Measurement of the shape of the surface of the back in patients with scoliosis. The standing and forward-bending positions

IA Stokes and MS Moreland

J Bone Joint Surg Am. 1987;69:203-211.

Measurement of the Shape of the Surface of the Back in Patients with Scoliosis

THE STANDING AND FORWARD-BENDING POSITIONS*

BY I. A. F. STOKES, PH.D.†, AND M. S. MORELAND, M.D.†, BURLINGTON, VERMONT

From the University of Vermont College of Medicine, Burlington

ABSTRACT: In order to determine if the configuration of the trunk is altered when a patient changes from an upright to a forward-bending position, the shape of the surface of the back of fifty-six patients who had adolescent idiopathic scoliosis was recorded, by means of Raster stereophotography, with each patient in three postures: standing erect, bending forward with the hands between the knees (forward bend 1), and bending forward with the hands touching the toes (forward bend 2). The effect of placing one foot on a block to produce a limb-length difference was also studied in the standing position (thirty patients) and in the forward-bending position (eighteen patients). The degree of rotation of the surface of the back and of kyphosis and lordosis of the surface of the trunk was measured from sections in the sagittal plane that were plotted from the computerized measurements of the surface of the back.

Qualitatively similar rotation of the surface of the back was found in both the standing position and the forward-bending position. When the patient was in the forward-bending position, the degree of rotation of the surface of the back was minimally changed in the thoracic region but increased in the lumbar region. The amount of rotation of the surface of the back was similar in both forward bending with the hands to the knees and forward bending with the hands to the toes. In the sections in the sagittal plane, with forward bending there was a large decrease in the lumbar lordosis and a minimum increase in the thoracic kyphosis. The correlation (r) of the rotation of the surface of the back with the Cobb angle was between 0.7 and 0.8 in the standing position, and this correlation was not substantially changed by forward bending. Therefore, it appears that the position of the patient is not critical when an examination of the surface of the back is used to assess the degree of scoliosis.

Placing a block under one foot to simulate a limb-length difference produced rotation of the surface of the back that could be misinterpreted as being due to scoliosis. This effect on the shape of the surface of the back was greater in the forward-bending position and was more pronounced in the lumbar region than in the thoracic region. Since this effect is a potential source of false-positive results when examining patients for scoliosis, we recommend checking the lengths of the lower limbs and equalizing any differences before performing a clinical examination of the surface of the back.

The forward-bending posture has become the standard position of the patient for the detection of scoliosis. As described initially by Adams, forward bending of the trunk when the patient is standing appears to produce an accentuation of the deformity of the surface of the back that is associated with the underlying spinal deformity in patients who have scoliosis[4,5,11,26]. The apparent increased prominence of the deformity of the surface of the back during forward bending is the basis of the screening test in schools that is recommended by the Scoliosis Research Society[22] and is used extensively throughout the world[9,14,16,20,21].

The standing, arms-to-the-side position, however, is the posture that is most commonly used in the clinical assessment of the height of the shoulders, the balance of the trunk, and pelvic obliquity. Recently, it has become the standard posture for moiré topography when that technique is used to quantify asymmetry of the surface of the back in patients who have scoliosis[1,4,15,18,23,28]. Moreover, the radiographic assessment of the severity of the curve in patients who have scoliosis is usually done in the standing position. Since radiographs of the spine that are made with the patient standing generally show a greater curve than do similar radiographs that are made with the patient recumbent, it has been assumed that the scoliotic deformity is at its worst when the patient is standing. It is not clear how the shape of the surface of the back might change between the standing position and the forward-bending position or what implications this might have for the interpretation of the tests.

In addition, deformity of the surface of the back that is seen when the patient is in the forward-bending position may be susceptible to differences in the lengths of the limbs

* No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article. Funds were received in total or partial support of the research or clinical study presented in this article. The funding source was National Institutes of Health Grant R01 AM 30235.

† University of Vermont College of Medicine, Burlington, Vermont 05405. Please address requests for reprints to Dr. Moreland, Department of Orthopaedics and Rehabilitation, Given Building.

TABLE I

DATA ON FIFTY-SIX PATIENTS WHO HAD ADOLESCENT IDIOPATHIC SCOLIOSIS

				Radiographic Data*				Rotation†				Sagittal Plane‡			
				Thoracic		Lumbar		Standing		FB1		Kyphosis		Lordosis	
Case	Sex	Treatment	Age (Yrs.)	Cobb	Apex	Cobb	Apex	Upper	Lower	Upper	Lower	Standing	FB1	Standing	FB1
1	F	None	14.6	10	T7(9)	−15	L1(5)	−1.7	−8.9	1.0	−20.7	35	51	−25	25
2	F	None	15.7	39	T8(6)	−32	L1(6)	11.5	−6.0	12.8	−23.0	53	24	−52	22
3	F	None	15.3	17	T9(7)			6.3	0.7	6.6	−13.7	49	49	−25	15
4	F	None	14.3	10	T9(8)	−21	L2(5)	2.0	−4.3	1.3	−13.3	45	50	−35	12
5	F	None	13.3	30	T8(9)			3.5	−2.1	7.1	−5.0	26	—	−25	23
6	F	None	13.6			−9	L1(4)	7.7	−2.2	7.6	−8.5	43	44	−28	20
7	F	Brace	16.4	18	T6(9)	−12	L2(6)	6.2	−6.4	−0.7	−12.6	21	15	−30	26
8	F	None	14.1			−12	L1(5)	0.1	−5.0	1.1	−13.2	47	—	−34	28
9	F	None	11.2			8	L2(6)	−1.7	2.0	3.0	1.2	37	52	−37	16
10	M	Brace	15.8	−12	T9(6)	16	L2(5)	−3.3	5.4	−4.0	2.3	30	48	−22	15
11	F	Brace	14.6	21	T8(8)	−25	L2(6)	3.3	−5.3	1.5	−17.8	22	22	−26	23
12	F	None	13.9	20	T7(7)	−38	L1(7)	4.0	−5.4	2.5	−16.1	45	60	−57	36
13	F	None	14.8	5	T9(5)	−8	L2(5)	5.0	−1.7	7.7	−6.6	25	35	−28	19
14	F	None	11.4			−10	L2(6)	−1.9	−5.0	−1.3	−5.8	48	67	−21	31
15	F	None	9.4	19	T9(6)	−23	L1(5)	2.2	−5.1	6.7	−7.9	32	52	−27	25
16	M	None	16.8			−8	L2(5)	0.3	−3.8	−1.8	−7.8	45	—	—	—
17	F	None	10.2	5	T7(6)	−21	L1(8)	−3.0	−8.5	0.3	−20.2	41	54	−34	23
18	F	Brace	12.6	22	T6(8)	−25	L1(6)	−0.8	−8.3	9.5	−3.2	18	37	−30	15
19	F	None	15.9	16	T8(7)	−20	L2(6)	2.4	−5.4	−1.5	−15.9	43	—	—	—
20	F	None	15.3	−14	T5(9)			4.4	−3.6	−4.3	−7.2	12	23	−12	14
21	F	Brace	12.7	19	T6(8)			7.0	3.3	5.7	−10.6	38	42	−35	8
22	F	Brace	13.8			−28	L1(5)	2.2	−3.1	1.0	−21.4	31	56	−41	18
23	F	Brace	15.4			14	L2(6)	1.1	9.6	0.0	8.6	43	59	−40	14
24	F	Brace	14.7			15	T11(7)	−3.8	6.3	−3.8	8.5	22	35	−33	33
25	F	None	13.5	36	T8(8)	−41	L1(5)	−0.8	−9.6	10.7	−10.5	41	33	−25	26

