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Scoliosis Associated with Limb-Length Inequality

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ABSTRACT: **We reviewed the records and physical findings of twenty-three young adults who had had significant untreated limb-length inequality, present since childhood. The spine was studied radiographically and clinically before and after neutralization of the discrepancy of limb lengths with a lift. Movements of the spine also were measured.**

A significant asymmetry of lateral flexion of the spine remained in nearly all of the patients after neutralization of the discrepancy. The lumbar scoliosis associated with the limb-length inequality was compensatory and non-progressive, but abnormalities of the Cobb angle and of axial rotation remained in the young adults.

No relationship was found between the underlying cause of the anisomelia or its duration and the severity of the spinal abnormality. The scoliosis was minor in patients with discrepancies of less than 2.2 centimeters. No patients complained of significant discomfort in the back, nor were degenerative radiographic changes evident there.

The pattern of scoliosis associated with limb-length inequality (anisomelia) usually is described as being compensatory, non-structural, and non-progressive [4,6]. In 1964, however, Scheller was of the opinion that anisomelia could produce structural changes in the spine with time, and many of the patients whom he investigated were experiencing back pain.

Previous studies of the scoliosis associated with anisomelia always have been qualitative and it is not known precisely what effect neutralization of the limb-length discrepancy has on the spine. That knowledge might be useful if a decision is to be made on the amount of operative or non-operative correction that is desirable or on when to perform an operation for correction.

In the present paper we are reporting our studies on a group of young adults who had a significant degree of untreated anisomelia that had been present since childhood. We asked the following questions:

1. Is there just one pattern of scoliosis associated with anisomelia? Are there irreversible structural changes that occur within the spine that might predispose to the development of back pain?

2. If the pelvis is leveled when the patient is an adult, will there be residual spinal deformity?

3. What range of lateral bending movement of the spine can be expected after neutralization of the limb-length discrepancy?

4. Are there correlations between the scoliosis and the cause of the anisomelia or its magnitude?

Material

Twenty-three patients were seen with anisomelia ranging from 1.2 to 5.2 centimeters. The discrepancy had been present through a large part of the patients' childhoods. Patients were excluded if the primary etiology of the discrepancy was poliomyelitis or another neuromuscular disorder that might include a muscle weakness influencing the shape of the spine. The underlying diseases in the twenty-three patients were: hemihypertrophy (nine patients); congenital shortening (four patients); previous fracture (three patients); hemiatrophy (two patients); and joint infection, radiation injury, congenital dislocation of the hip, overgrowth due to Klippel-Trenaunay syndrome, and congenital constriction bands (one patient each). The ages of the patients at the time of examination ranged from seventeen to thirty-nine years (mean, twenty-eight years). There were twelve male and eleven female patients.

Methods of Study

Radiographic Assessment

Standing anteroposterior radiographs of each patient were made, first with the patient barefoot with both heels on the floor and with both knees extended. The cassette was placed behind a sheet of methylmethacrylate with accurately aligned horizontal and vertical steel wires set into its surface. These wires provided a horizontal and a vertical reference on each radiograph. The radiograph was 350 by 430 millimeters in size and showed the positions of the femoral heads, the iliac crests, and most of the thoracolumbar spine. The distance from the horizontal reference line to each femoral head was measured from this radiograph. The tube-to-film distance for these radiographs was one meter. The position in which the patient stood was such that the femoral heads were approximately twenty centimeters from the plane of the film, which gave a magnification factor of 20 per cent. After correction for

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magnification, we calculated the limb-length inequality in centimeters. The beam was centered at the level of the fifth lumbar vertebra.

A second radiograph was made under identical conditions, with the patient standing as with the first, except that a wooden block was placed under one foot. The thickness of the block was chosen to neutralize the limb-length inequality which was calculated from the first radiograph. The x-ray beam was raised sixty millimeters and the beam was coned in order to minimize gonadal irradiation. Before making the radiograph the patient was allowed several minutes to achieve a comfortable position. Three patients could not achieve such a position after correction of limb length and they stood uncomfortably, in a manner that did not satisfy the conditions for radiographic measurement. Thus, no data are presented for the findings after correction of limb length in these three patients.

