A CONTRIBUTION TO THE STUDY OF THE MECHANICS OF THE SPINE

BY

ROBERT W. LOVETT, M. D., *of Boston*

From the Anatomical Laboratory, Harvard Medical School

Reprinted from The American Journal of Anatomy, Vol. II, No 4, pages 457–462, October 1, 1903

A CONTRIBUTION TO THE STUDY OF THE MECHANICS OF THE SPINE.[1]

BY

ROBERT W. LOVETT, M.D., *of Boston.*

From the Anatomical Laboratory, Harvard Medical School.

Our present knowledge of spinal mechanics and of the motions of the spine is of an inexact and unsatisfactory character. The books on anatomy contain for the most part loose descriptions of spinal movements and few careful investigations have been made. An exception is the work of Hughes (3) on the rotation movements of the spine.

The chief study of spinal mechanics has been made in connection with lateral curvature by orthopedic surgeons rather than by anatomists. They have done this in the attempt to explain the phenomenon of "rotation" which occurs in lateral curvature. Any patient who develops a marked degree of side bending of the spine shows also a twisting of the laterally curved portion of the spine upon a vertical axis. To the latter phenomenon the name "rotation" has been applied. This association of twisting with lateral curvature has always been regarded as a most obscure phenomenon and Lorenz (1) in his book on scoliosis agrees with a quotation from Bouvier (2) "Man müsste ein Euklides sein, um dieses Räthsel zu lösen."

In the attempt to solve this problem a very large amount of literature has accumulated without obvious practical result (4). But essentially, all of this work has been done from one point of view and the human spine has alone been investigated with the exception of occasional reports of cases in animals (5) and some experiments on dogs by Wullstein (6). The question has either been taken up from the point of view of the pathological changes found in scoliosis and theories constructed to account for these, or suppositions of a purely theoretical character have been formulated embodying general mechanical principles. The shape of the individual vertebrae, normal and distorted, has been studied, the physiological curves have been investigated, the shape of the articular processes has been formulated and the most complicated and confusing results have

[1] Read before the Boston Society of Medical Sciences, May 19, 1903.

been reached. In this literature one reads of hypomochlions, tangents, horizontal and lateral axes, centres of motion, etc., and mental confusion must result from a careful study of these theories.

One way of approaching the question has been left practically untouched except for a single experiment of Bradford's (7). This line of investigation would be to see what the normal spine would do in a scoliosis artificially produced and again to inquire if there is anything in the normal movements of the spine to account for this phenomenon of rotation in connection with lateral curvature. Perhaps the most popular theory to-day is that of Meyer (8), proposed in 1865 and then falling into discredit until taken up by Albert (9) in 1899. This theory maintained that rotation occurred because the human spine consisted of two columns, the column of bodies and the column of arches, and that these two columns possessed a different degree of elasticity. In lateral curvature, therefore, rotation occurred because these two elements of the human spine reacted in different degrees to side bending and one lagged behind the other in side yielding. In some experimental work upon the cadaver undertaken by the writer at the Harvard Medical School (10) certain phenomena were observed which seemed to have a bearing on the occurrence of rotation in lateral curvature, and Prof. Thos. Dwight suggested that it might be worth while to investigate the question whether the spine did not follow certain general laws of mechanics and did not behave as would a flexible rod under similar conditions. The writer is indebted to Prof. Dwight not only for his anatomical material but for his continued advice and criticism throughout the work.

With the aid of Prof. I. N. Hollis, of Harvard University, two general laws governing flexible rods were formulated as follows:

(A) Although a straight flexible rod (e. g., a quadrilateral rod of rubber or lead) may be bent in one plane without twisting, if such a rod is already bent in one plane it cannot be bent in another plane without twisting.

(B) Although a straight flexible rod may be twisted without acquiring a side bend, a flexible rod already bent in one plane cannot be twisted without acquiring a side bend.

The following experiments were then undertaken:

1. A quadrilateral rod of rubber was fixed at its lower end and then bent forward away from the observer. The top of the rod was then bent to the left and the front of the rod was observed to twist to the right.

2. A similar rod of lead followed the same rule under the same conditions.

3. The backbone of a fish followed the same rule under the same conditions.

4. The backbone of a cat followed the same rule under the same conditions.

5. The spinal column of a human cadaver with ribs attached but with the sternum removed when bent forward to the left, twisted in the same way as the flexible rods described above and could not be made to twist in any other way when bent forward to the left.

6. The spine of the living model, bent in this way, twisted in the same way and when bent forward to the left could be made to twist in no other way.

The following experiments in twisting were then made:

(1). A quadrilateral strip of rubber was fixed at its lower end and bent forward away from the observer and then twisted at its upper end with its front surface to the left. In its upper two thirds appeared a lateral curve to the right as seen by the observer from the median plane behind.

(2). A similar strip of lead behaved in the same way under the same conditions and it was noticeable that the lower third or quarter of the strip did not share appreciably in either the twisting or the side bend when the force was applied to its upper free end.