* A positive value indicates a curve that is convex to the right and a negative value indicates a curve that is convex to the left. The Cobb angles were measured in degrees. The length of the curve (number of vertebrae) is given in parentheses after the listing for the apex of the curve.

† A positive value indicates clockwise rotation as viewed from above. Rotation of the surface of the back was measured in degrees as shown in Figure 2. FB1 = forward bend 1.

‡ A positive value signifies kyphosis and a negative value signifies lordosis. Curves in the sagittal plane were measured in degrees as shown in Figure 4. FB1 = forward bend 1.

§ LESS = lateral electrical surface stimulation.

that may affect the clinical detection of the presence of scoliosis[6,8,13].

This study was designed to determine if asymmetry of the surface of the back is different in the standing and forward-bending postures in patients who have adolescent idiopathic scoliosis, if the amount of forward bending makes a difference in the shape of the surface of the back, if the amount of any such change is related to the degree of scoliosis, if the curvature of the surface of the back in the sagittal plane changes significantly during forward bending, and if the shape of the surface of the back is altered by simulating differences in the lengths of the lower limbs.

Methods

Patients

Fifty-six patients who had adolescent idiopathic scoliosis were studied. These unselected consecutive patients were seen for a radiographic examination as part of their initial or follow-up care in 1984. Details regarding the patients are given in Table I. All of the patients were evaluated clinically, radiographically, and by back-surface topography. The average age of the patients was 14.7 years (range, nine to thirty-six years). There were fifty-two female and four male patients. None of the patients in this study had a limb-length difference of more than one centimeter, as measured clinically from the medial malleolus to the anterior superior iliac spine. Twelve patients had worn a brace or were wearing one at the time of study; one patient was undergoing lateral electrical surface stimulation. All patients were examined using standing posteroanterior radiographs of the spine with the low-dose technique of Ardran et al. The mean Cobb angle[7] was 20.6 degrees, with a range from 5 to 55 degrees. Thirty-one patients had a single curve and twenty-five patients had a double curve, for a total of eighty-one curves. In patients who had two or more curves, only the curves that were structural rather than compensatory were studied. In order to select curves systematically for this study, only the additional curves that showed vertebral rotation and were within 10 degrees of the measurement of the major curve were considered structural. Also, for the purposes of this study, the curves were defined as being thoracic if the apex was located at or cephalad to the eleventh

TABLE I *(Continued)*

DATA ON FIFTY-SIX PATIENTS WHO HAD ADOLESCENT IDIOPATHIC SCOLIOSIS

				Radiographic Data*				Rotation†				Sagittal Plane‡			
				Thoracic		Lumbar		Standing		FBI		Kyphosis		Lordosis	
Case	Sex	Treatment	Age *(Yrs.)*	Cobb	Apex	Cobb	Apex	Upper	Lower	Upper	Lower	Standing	FBI	Standing	FBI
26	F	Brace	19.0	45	T9(7)			5.8	2.0	6.4	−6.5	40	22	−24	16
27	F	None	15.6	17	T9(7)	−10	L2(6)	7.1	−3.5	8.1	−8.9	32	27	−38	23
28	F	Brace	15.7	23	T8(7)	−20	L2(6)	4.3	−2.3	6.5	−4.7	31	47	−46	18
29	F	None	16.6	37	T8(5)			5.6	−1.6	8.6	−10.2	49	38	−11	23
30	F	None	12.6			−25	T12(3)	0.0	−3.5	3.8	−8.4	40	57	−38	18
31	F	None	11.6	14	T4(7)			−2.3	−6.2	3.7	−9.3	42	—	—	—
32	M	None	15.2	37	T8(8)			7.7	−3.3	11.2	−12.3	25	—	—	—
33	F	None	14.1	35	T8(5)	−42	L1(5)	4.2	−7.2	9.0	−10.7	34	44	−36	8
34	F	None	18.0	8	T8(7)	−15	L2(5)	2.6	−4.4	3.1	−11.0	42	22	−51	19
35	F	None	10.5			8	L1(5)	−2.0	1.6	−1.0	4.0	45	40	−27	15
36	F	None	13.7			−15	L3(3)	3.6	−2.2	−2.7	−7.0	34	53	−40	22
37	F	None	36.3	47	T9(7)			12.9	0.0	14.0	−1.3	43	51	−36	6
38	F	None	13.6	−14	T3(7)	20	T11(9)	−3.8	6.6	−5.1	5.4	30	31	−40	18
39	F	None	14.2			11	L2(5)	0.0	8.2	−0.6	9.8	29	62	−19	24
40	F	None	11.3			16	T12(7)	−0.5	2.9	4.4	8.2	44	65	−54	27
41	F	None	11.1	26	T8(7)	−18	L3(6)	4.0	−4.5	10.0	−3.6	31	49	−29	26
42	F	None	15.6			−5	L2(5)	−2.5	−9.0	−2.5	−10.3	32	35	−29	26
43	F	None	14.6	−13	T8(4)	20	L2(6)	−1.7	11.2	−2.6	11.1	42	53	−30	22
44	F	None	12.3			10	T10(10)	0.6	2.4	0.3	4.0	—	—	—	—
45	F	Brace	16.3	55	T8(7)			15.0	0.1	17.4	−12.9	26	52	−40	15
46	M	None	14.6			16	T11(5)	−4.8	5.8	2.6	9.2	44	50	−20	24
47	F	None	14.8			32	T12(6)	−6.0	9.2	−2.1	12.0	46	52	−38	17
48	F	Brace	18.1	14	T8(0)	−13	L2(4)	2.9	−3.9	6.7	−0.6	68	78	−51	0
49	F	LESS§	13.4	43	T10(8)			8.0	0.0	11.7	0.0	29	36	−34	34
50	F	None	12.6	5	T6(5)			4.5	−1.9	5.3	−4.9	42	53	−37	18
51	F	None	13.8	14	T8(5)	−18	T12(6)	2.0	−2.6	5.0	−7.8	35	44	−37	24
52	F	None	21.4			50	T11(9)	−1.6	4.0	1.3	10.0	32	50	−39	21
53	F	None	13.9	−20	T9(6)	23	L2(6)	−7.5	−0.3	−6.7	8.5	44	51	−48	18
54	F	None	12.3	10	T8(6)	−11	L1(6)	−3.0	−9.3	6.8	−9.1	28	30	−33	31
55	F	None	14.9			22	L2(6)	−2.5	7.1	−1.6	7.3	45	48	−32	20
56	F	None	15.2	24	T8(7)	−31	L1(5)	7.8	−5.1	7.1	−18.1	31	52	−40	22

