THE ROLE OF SPINAL AND ABDOMINAL MUSCLES IN THE PATHOGENESIS OF SCOLIOSIS

TOMASZ ŻUK, WARSAW, POLAND

From the Orthopaedic Department of the Medical Academy, Warsaw

There have been a number of studies of muscle activity and the role of muscle action in the development of scoliosis, but so far no definite conclusions have been reached. The results of my electromyographic examinations are similar to those of Allenbach and Wiest (1953), Bayer (1953), Riddle and Roaf (1955), Hertle and Jentschura (1958), but my interpretation of electromyographic and chronaxy tests differs considerably from theirs. It is only fair to point out that the hypothesis proposed in this paper was considered by some of these authors. I have tried to distinguish primary etiological factors in the different types of scoliosis from associated or secondary changes which are common to all types and do not necessarily play a part in causation. There have been two main reasons for undertaking this work: 1) to examine the role of paraspinal and abdominal muscles in the production of scoliosis by means of electromyographic and chronaxy investigations; and 2) to attempt to decide whether the greater electrical activity of the muscles on the convex side is the cause of the scoliosis or is merely secondary to its development.

MATERIAL AND METHODS

For this investigation, electromyographic and chronaxy investigations were made on 112 patients with scoliosis under treatment in the Orthopaedic Hospital in Warsaw. Eighty-six cases were "idiopathic" in children and adolescents, twelve "paralytic," eight "spastic," four "congenital," and two "unclassified." Fifty patients were examined after surgical treatment, and five in either a Risser's plaster or a Milwaukee brace; also, five healthy individuals with normal spines were examined.

Schwarzer's eight-channel electromyograph was used with an amplitude of 100 microvolts corresponding to an excursion of ten millimetres on the record. The recording paper ran at a rate of ten centimetres a second. Surface electrodes, single needle electrodes or co-axial needle electrodes were used.

Electrical potentials were recorded from sacrospinalis [erector spinae] muscles on both sides: 1) at the apex of the curve, 2) three or four vertebrae above, 3) three or four vertebrae below the apex, and 4) from the external oblique muscles in the twelfth thoracic segment. In those patients who had two curves, the upper parts of the compensatory curves were also examined. In certain patients the deep paraspinal muscles were tested with needle electrodes. The following sequence was used: 1) in the prone position with head *a*) straight, *b*) to the left, *c*) to the right; 2) in the prone position with head raised upwards; 3) in the prone position with trunk raised upwards; 4) in the prone position with trunk rotated; 5) in upright position with the muscles completely relaxed; 6) in upright position with the head loaded with 2, 3, 5 or 8 kilograms; 7) in upright position with axial traction on the head; 8) in upright position with bowing or standing on tiptoe.

In order to determine the correspondence between the electrical potentials recorded and the tension in the muscles, electromyographic records were also taken in five patients from the flexor digitorum sublimis muscles of the fingers with loads of from 1–12 kilograms.

TABLE I
ELECTROMYOGRAPHIC RECORDS IN NORMAL AND SCOLIOTIC SPINES
Analysis of Results

	Number of patients	Electrical activity of sacrospinalis					
		Recumbent	Upright	Position			During action of raising head or trunk
				Upright with axial pressure on the head			
				2 kg.	5 kg.	Over 5 kg.	
Straight spine	5	Absent	Absent	Absent	Absent	Absent	Symmetrical or nearly symmetrical
Non-progressive scoliosis	12	Absent	Absent	Absent	Absent	Absent	In 3 patients symmetrical. In 9 patients higher on convex side (2-4 times)
Progressive idiopathic scoliosis	35	From trace to 50 μ V in 27 patients	To 60 μ V in 30 patients	10-80 μ V	15-100 μ V	20-120 μ V	In 28 patients higher on convex side(2-10 times). In 5 patients higher on concave side. In 2 patients symmetrical
		In all patients on convex side					
Doubtfully or minimally progressive scoliosis	10	In 7 patients trace	In all patients from trace to 30 μ V on convex side (no increase of potentials with increase of load)				In 3 patients symmetrical. In 7 patients higher on convex side
Paralytic scoliosis (poliomyelitis)	12	In all patients on convex side. The frequency increases gradually from single potentials to interference pattern					In 8 patients higher on concave side. In 4 patients higher on convex side
		To 100 μ V	To 100 μ V	To 120 μ V	To 150 μ V	To 200 μ V	
Spastic (neuro-genic) scoliosis	8	In 3 patients On concave side	In all patients	On both sides	Higher potentials on convex side		Higher potentials on concave side
Scoliosis stabilised by operation	13	Absent	Absent	Absent	Absent	Absent	In 5 patients symmetrical. In 8 patients higher on convex side (2-3 times)
Scoliosis relapsing after insufficient operative stabilisation (alloplasty of Gruca)	20	In 5 patients	In 16 patients	In all patients increases 3-6 times on convex side			Higher on convex side (2-10 times)
Doubtfully progressive scoliosis after operation	5	Trace in 1 patient	To 15 μ V in 4 patients	Minimal increase of potentials on convex side			Higher on convex side

