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POSTURAL AND TIME-DEPENDENT EFFECTS ON BODY HEIGHT AND SCOLIOSIS ANGLE IN ADOLESCENT IDIOPATHIC SCOLIOSIS

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Changes in body height and scoliosis angle under the influence of gravity were studied in 40 patients with adolescent scoliosis. The average decrease in body height was 1% during a day. There were no significant changes in the mean angles of the scoliosis curves during the day. The patients were grouped according to age, standing and sitting heights, weight and skeletal maturation. A decrease in the scoliosis angles occurred in younger, more skeletally immature and lighter individuals, while an increase occurred in older, more skeletally mature and heavier individuals.

The difference between the scoliosis angles measured from standing and supine views was also analyzed. The correction of the scoliosis angle in the supine position was on average 19%. No correlation was found between the change in angle and any of the growth factors studied. There was also no correlation between the change in angle and the degree of curvature.

Key words: biomechanics; muscles; posture; scoliosis; spinal curvature

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The influence of posture and gravity on the spine in scoliosis is still uncertain. It is known that the normal adolescent female spine decreases in height by about 1.5 cm during the day as an effect of gravity (De Puky 1935, Fitzgerald 1972). This shortening is mainly caused by outflow of fluid from the loaded intervertebral discs (Krämer & Gritz 1980). The morphology of the disc is altered in scoliosis (Taylor et al. 1981) and the behaviour of the scoliotic spine under the physiological load of normal daily activity is unknown. For mechanical reasons an increase in angle can be expected during the days as the moment acting on the discs in scoliosis is greater than that acting on a straight spine, and hence the fluid outflow might be greater. If that were the case, a greater loss in height and an increase in the scoliosis angle could be expected during the day.

The main aim of the present investigation was to study the changes in body height and scoliosis angle occurring during the day. A further aim was to relate any such changes to age, skeletal maturity, weight, standing and sitting height, and other anthropometric data used in the clinical management of scoliosis patients.

PATIENTS AND METHODS

Patients

Thirty-eight patients, three boys and 35 girls with scoliosis were studied. All had adolescent idiopathic scoliosis. Twenty-eight patients had a major thoracic curve. The thoracic curves had a mean angle of 31.8 degrees (range 9–77 degrees) and the lumbar curves had a mean of 24.8 degrees (range 9–50 degrees). The mean age of the patients was 14.0 years (range 9.5 to 16.8 years). All patients had been admitted to the Sahlgren Hospital, Göteborg, Sweden, for treatment with a brace or surgery.

Methods

Routine radiographs of the spine were taken in the early morning. The patients had been in the upright posture for only about 15 min. The projections were standing antero-posterior and lateral views and supine antero-posterior views. The entire spine was included on each film. In addition, radiographs were taken of the iliac apophysis and left hand in order to measure the skeletal age (Risser 1958, Greulich & Pyle 1959). A standing antero-posterior radiograph of the spine was again obtained at 8 p.m. No activity aimed at influencing the scoliosis took place during the day. The scoliosis angles were measured according to Cobb (1948) by two of the investigators (CZ and TH). The biggest curve was always measured, irrespective of changes in its extension during the day. Three angles were measured: that of the primary (major), secondary and compensatory curves (where primary (major) denotes the worst curve, secondary the second in magnitude, and compensatory the third in magnitude). The compensatory curves were impossible to measure accurately in six patients.

The measurement error of a curve measured according to Cobb has been estimated to be 3.12 ± 0.48 degrees in curves of the magnitude reported in this study (Sevastikoglou & Bergqvist 1969). The measurement error is not believed to be systematic and is accounted for in the statistical analysis.

The standing and sitting heights were measured in the morning immediately after the patients left their beds, and at 8 p.m. The methodological error was estimated from 26 double measurements. The standard deviation was ±3.2 mm.

The statistical analysis was performed by means of Pitman's nonparametric test (Bradley 1968). The tests were made on the 5% level of significance. The results are given in mean values (±SEM).

RESULTS

The standing height decreased by a mean of 10.8 (± 5.7) mm, or about 0.7% of initial height, during the day, while the sitting height decreased by on average 8.8 (± 0.7) mm. Thus, approximately 80% of the decrease in body height occurred between the ischial tubercle and the skull.