thoracic vertebra and as being lumbar if the apex occurred at or caudad to the twelfth thoracic vertebra. In the thoracic region, there were thirty-two right and five left-sided curves, for a total of thirty-seven. In the lumbar region, there were fifteen right and twenty-nine left-sided curves, for a total of forty-four.

Measurement of the Shape of the Surface of the Back

The shape of the surface of the back was recorded by means of Raster stereophotography, using a method based on that of Frobin and Hierholzer. In our method[24], a square grid pattern of light was projected from a slide projector onto the patient's back (Figs. 1-A and 1-B), and this pattern of light was then photographed from an angle of 50 degrees with a thirty-five-millimeter camera. The apparent distortion (parallax) of the square grid compared with that seen on a calibration photograph permitted calculation of the three-dimensional location of the intersections of the grid in space. The Raster pattern was digitized to give the coordinates of the intersections of the grid to a computer. These were analyzed using a direct linear-transformation program[17] to make the close-range photogrammetric calculations of the locations of these points on the patient's back.

Using these data, a computer program was used to construct cross sections through the surface of the back at the level of twenty equally spaced horizontal planes between the first thoracic and fifth lumbar vertebrae, both of which were marked at the time of photography by means of small black dots on the skin (Fig. 2). The asymmetry of the cross-sectional shapes of the right and left sides of the back was measured by means of a line that was drawn tangentially across both sides of the surface of the back. This double-tangent measurement gave the angulation from the coronal plane for each of the twenty cross sections. The angulation was the measure of rotation of the surface of the back. It was given a positive value if the right side was more elevated and a negative value if the left side was more elevated. For each patient, graphs were drawn showing the value of each double-tangent angle at each of the twenty cross sections (Fig. 3). The shapes of these graphs have been shown to be similar to the shape of the spine as seen on the frontal

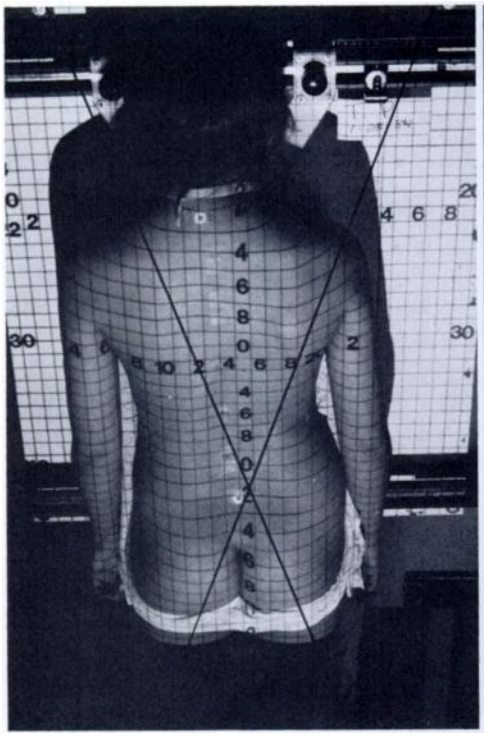

FIG. 1-A

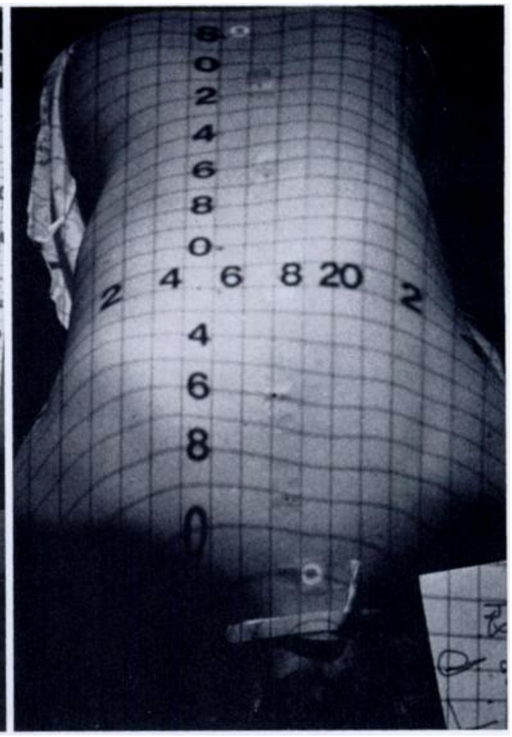

FIG. 1-B

Fig. 1-A: Raster photograph of a patient in a standing position. The cross-hair images were used for calibration purposes.
Fig. 1-B: The same patient in the forward-bending position. The patient's neck is at the bottom of the photograph.