The following measurements were made from the two radiographs with the horizontal as the reference line.

Angles to the horizontal: A line was drawn through the superior articular surfaces of the two femoral heads; another was drawn along the proximal margins of the two iliac crests; and a third was drawn along the upper surface of the sacrum. These three lines defined the extent of pelvic obliquity. There was a high correlation between the angle formed by the horizontal and the line drawn along the femoral heads (representing limb-length discrepancy) and the angle of the sacral tilt ($r = 0.98$). These angles were the same within a limit of accuracy of measurement ($\pm$ 2.5 per cent), and the angle formed by the line drawn along the iliac crests also correlated well with the femoral head angle ($r = 0.99$). Thus, there was no evidence of significant pelvic asymmetry in the patients who were studied.

Cobb angle of the spine [1]: This was measured and the upper and lower vertebrae used in this measurement were recorded.

Axial rotation of the vertebrae: This was measured at multiple levels [2,7].

The clinical ranges of lateral bending to the right and to the left were measured [6] and expressed in degrees for each side as the patient bent maximally to the right and to the left in turn. The approximation and separation of marks that had been made on the skin were measured [6]. A correlation ($r = 0.5$, $p < 0.1$) with a one-to-one relationship was found between the measurements of lateral bending obtained from the approximation of the marks and those obtained from the separation of the skin marks. Therefore, the mean of the two values was used in the subsequent analysis of ranges of movement.

Results

When the patients were standing without the block under the short limb the expected lateral curve of the spine, convex toward the short limb, was seen in all patients and the first sacral segment always was the lowest affected vertebra. The first lumbar vertebra was the uppermost level of involvement in every patient except one, in whom the curve extended to the eleventh thoracic vertebra.

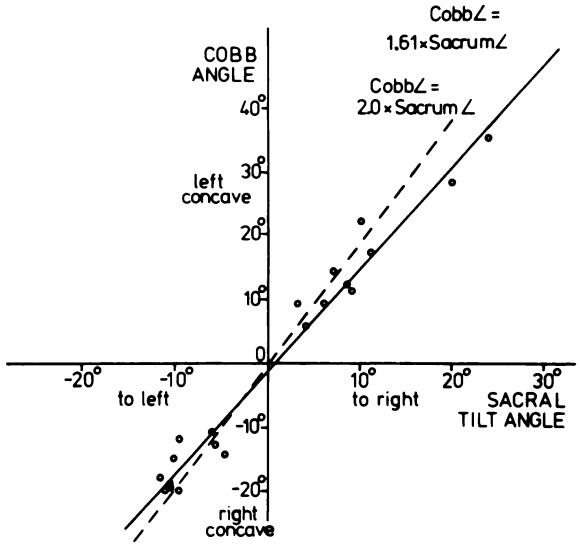

FIG. 1

Relationship between the tilt of the sacrum to the horizontal and the Cobb angle before limb-length correction. The slope of the regression line is 1.61. In this graph allowance is made for the side of the limb-length discrepancy and the direction of the curve of the overlying scoliosis.

FIG. 2

Lumbar scoliosis associated with uncorrected limb-length discrepancy. The Cobb angle is less than the angle of sacral tilt, so that the upper vertebra of the compensatory lumbar curve is not vertically above the sacral body.

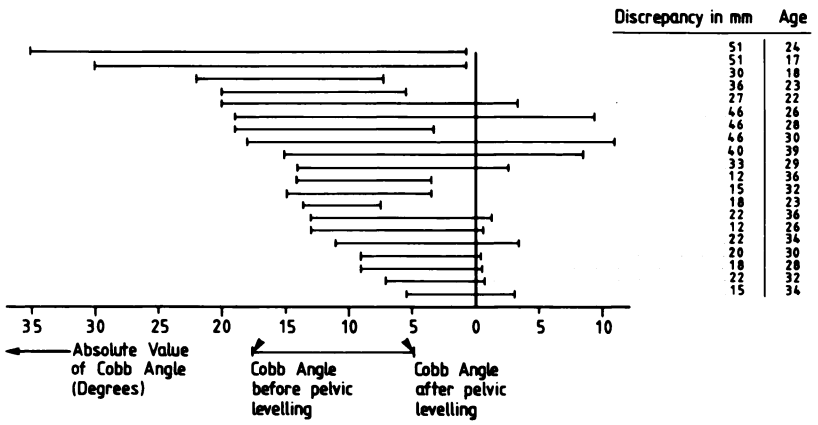

FIG. 3

The Cobb angles (abscissa) before and after limb-length correction for each patient. The number of millimeters of limb-length discrepancy before neutralization and the age of the patient in years are recorded alongside (see text for a description of the three patients who were excluded).

