in 1500 patients with idiopathic scoliosis. The *black line* and *shaded area* show the heights of average girls (mean \pm SD)

had spondylolysis (9%) was 16.6% (SD 13.6%). An accurate time of menarche (year and month) was known for 634 patients. From these data, the mean menarcheal age was calculated to be 13.1 years (SD 1.1 years). This is not significantly lower than the menarcheal age of 13.2 years for normal Finnish girls [7]. The mean menarcheal age of patients with major curve magnitudes above the mean ($\geq 29^\circ$) did not differ from those with major curve magnitudes below the mean ($< 29^\circ$).

The formula for height loss of T4–L4 caused by lateral curves is shown in Fig. 3, and for that caused by thoracic kyphosis in Fig. 4. Thoracic kyphosis, on average, did not affect the heights of patients with scoliosis when compared with the mean magnitude of kyphosis for normal girls of the same age, and this was therefore ignored when the corrected height was calculated. The girls without correction for height loss caused by lateral curves are statistically highly significantly ($P < 0.001$) taller than average girls aged 11–13, and significantly ($P < 0.05$) taller at the age of 14–15. When the height loss caused by lateral curves is corrected for, girls in the age group 14–15 were also highly significantly ($P < 0.001$) taller than average Finnish girls (Fig. 5). After the age of 15, the girls with idiopathic scoliosis were taller than average Finnish girls, but not significantly so.

Discussion

The formula proposed by Bjure et al. [2] for the correction of height loss caused by scoliosis was not used, as it only takes account of the major curve, and because it is based on data from quite large curves. Minor curves also lead to spine height loss, and their effects may be as great as a major curve for individuals with double scoliosis. Therefore, in the present study, the magnitudes of the major and minor curves were added together when calculating the formula for the height loss caused by lateral curves, and the full spectrum of magnitudes of scoliosis, from lesser to greater curves, was used. The measurements were made from T4 to L4, as in most cases lateral curves extend over these segments.

To study the effect of thoracic kyphosis on standing height, a control group of age-matched average girls was used. In the present study the magnitude of thoracic kyphosis had, on the average, no effect on the standing height of girls with idiopathic scoliosis. This is in contrast to the suggestion of Archer and Dickson [1] that increased standing height in scoliotic girls may be caused by the straightening of normal kyphosis. However, as the vertebrae in the scoliotic region are rotated, normal lateral radiographs do not show the real lateral view of thoracic kyphosis. According to the present study with a large number of girls from the homogeneous Finnish population, girls with idiopathic scoliosis after maturation are somewhat taller than average Finnish girls, but not signif-

icantly so. The result is in disagreement with the studies of Leong et al. [6] and Willner [16].

In the present study in a Finnish population, the growth pattern of girls with idiopathic scoliosis was clearly different from that of age-matched girls; the scoliotic girls had an earlier pubertal growth spurt. The result is in agreement with those of Willner [15], Nordwall and Willner [10], Goldberg et al. [4], and the follow-up study of Nissinen et al. [8], in which 41 out of 430 girls developed idiopathic scoliosis with a magnitude of 10° or more. The girls with scoliosis had their period of peak rate of increase in sitting height significantly ($P=0.02$) earlier than the other girls, and on the average they had a higher ($P=0.08$) peak rate of increase in sitting height than the other girls.

Surprisingly, the mean menarcheal age was only slightly, but not significantly, lower than that of normal Finnish girls. The result is in agreement with the study of Nissinen et al. [7]. In contrast, Häggglund et al. [5] found that girls with idiopathic scoliosis had their menarche significantly ($P<0.01$) earlier than healthy girls. Goldberg et al. [4] came to the same result when they compared girls with scoliosis and girls in the general population in Ireland.

Conclusions

In a Finnish population, girls with idiopathic scoliosis are highly significantly taller than average girls at the age of 11–15 when height loss caused by scoliosis is corrected for, and also at the age of 11–13 years even without any correction for height loss.

After maturation, girls with idiopathic scoliosis are not significantly taller than the average girls in the Finnish population.

The magnitude of thoracic kyphosis, on the average, does not affect the height of patients with scoliosis when compared with normal girls of the same age.

The mean menarcheal age for girls with adolescent idiopathic scoliosis is not significantly lower than that of normal girls in the Finnish population.

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