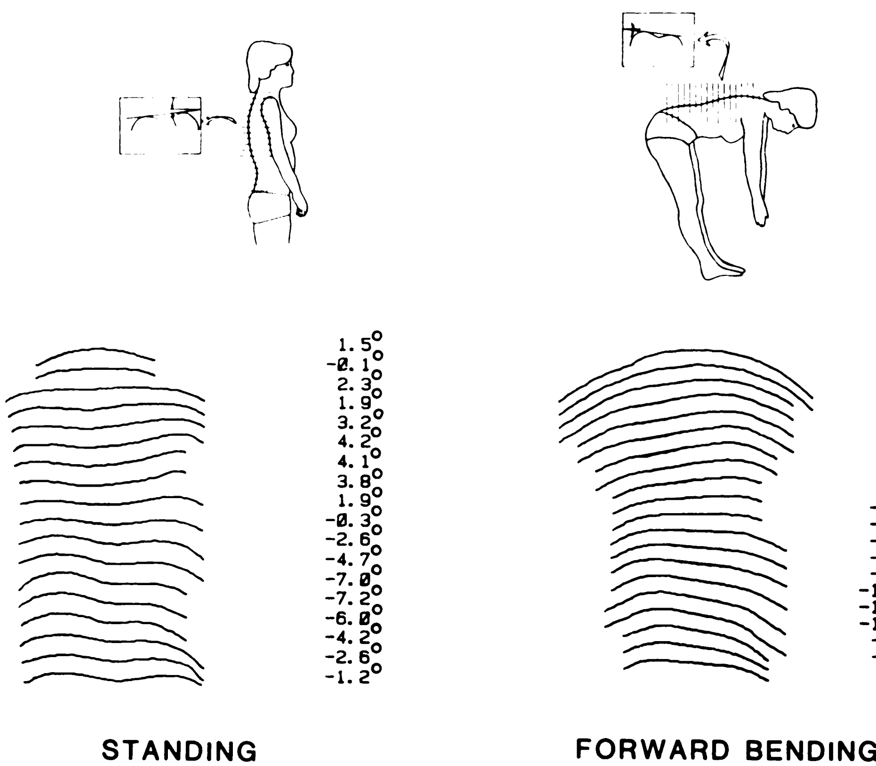

FIG. 2

Transverse cross section through the surface of the back, derived from the Raster stereophotographs shown in Figs. 1-A and 1-B. The twenty cross sections in each view were made at equally spaced intervals between skin-markers that were attached at the first thoracic and fifth lumbar levels. The rotation of the section to the sagittal plane (measured by the double tangents) was used to quantify the symmetry of each section of the surface of the back. This angle was the measure of rotation of the surface of the back.

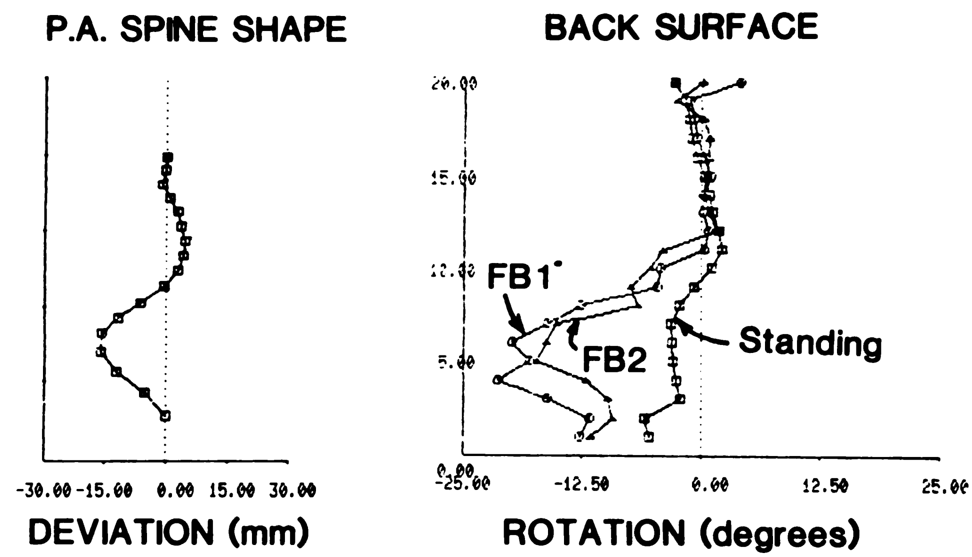

FIG. 3

Similarity of the shape of the spine and rotation of the surface of the back in a fourteen-year-old girl who had a 28-degree left lumbar idiopathic scoliosis. The posteroanterior view of the shape of the spine that is shown on the left is a frontal plane projection derived from the radiograph. The back-surface plot was derived from the angles of rotation of the surface of the back that were measured from the Raster stereophotographs for the three postures: standing, forward bend 1, and forward bend 2.

plane projection, with rotation of the surface of the back clockwise as seen from above for curves that are convex to the right and counterclockwise for those that are convex to the left, and with maximum rotation of the surface of the back close to the apex of the skeletal curve[19].

The shape of the surface of the back was recorded with the patient in three positions: standing, bending forward with the hands to the knees (forward bend 1), and bending forward with the hands to the toes, if possible (forward bend 2). For the first position, the patient was asked to stand in a relaxed posture against four positioning posts, one located anterior to the middle of each clavicle and one located anterior to each anterior superior iliac spine. This position was maintained for both the posteroanterior radiograph of the spine and the standing Raster stereophotograph. The patient was then asked to step out of the positioning device and to assume the forward-bend-1 position and then the forward-bend-2 position. For these examinations, a camera and Raster grid-projector were located in the ceiling so that the patients were photographed from above the surface of the back (Fig. 1-B).