The Cobb angle varied in proportion to the severity of the anisomelia. There also was a close relationship between the Cobb angle and the angle of sacral tilt (Fig. 1), the ratio being 1.6:1. In a patient with a fully compensated and balanced scoliosis, the occiput will be vertically above the sacrum and the ratio of the Cobb angle to the angle of sacral tilt[3] will be 2:1. The ratio of 1.6:1 seen in our patients reflects a lack of complete balance in the spine and is indicative of undercorrection of the compensatory scoliosis. This undercorrection also was seen as a deviation of the mid-point of the uppermost vertebra of the compensatory lumbar curve from the midline (Fig. 2).

When the pelvis was made level by placing the proper block under the short limb, the spine did not become completely straight in our patients. The Cobb angles (Fig. 3) revealed that in six patients there was a small residual lumbar curve (4 to 8 degrees) in the initial direction. In seven patients, there was a reversal of the lumbar scoliosis of 3 to 10 degrees. In eight patients, although there was a good correction of the Cobb angle of the lumbar curve on neutralization of the anisomelia, some abnormality remained in the spine above the lumbar region. In these patients the upper part of the spine was decompensated, tilting toward the previously short limb but with minimum lumbar scoliosis (Figs. 4-A and 4-B).

There was a close correlation between the measurements of axial rotation obtained by the two methods used, and there was a very variable relationship between

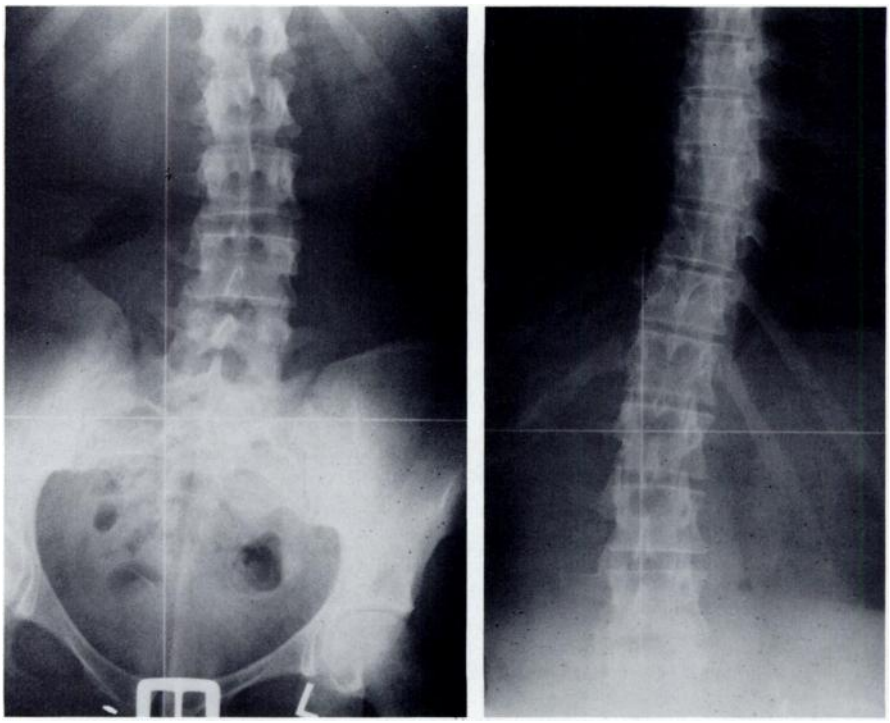

FIG. 4-A

FIG. 4-B

Fig. 4-A: Lumbar scoliosis in a patient with 3.3 centimeters of shortening of the left limb.
Fig. 4-B: Correction of the compensatory lumbar curve with limb-length equalization. Note that the upper portion of the spine becomes decompensated.