RESULTS

Significance of amplitude and frequency—These studies showed that the amplitude and frequency of potentials do not depend only on the work done but also on the size and the power of the muscle. For instance, frequent large potentials were obtained when weak individuals lifted a load of 8 kilograms and less frequent smaller potentials were recorded when strong individuals raised a load of 12 kilograms. It is therefore concluded that the amplitude and frequency of potentials reflect the strain to which a muscle is subjected, rather than the amount of work it performs. In other words, a weak muscle lifting a certain load, will show greater electrical activity than a strong muscle lifting a bigger load. It is suggested that the increased electrical activity is therefore a sign that a muscle is reaching the limit of its power and may be a sign of weakness rather than strength, because strong muscles

will need to use only a few of their fibres to perform a given task but weak muscles will have to use more of their fibres and the contractions will have to be more frequent (Fig. 1). In other words, greater electrical activity in muscles on the convex side in scoliosis does not prove that these muscles are stronger unless the conditions under which they are working are taken into consideration.

FIG. 1

Amplitude of action potentials in longissimus spinae during extension of the trunk. Note the equality of amplitude in the healthy spine and the greater amplitude in the muscle on the convex side in the scoliotic spine.

FIG. 2

Action potentials in the sacrospinalis in different types of scoliosis under various conditions. Recordings taken at the apex of the primary curve. Note the greater amplitude of the potentials on the convex side in idiopathic progressive and in paralytic scoliosis.

Findings in healthy and in scoliotic spines (Table I)—1) In individuals with straight spines there was no spontaneous electrical activity of the erector spinae muscles when the subject lay recumbent at rest or stood upright also with the head loaded with 2–8 kilograms. Head and trunk raising gave symmetrical electrical potentials (Fig. 2). 2) In non-progressive scoliosis, or

in patients whose scoliosis had been stabilised by operation, similar potentials were found (Figs. 2 and 3). 3) In progressive scoliosis spontaneous electrical activity of the muscles on the convex side was found in recumbency; the activity was increased in the upright position, and much increased with the head loaded or with lifting the head and trunk from recumbency (Fig. 2). 4) The worse the scoliosis the higher were the electrical potentials on the convex side. 5) If a formerly progressive scoliosis were stabilised by alloplasty or fusion, the difference in electrical potentials diminished and spontaneous electrical activity disappeared (Fig. 3). 6) If a previously stabilised scoliosis recurred, the difference in electrical activity again appeared. 7) In other rapidly progressive scolioses the muscles on the convex side were permanently active and, during work, the amplitude of the potentials was found to be higher than at rest (Fig. 2). 8) If a scoliosis which appeared to be non-progressive were corrected by a plaster jacket, it then behaved like a progressive type. 9) If a plaster jacket were removed for a spinal

FIG. 3

Action potentials in longissimus spinae in a child aged six years with progressive scoliosis, before and after operative stabilisation.

fusion, the electrical activity was like that of a progressive scoliosis. 10) In spastic neurogenic scoliosis the electrical activity of the muscles on the concave side was higher during unloaded standing. When the head was loaded the activity on the convex side was increased.

CONCLUSIONS

It is concluded that the development of scoliosis is due to muscle imbalance, the weaker muscles being on the convex side of the curve. It is suggested that the increased electrical activity in the muscles on the convex side is secondary to the scoliosis, being part of the body's attempt to compensate for the curvature.

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