In order to determine the effect of the lengths of the lower limbs on the apparent shape of the surface of the back, thirty of the fifty-six patients were randomly selected to be photographed in the standing position with a four-centimeter-thick block placed under the right foot and then under the left foot. Eighteen of the thirty patients also were studied in the forward-bending position with a block placed under the right foot and then under the left foot. The effects of placing a block under the foot in these subsets of patients were found to be consistent, so the other patients were not asked to participate in these studies.

Sagittal Curvature

The curvatures of the surface of the back in the mid-sagittal plane (back-surface kyphosis and lordosis) for the standing position and the two forward-bending positions were measured from cross sections in the sagittal plane of the surface of the back that were plotted from information that had been stored in the computer (Fig. 4).

Results

Rotation of the Surface of the Back

For the purposes of measuring the maximum rotation of the surface of the back for each of the two regions, thoracic and lumbar, the cross section with the greatest rotation was selected (Table II). In the standing position, the mean value of the maximum rotation in the thoracic spine (thirty-seven curves) was 3.98 degrees (standard deviation, 3.14 degrees); for the lumbar region (forty-four curves), it was 4.62 degrees (standard deviation, 2.82 degrees). The patients who had been or were undergoing therapy had a slightly higher mean Cobb angle (23.67 degrees, compared with 20.60 degrees for the group as a whole). In the thoracic region, the mean rotation was slightly greater

TABLE II

ROTATION OF THE SURFACE OF THE BACK IN THE STANDING AND TWO FORWARD-BENDING POSITIONS*

	No. of Curves	Standing (N = 56)	Forward Bend 1 (N = 56)	Forward Bend 2 (N = 29)
Thoracic	37	3.98 ± 3.14	5.02 ± 3.92	4.91 ± 3.54
Lumbar	44	4.62 ± 2.82	9.44 ± 5.25	10.49 ± 6.45

* Measurements in degrees were obtained as shown in Figure 2. The mean and standard deviation are given for each condition. Absolute values were used because right and left curves produce rotations of the surface of the back in opposite senses. Because only small changes were seen between forward bend 1 and forward bend 2, forward bend 2 was discontinued after examination of the first twenty-nine patients.

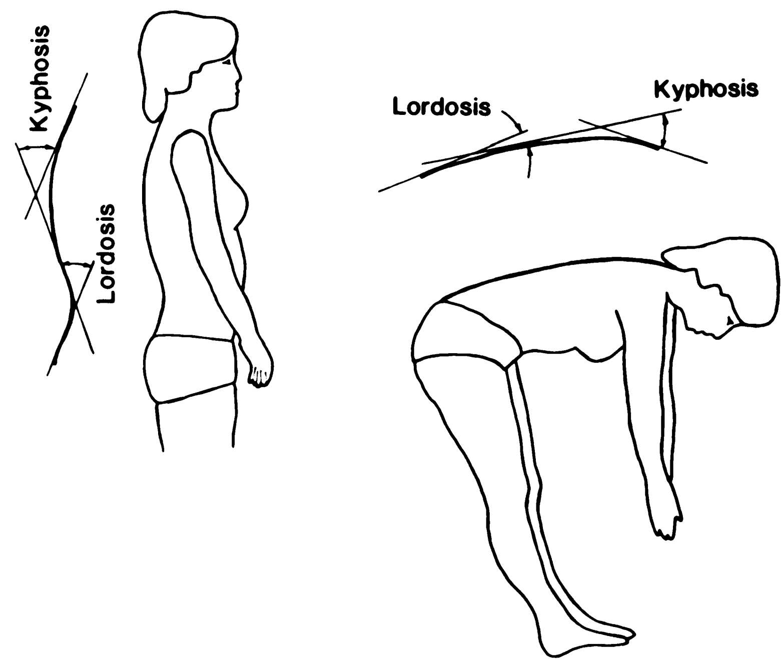

FIG. 4

Measurement of the lordosis and kyphosis of the surface of the back in the standing and forward-bending positions. The measurements were made from cross sections in the mid-sagittal plane of the surface of the back, plotted from back-surface photogrammetric measurements that had been stored in the computer. In the section for the standing position, a line was drawn tangentially to the section at each end and at the inflection point between positive and negative curves (kyphosis and lordosis). The angles were then measured as shown. For the forward-bending position, the cross section was divided in the same proportions as for the section for the standing position, so that the measurements of kyphosis and lordosis were made over the same parts of the back. (This method was based on that of Willner[27].)

(4.90 degrees for the patients who had been or were undergoing therapy, compared with 3.98 degrees for the group as a whole). In the lumbar region, it was slightly less (4.31 degrees compared with 4.62 degrees). Since our findings were similar in treated and untreated patients, the data for all patients were considered together in subsequent analyses. Bending forward from the standing position produced a mean increase in the maximum rotation of the surface of the back for the thoracic region of 1.04 degrees ($p < 0.01$). In the lumbar region, there was a larger mean increase of 4.82 degrees ($p < 0.001$), which was a doubling of the mean angle of rotation. There was no significant change in the angle of rotation (Table II) between forward bend 1 and forward bend 2. In addition, no significant change in the location of the level of maximum rotation with respect to the long axis of the spine was noted when the patient changed from the standing posture to either of the forward-bending positions.

The relationship between the angle of rotation of the surface of the back and the Cobb angle, measured radiographically with the patient standing, was studied by regression analysis. When the patient was in the standing position, the correlation coefficients were 0.73 and 0.82 for the thoracic and lumbar areas, respectively (Fig. 5-A), whereas on changing to the forward-bend-1 position these coefficients increased to 0.87 and 0.86 (Fig. 5-B). The correlations when the patient was in the standing position were similar to those that we reported previously in a smaller group of patients[25].

In order to examine further the possible reasons for changes in the rotation of the surface of the back with forward bending, we used a regression analysis to determine whether these changes were related either to the severity of the underlying scoliotic curve or to the change in the curve in the sagittal plane (change in back-surface kyphosis or lordosis). These analyses revealed a significant positive correlation in the lumbar region ($r = 0.64$, $p < 0.001$) between the change in rotation of the surface of the back and the Cobb angle but no significant relationship with the degree of forward bending, measured as the change in the curvature of the surface of the back.