the Cobb angle and the degree of rotation. A rotatory abnormality was seen in nearly all patients before neutralization of the anisomelia. The maximum rotation usually occurred in the lower lumbar levels. In sixteen patients there was axial rotation of zero to 5 degrees; in six, of 6 to 10 degrees; and in one, of 17 degrees. The mean axial rotation prior to limb-length correction was 4.39 ± 3.66 degrees. There was a small, persistent degree of axial rotation after the pelvis was made level in eight patients, but in only one was it more than 10 degrees (mean axial rotation, 3.60 ± 2.57 degrees).

Degenerative changes in the facets or disc spaces of the lumbar spine were not seen on the radiographs of any patients. No patients complained of pain in the back either during or before the test.

There was considerable asymmetry of lateral bending in all of the patients, consisting of a reduction of lateral bend to the side of the concavity of the curve compared with bending the other way (mean bend to the concave side, 23.7 ± 7.43 degrees; mean bend to the convex side, 34.4 ± 7.67 degrees). The decreased amplitude of bending correlated strongly with the size of the limb-length discrepancy ($r = 0.83$, $p < 0.001$), and is to be expected in patients with compensatory scoliosis. After neutralizing the anisomelia, and thus correcting for the scoliosis, there still was considerable asymmetry of movement. There remained a reduced range of lateral flexion toward the previously *convex* side of the lumbar curve (mean bend to the concave side, 40.15 ± 9.16 degrees; mean bend to the convex side, 17.15 ± 8.50 degrees).

There were no clear-cut correlations between the radiographic or clinical observations recorded and the etiology of the anisomelia.

There was a good correlation between the degree of anisomelia and the amount of residual scoliosis when the anisomelia was neutralized. Patients with less than 2.2 centimeters of limb-length discrepancy showed a very small residual scoliosis when a lift of appropriate thickness was used under the short extremity.

Discussion

Only young adults were chosen for the investigation. They were selected from patients attending a clinic for limb-length discrepancy, and their only complaint was the discrepancy. None had back pain.

There was definite asymmetry of the movements of the spine on lateral flexion, particularly noticeable after the limb-length discrepancy was neutralized. Then, nearly always, a considerable reduction of lateral flexion toward the side of the short limb was evident. The method of measuring lateral flexion of the spine was described and assessed by Moll et al., who found a wide scatter of measurements for each decade of life, but there was a high degree of accuracy and repeatability of measurements for each patient no matter what his or her age.

In the present study, the test was performed under only one static condition. It is possible and perhaps probable that spinal movement would have become more symmetrical if, during a period of months or years, treatment in the form of neutralization of the anisomelia had been administered to these patients. Nevertheless, the asymmetry was very marked under the conditions of this study.

In 1964 Scheller noted that there were different types of scoliosis associated with anisomelia, sometimes involving even the cervical spine. In our study the curves were lumbar except for one that extended to the eleventh thoracic vertebra.

After neutralization of the limb-length inequality the Cobb angle was reduced considerably, but it was not always totally corrected. An abnormality consisting of a shift to the side of the short limb frequently persisted above the lumbar region of the spine, but the pattern was unpredictable and no relationship to the degree of anisomelia was detected. Nearly all patients also were left with some loss of lateral flexion to the short side. It is not known what might have happened to this shift if the patients had been treated with leveling of the pelvis for a prolonged period of time.

Axial rotation is difficult to measure radiographically with accuracy, but definite rotatory deformity was seen in nearly all patients before the limb-length discrepancy was neutralized. With neutralization there was generally a considerable reduction in the axial rotation but in a number of patients there was some residual rotation.

The unpredictable changes that we observed when we leveled the pelvis in our patients suggest that it might be advisable for an adult with anisomelia to wear a corrective device in the shoe for several months prior to surgical correction (that is, if an operation is indicated). After the trial interval, the type of study that we have described might be done to assess what the effect of a correction of sacral tilt would be on the spinal balance, and vice versa.

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