The thoracic curves decreased by on average 1.3 (± 0.7) degrees during the day, while the lumbar curves increased by 0.3 (± 0.7) degrees. The compensatory curves decreased by a mean of 0.9 (± 0.7) degrees. When the two major curves were considered together, a decrease of 1.0 (± 1.1) degrees was found and for three curves a decrease of 1.9 (± 1.3) degrees (Table 1). These changes occurring during the day were not statistically significantly different from the null hypothesis, nor were they significantly correlated to the degree of the thoracic, lumbar or compensatory curves.

The sum of the changes for the two major curves during the day was positively correlated to age ($P < 0.05$), to maturation of the iliac apophysis ($P < 0.01$, Figure 1), and to the skeletal age of the left hand ($P < 0.01$). The curves decreased in younger, more skeletally im-

Table 1. The average change of the scoliosis during the day. N = 38. The result did not reject the null hypothesis.

Scoliosis	Mean (degrees)	SEM
Thoracic	−1.3	0.7
Lumbar	+0.3	0.7
Compensatory (N = 32)	−0.9	0.7
The major curves	−1.0	1.1
All three curves	−1.9	1.3

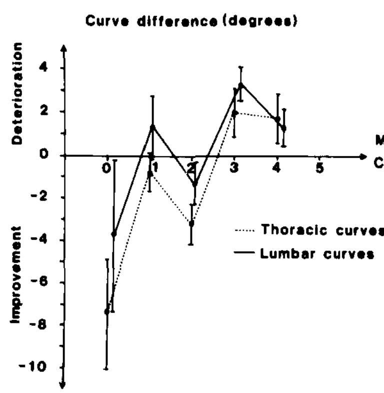

Figure 1. The change of the degree of the scoliosis angle during the day in relation to skeletal maturity measured as the iliac apophysis sign. (N = 38.)

mature patients and increased in older, skeletally more mature patients. This was also the case for the thoracic curves ($P < 0.01$), but not for the lumbar curves when analyzed separately.

The two major curves increased significantly more, the heavier the individual was ($P < 0.05$). There was a slight, non-significant increase in the change in angle of the two curves with an increase in body height.

A ratio of standing height to body weight was negatively correlated to the change of the two major curves ($P < 0.05$). A ratio of sitting height to body weight was used as a measure of trunk slenderness. This index was found to be negatively correlated to the sum of the change of the two major curves ($P < 0.05$, Figure 2), and also to the change of the thoracic curves when tested separately ($P < 0.01$). This implies that the taller and lighter the individual, the more the curve improved over the day, and the shorter and heavier the individual, the more it deteriorated.

There was no correlation between the degree of kyphosis and the change of the thoracic curve during the day and no correlation of the degree of lordosis to the change of the lumbar curve.

The difference in scoliosis angle as measured from the standing and supine films was similar for the thoracic and lumbar curves, 6.1 (± 0.9) and 7.9 (± 0.9) degrees, respectively. This corresponds to a 19% correction of the thoracic curve and a 31% correction of the lumbar curve when lying down. The magnitude of the difference was

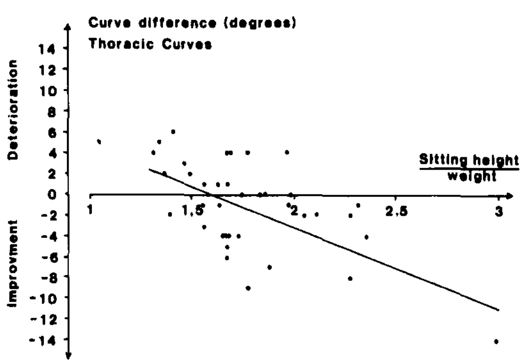

Figure 2. The change in degrees of the thoracic curve during the day related to the quotient sitting height/weight. The slope was statistically significant ($P < 0.01$).

Table 2. The supine scoliosis degree and the difference standing-supine scoliosis. Mean value in degrees (SEM).

Supine scoliosis degrees	Difference standing – supine scoliosis			
	Thoracic	N	Lumbar	N
≤20	6.2 (1.9)	9	7.9 (1.1)	25
21–30	6.8 (1.2)	17	6.7 (1.6)	6
31–40	1.8 (2.6)	5	10.7 (1.5)	3
41–50	6.0 (3.0)	2		
Total	6.1 (0.9)	33	7.9 (0.9)	34

not correlated to the degree of the supine scoliosis (Table 2). Nor was it correlated to the age, body weight or iliac apophysis maturation.