Changes in the Surface of the Back with Limb-Length Discrepancy

Placing a four-centimeter block under the foot produced a noticeable clinical effect, with unequal pelvic heights and compensation of the trunk to maintain alignment. The changes in rotation of the surface of the back with the block in place are shown in Table III. In all patients, placing the lift under one side produced elevation of the surface of the back on that side. When the patient was standing, this change was minimum in the thoracic region, averaging 1.32 degrees, but was somewhat greater in the lumbar region, with a mean change of 3.73 degrees. The changes in rotation of the surface of the back that were due to induced differences in the lengths of the lower limbs were more notable in the forward-bending position, with thoracic rotation increasing by a mean of 5.64 degrees and lumbar rotation, by a mean of 8.71 degrees. These changes were similar in magnitude to the original values (Table II). Thus, a four-centimeter difference in the lengths of the limbs gave

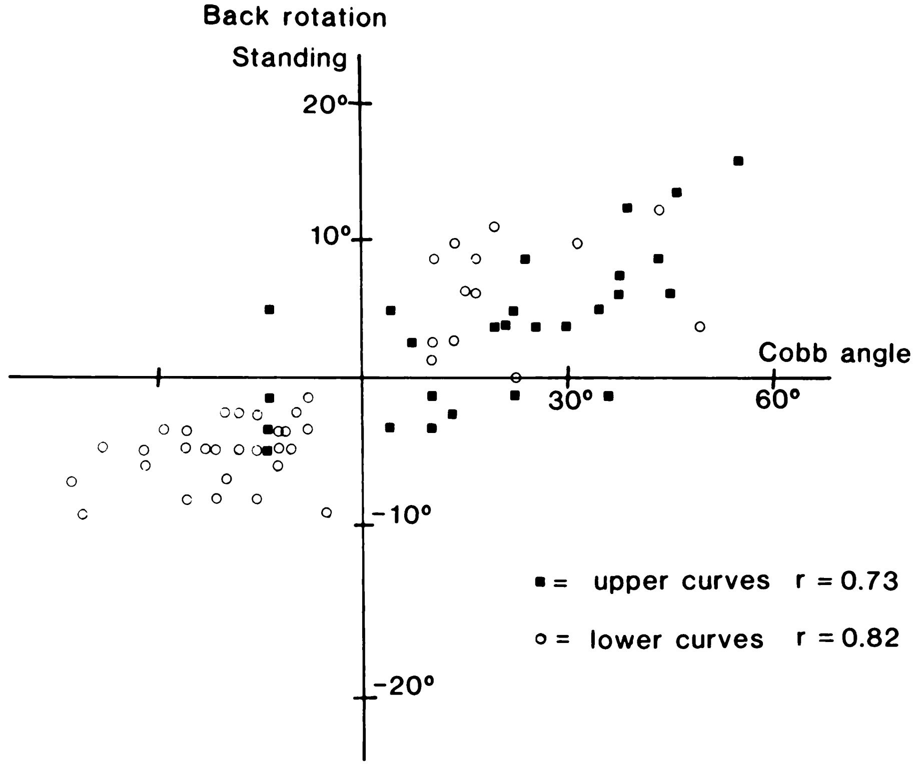

Fig. 5-A

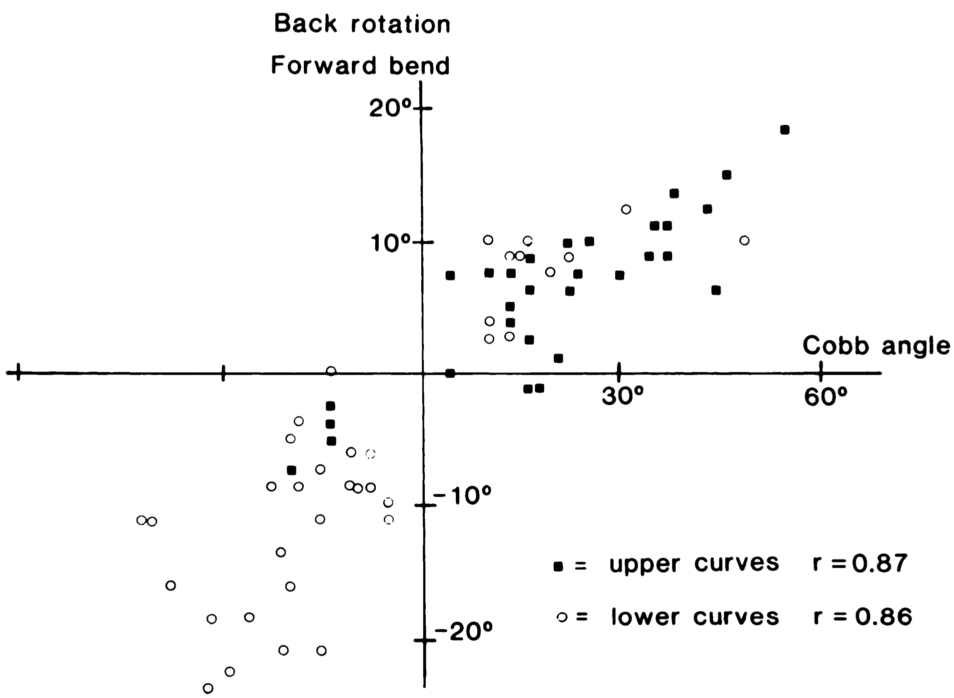

Fig. 5-B

Figs. 5-A and 5-B: The relationship between the maximum rotation of the surface of the back in the region of the curve and the corresponding Cobb angle when the patient was standing (Fig. 5-A) and when the patient was in the forward-bending position (Fig. 5-B). A negative Cobb angle signifies a curve that is convex to the left. Curves in the lower region of the spine (lumbar and thoracolumbar curves) were associated with a slightly greater rotation of the surface of the back in the forward-bending position.

a rotation of the surface of the back of similar magnitude to that associated with the average scoliotic curve in these patients. The right and left sides were equally affected; that is, the existing scoliotic pattern did not influence the changes that were produced by artificially creating differences in the lengths of the lower limbs.

TABLE III

CHANGES IN ROTATION OF THE SURFACE OF THE BACK (IN DEGREES) IN THE THORACIC AND LUMBAR REGIONS THAT WERE PRODUCED BY PLACING A FOUR-CENTIMETER BLOCK UNDER ONE FOOT*

	Standing (N = 30)	Forward Bend 1 (N = 18)
Thoracic	1.32 ± 2.72	5.64 ± 4.48
Lumbar	3.73 ± 3.70	8.71 ± 6.09

* In all patients, the use of the lift produced increased prominence of the back on the same side. The values that are given here are differences from the amount of rotation that was seen when the lift was not used. The values are means and standard deviations.

Changes in the Sagittal Plane

Using the topographic information for the surface of the back in the sagittal plane, the back-surface kyphosis and lordosis for the thoracic and lumbar regions were measured (Fig. 4). In the thoracic region, when the patient was standing, the mean back-surface kyphosis was 35.82 degrees, although there was a wide variation (standard deviation, 9.96 degrees) (Table IV). In the forward-bend-1 position, this increased only 8.88 degrees (standard deviation, 12.1 degrees) on average (Table IV). In the lumbar region, when the patient was standing, there was a mean lordosis of the surface of the back of 32.0 degrees (standard deviation, 12.6 degrees). In the forward-bending position this changed significantly, with a loss of lordosis in the lumbar region of 52.57 degrees, leading to a frank kyphosis. There was no significant additional change in forward bend 2.

TABLE IV

CURVATURES OF THE SURFACE OF THE BACK IN THE SAGITTAL PLANE IN FIFTY-SIX PATIENTS*

	Standing	Forward Bend 1
Thoracic	35.82 ± 9.96	44.70 ± 13.00
Lumbar	−32.00 ± 12.6	20.57 ± 6.50

* Measured in degrees as shown in Figure 4. The values are given as means and standard deviations.

Discussion

Rotation of the surface of the back qualitatively reflects the deformity of the spine and is a part of any structural scoliotic deformity. The optical precision of the Raster stereophotography technique that was used in this study allows the measurement of very small angular changes over a greater area of the back than has been available using previous methods.

The results of this study revealed that there is very little change in the rotation of the surface of the back or in the sagittal curvature when the patient changes position from standing to forward bending. The mean increase with forward bending of 4.82 degrees in the rotation of the surface of the back in the lumbar region, while double the amount of rotation compared with that when the patient is standing, is still quite small. It appears that the actual position in forward bending (forward bend 1 or forward bend 2) has little effect on the degree of rotation of the surface of the back, which suggests that there is not a preferred forward-bending position for examining or measuring children in screening programs in school. It also appears that variations in the degree of forward bending between follow-up examinations may not significantly alter the accuracy of the evaluation, either visually or topographically. While our findings suggest that measurements of the surface of the back have similar validity for demonstrating scoliosis in the absence of limb-length inequality, the visual examination of patients in the forward-bending position is probably preferred by clinicians because subjectively the horizontal gives a reference for judging the symmetry of the back.

Like the findings with regard to rotation of the surface of the back, with forward bending there was little change in the curvature in the sagittal plane in the thoracic region, again regardless of the degree of bending. In most patients, however, the lumbar lordosis reversed to a kyphosis, reflecting the flexibility of the lumbar spine. This flexibility may also account for the increase in rotation of the surface of the back in the lumbar region that was seen with forward bending. The minimum change in either the rotation of the surface of the back or the curvature in the sagittal plane in the thoracic region suggests that because the thoracic spine and rib cage are less flexible than the lumbar region in these patients, the shapes of both the spine and the surface of the back are more constant.

The Cobb-angle measurement of scoliosis has been accepted as the standard of measurement with which varying degrees of deformity are compared. While there was no adequate way of ascertaining the Cobb-angle measurement of the spine in the forward-bending position, the correlation coefficients between the rotation of the surface of the back and the Cobb angle that were measured when the patient was standing were similar in the standing and in the forward-bending position. We could not explain why there was an increase in this correlation in the thoracic region with forward bending. In terms of the magnitude of the measurements, in the forward-bending position the rotation of the surface of the back (in degrees) was consistently smaller than the Cobb angle by a factor of roughly four for thoracic curves and two for lumbar curves. This means that surface-measurement techniques must be more sensitive than the precise Cobb-angle measurements to obtain comparable sensitivity in measurement of the deformity.

Burwell et al. and Harada et al.[12] recommended that examination for rotation of the surface of the back be performed when the patient is sitting in order to eliminate apparent rotation due to limb-length inequality. The changes in rotation of the surface of the back that were produced by a rather drastic change in the lengths of the limbs of four centimeters in our study indicate that when the patient is standing an inequality of less than this amount would have a minimum effect on the rotation of the surface of the back in the thoracic region and only a mild effect on the rotation in the lumbar region. When the patient was in the forward-bending position, both the thoracic region and the lumbar region showed greater changes than were seen when the patient was standing, with the largest changes occurring in the lumbar region. The forward-bending position is apparently more sensitive to the effects of small differences in the lengths of the lower limbs. This finding suggests that any limb-length inequality should be noted and that the pelvis should be leveled by placing a block under the foot before the back is examined for rotation.

Conclusions

This accurate photo-optical technique for evaluating rotation of the surface of the back over the entire spine demonstrated that in the thoracic region there are only small differences in rotation between the standing and forward-bending positions, but there are greater changes in the lumbar region. The amount of forward bending did not affect the angle of rotation. There was only a small increase in the curvature in the sagittal plane in the thoracic region when the patient went from the standing to the forward-bending position. It appears that small differences in the lengths of the lower limbs can affect the shape of the surface of the back in the lumbar region, both in standing and in forward bending, and they should be compensated for before any quantitative assessment of the rotation is performed.

NOTE: Technical support for this study was given by Lise McDonald, Rachael Cohen, and Debra Shuma.