DISCUSSION

There are two principal stabilizing mechanisms of the spine: passive stabilizing factors such as ligament and discs and active stabilizing factors, the muscles. The normal ligamentous spine buckles already at a load of 20 N (Lucas & Bresler 1961). In the presence of a scoliosis the spine would be expected to buckle more easily (Olsen & Allan 1969). The height of a human being decreases by about 1–2% during the day, mainly due to changes of the fluid content of the intervertebral discs (Fitzgerald 1972, Krämer & Gritz 1980).

In this investigation of scoliotic patients, the decrease in height was found to be 11.2 mm, or about 0.7%, and the major portion (80%) of this change in height took place in the spinal column. In this respect, the spinal column seems to behave as in normal individuals, supporting the statements by Akeson et al. (1977) that the immature disc under continuous disproportionate compression maintains its resilience.

The degree of standing scoliosis is corrected by about 21% if the subject lies down supine (Torell et al. 1982). The upright posture can be considered as an aggravating factor for the scoliosis and the curve can be expected to deteriorate during the day due to the effect of gravity. The spine has viscoelastic properties and the deterioration could therefore be expected to occur gradually (Smith et al. 1979, Krämer & Gritz 1980). Therefore, a residual effect of the correction of the scoliosis overnight can be anticipated in the roentgenograms obtained in the morning. No deterioration over the day was found, however. The thoracic and compensatory curves showed a slight improvement and the lumbar curves a slight increase. The net change for the two major curves was a slight improvement (Table 1). The postural activity of muscles is the most likely explanation for the maintenance of the configuration of the spine during the day. The flexibility of the spine decreases with increasing age and skeletal maturation. Further scoliosis under approximately 50 degrees is known not to progress significantly after skeletal maturation. The effect of muscle activity on the spine would be expected to be greatest in the more flexible, less mature spine, but the negative influence of gravity would also be greatest in these patients (Haderspeck & Schultz 1981). We found that the scoliosis improved during the day in younger ($P < 0.01$) and more skeletally immature individuals (iliac apophysis sign $P < 0.01$ and hand skeleton maturation $P < 0.05$). Deterioration of the curve was found in the older and more mature individuals.

Therefore, it seems that the muscles may correct the scoliosis partly in a flexible spine, at least during a short period, and that dynamic factors are important to keep the spine as straight as possible. This is in agreement with results of computer simulation models (Haderspeck & Schultz 1981, Miller et al. 1981, Schultz et al. 1981).

The theory of columns says that a longer and thinner rod buckles more easily than a shorter and thicker rod. Therefore, the influence of standing and sitting height and weight on the change of the scoliosis during the day was of interest. The standing and sitting heights showed no statistically significant correlation to the change of the curve, although there was a tendency for taller persons to deteriorate more than shorter persons. The scoliosis showed a significant deterioration with increase in weight ($P < 0.05$). When these factors were combined in the quotient length to weight, however, it was found that the taller and lighter the individual the more the curve improved ($P < 0.01$, Figure 2). The body weight seems, therefore, to be of comparatively greater importance than the height to changes in the degree of scoliosis during the day.

The difference between the standing and supine scoliosis angles did not correlate to age, weight or skeletal maturation. The change in posture from supine to standing adds axial load to the spine and this load differs between individuals. A higher load can be postulated in a heavier individual. The effects of this increased load have been discussed by Haderspeck & Schultz (1981) and have been experimentally shown to be able to cause a significant increase of the scoliosis in the short term. These biomechanical findings seem to be in agreement with the findings in this clinical study.

CONCLUSIONS

1. The decrease in height of a scoliotic subject during the day (0.7% of initial height) corresponds to the figures reported for healthy individuals.
2. In general, the scoliosis curves did not show any statistically significant increase or decrease during the day.
3. In the younger and more skeletally immature individuals, however, the scoliosis curves improved during the day while the reverse was found in the older and more skeletally mature individuals. A higher body weight was positively correlated to an increase of the curve. The height-to-weight ratio showed a negative correlation to the change of the curve, i.e. the taller and lighter the individual the more the curve improved.
4. The correction of the scoliosis on supine roentgenograms compared to standing did not correlate to the degree of supine scoliosis, age, weight or skeletal maturity. The correlation in supine position compared to standing was 19% for the thoracic curve and 31% for the lumbar.

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