References

1. ADAIR, I. V.; VAN WIJK, M. C.; and ARMSTRONG, G. W. D.: Moiré Topography in Scoliosis Screening. Clin. Orthop., **129:** 165-171, 1977.
2. ADAMS, WILLIAM: Lectures on the Pathology and Treatment of Lateral and Other Forms of Curvature of the Spine. London, Churchill, 1865.
3. ARDRAN, G. M.; COATES, R.; DICKSON, R. A.; DIXON-BROWN, A.; and HARDING, F. M.: Assessment of Scoliosis in Children. Low Dose Radiographic Technique. British J. Radiol., **53:** 146-147, 1980.
4. BERNTSEN, E.: Screening of School Children for Scoliosis [abstract]. Acta Orthop. Scandinavica, **53:** 312, 1982.
5. BUNNELL, W. P.: An Objective Criterion for Scoliosis Screening. J. Bone and Joint Surg., **66-A:** 1381-1387, Dec. 1984.
6. BURWELL, R. G.; JAMES, N. J.; JOHNSON, F.; WEBB, J. K.; and WILSON, Y. G.: Standardised Trunk Asymmetry Scores. A Study of Back Contour in Healthy Schoolchildren. J. Bone and Joint Surg., **65-B(4):** 452-463, 1983.
7. COBB, J. R.: Outline for the Study of Scoliosis. *In* Instructional Course Lectures, The American Academy of Orthopaedic Surgeons. Vol. 5, pp. 261-275. Ann Arbor, J. W. Edwards, 1948.
8. DICKSON, R. A.; STAMPER, PETER; SHARP, A.-M.; and HARKER, PAUL: School Screening for Scoliosis: Cohort Study of Clinical Course. British Med. J., **281:** 265-267, 1980.
9. DRENNAN, J. C.; CAMPBELL, J. B.; and RIDGE, H.: Denver. A Metropolitan Public School Scoliosis Survey. Pediatrics, **60:** 193-196, 1977.
10. FROBIN, W., and HIERHOLZER, E.: Analysis of Human Back Shape Using Surface Curvatures. J. Biomech., **15:** 379-390, 1982.
11. GÖTZE, H. G.: Die Bedeutung des Rotationsindex für die prognostische Beurteilung von idiopathischen Thorakalskoliosen. Zeitschr. Orthop., **113:** 563-565, 1975.
12. HARADA, YOSHIO; TAKEMITSU, YOSHIHARU; and IMAI, MITSURU: The Role of Contour Line Photography Using the Light Cutting Method and Moiré Topography in School Screening. *In* Moiré Fringe Topography and Spinal Deformity. Proceedings of an International Symposium, pp. 113-121. Edited by M. S. Moreland, M. H. Pope, and G. W. D. Armstrong. New York, Pergamon Press, 1981.
13. HARADA, Y.; TAKEMITSU, Y.; and IMAI, M.: Follow-up Study on Hump Measurement in Idiopathic Scoliosis Using Moiré Fringe Topography. *In* Moiré Fringe Topography and Spinal Deformity, pp. 149-154. Edited by B. Drerup, W. Frobin, and E. Hierholzer. Stuttgart, Fischer, 1983.
14. HENSINGER, R. N.; COWELL, H. R.; MACEWEN, G. D.; SHANDS, A. R., JR.; and CRONIS, S.: Orthopaedic Screening of School Age Children. Review of a 10 Year Experience. Orthop. Rev., **4:** 23-28, 1975.
15. LAULUND, T.; SØJBJERG, J. O.; and HØRLYCK, E.: Moiré Topography in School Screening for Structural Scoliosis. Acta Orthop. Scandinavica, **53:** 765-768, 1982.
16. LONSTEIN, J. E.; BJORKLUND, S.; WANNINGER, M. H.; and NELSON, R. P.: Voluntary School Screening for Scoliosis in Minnesota. J. Bone and Joint Surg., **64-A:** 481-488, April 1982.
17. MARZAN, G. T.: Rational Design for Close-Range Photogrammetry. Thesis, University of Illinois, 1976. Ann Arbor, University Microfilms International, Order No. 76-16, 1976.
18. MORELAND, M. S.; BARCE, C.; and POPE, M. H.: Moiré Topography in Scoliosis: Pattern Recognition and Analysis. *In* Moiré Fringe Topography and Spinal Deformity. Proceedings of an International Symposium, pp. 171-185. Edited by M. S. Moreland, M. H. Pope, and G. W. D. Armstrong. New York, Pergamon Press, 1981.
19. MORELAND, M. S.; BIGALOW, L. C.; and STOKES, I. A. F.: Concordance of Back Surface Rotation and Scoliosis. *In* Proceedings of the Third International Symposium on Surface Topography and Spinal Deformity, pp. 165-179. Edited by J. D. Harris and A. R. Turner-Smith. Stuttgart, Fischer, 1986.
20. NEWMAN, D. C., and DEWALD, R. L.: School Screening for Scoliosis. Illinois Med. J., **151:** 31-34, 1977.
21. ROGALA, E. J.; DRUMMOND, D. S.; and GURR, JEAN: Scoliosis. Incidence and Natural History. A Prospective Epidemiological Study. J. Bone and Joint Surg., **60-A:** 173-176, March 1978.
22. SCOLIOSIS RESEARCH SOCIETY: Spinal Screening Program Handbook. Chicago, Scoliosis Research Society, 1980.
23. SHINOTO, AKIRA: Quantitative Analysis of Scoliotic Deformity by Moiré Method. J. Japanese Orthop. Assn., **55:** 1703-1718, 1981.
24. STOKES, I. A. F.; COBB, L. C.; and MORELAND, M. S.: Surface Shape Analysis of Spinal Deformity. Automedica, **5:** 71-83, 1985.
25. STOKES, I. A. F.; COBB, L. C.; POPE, M. H.; and MORELAND, M. S.: Back Surface Shape Relationship to Spinal Deformity. *In* Biomechanical Measurement in Orthopaedic Practice, pp. 114-124. Edited by Michael Whittle and Derek Harris. Oxford, Clarendon Press, 1985.
26. THULBOURNE, T., and GILLESPIE, R.: The Rib Hump in Idiopathic Scoliosis. Measurement, Analysis and Response to Treatment. J. Bone and Joint Surg., **58-B(1):** 64-71, 1976.
27. WILLNER, STIG: Spinal Pantograph. A Non-Invasive Technique for Describing Kyphosis and Lordosis in the Thoraco-Lumbar Spine. Acta Orthop. Scandinavica, **52:** 525-529, 1981.
28. WILLNER, S.: A Comparative Study of the Efficiency of Different Types of School Screening for Scoliosis. Acta Orthop. Scandinavica, **53:** 769-774, 1982.