(3). The backbone of the human cadaver, fastened in a vise at its lower end, and twisted by its upper end, showed a similar lateral bend, beginning when fairly erect in the dorso lumbar region.

(4). The spine of the living model in active and passive twisting showed a similar curve to the same side under the same conditions.

Here then were certain tangible facts to be looked into. The suggestion from the above mentioned experiments is that in its association of side bending and twisting, the human spine follows certain more general laws than are to be formulated by a study of its especial structure, in short that its general behavior is governed by the laws which would control any flexible rod of similar shape, size, and elasticity.

The history of the spine in its evolution is of interest. In the Cyclostomata the vertebral column consists of a non segmented homogeneous cartilaginous rod. Articular processes first appear in the Rays and Teleostei. The backbone of the lower fishes consists of a series of bony discs bound together by elastic intervertebral discs. It would seem from the history of the spine as if articular processes developed concomitantly with the elaboration of structure, as if they were incidental to its use rather than factors determining of themselves its types of motion. In the human spine, from this point of view, they would be regarded rather as helping it to carry out its functions as a flexible rod than as causes of its particular movements.

An experiment was then undertaken to determine whether the articular processes were a factor in causing rotation in side bending and also whether Meyer's theory of rotation was true.

In the spine of an adult cadaver from the dissecting room the column of vertebral bodies was separated from the laminae and arches by cutting through the pedicles and the column of bodies was observed by itself.

1. When fixed at the lower end and bent forward and to the left, the column of bodies turned with its front to the right, twisting to the right as did the intact spine and apparently to the same extent. In all other motions it behaved in the same way as did the intact spine.

2. When fixed at the lower end and twisted with its front to the left, a lateral curve to the right of the same character and extent as in the intact spine occurred. In all other manipulations, also, it behaved as did the intact spine. Even the absence of torsion movement in the lumbar region in the intact spine, supposed to be due to the close interlocking of the articular processes, was present to the same extent in the column of vertebral bodies alone. The column of arches on the other hand did not behave as did the intact spine in its relation of twisting and side bending as demonstrated in a former paper. The whole experiment was repeated with similar results on a second cadaver. It would therefore seem reasonable to conclude:

(1) That the articular processes do not cause the torsion of the spine in side bending.

(2) That torsion of the spine in lateral bending is not caused by the fact that the spinal column is made up of two components, the column of bodies and the column of arches.

(3) That the column of vertebral bodies is the determining factor in this association of movements.

(4) That the column of vertebral bodies alone and the intact spine behave alike and behave as would any flexible rod of the same shape, size, and elasticity.

The bearing of this is obvious in its practical aspect. There is no such thing, as is generally taught in anatomies, as a pure side bending of the spine. Every side bending of the whole spine and every side yielding of any part of the spine is also a torsion, and carries with it from the first an element of torsion. Every twisting of the spine carries with it a side bending of the spine and there exists no such movement as a pure twist or torsion of the spine.

There are, therefore, apparently only three types of spinal movement:

1. Forward bending (flexion).
2. Backward bending (extension).
3. { Side bending / Torsion } a compound movement of the two elements which can not be disassociated.

This is the case because from a mechanical point of view the spine is a flexible rod permanently curved by the physiological curves in the antero posterior plane. Side bending necessitates movement in another plane and consequently a twist, and twisting for a similar reason causes side bending.

In lateral curvature the problem is simplified by a recognition of these facts. Any lateral yielding of the spine at any part must be accompanied by a twist of the spine and the transverse axis of the shoulder girdle will no longer be parallel to that of the pelvis. As the lateral curve increases, the twist will tend to increase. But in addition to being a flexible rod the human spine must be regarded as a flexible rod endowed with a sense of equilibrium and adjustment. In a general way in the upright position the head must be kept over the base of support and the head pointing approximately straight ahead. This is a matter of continual and instinctive muscular effort on the part of the patient. If now a lateral curve has been acquired, the shoulders will be twisted in their relation to the pelvis and as the curve increases, the twist would naturally increase. That a twist exists in each case of lateral curve is easily seen in any case of postural lateral curvature looked down on from above in the standing position, when the shoulders can be seen to be no longer parallel to the pelvis. But the twist cannot increase beyond a certain point because of the patient's instinctive effort to keep the shoulders parallel to the pelvis. The lateral curve is a present and probably increasing factor, and to bring the shoulders again parallel to the pelvis, a compensating twist must be added to the one already existing which results in the phenomenon known as rotation and enables the shoulders to be again brought into approximate parallelism with the pelvis. To this resultant combination of two twists which results in the prominence of the ribs on one side of the spine, or of the transverse processes of the lumbar vertebrae on one side of the spine, or to both together, the name "rotation" has been applied in the nomenclature of lateral curvature.

REFERENCES.

1. LORENZ.—Path. und Ther. der Seitl. Ruckgrats-Verkrummungen, p. 28, Wien, 1886.
2. ENLENBURG.—Die Seitl. Ruckgrats-Verkrummungen, Berlin, 1876, p. 116.
3. HUGHES.—Archiv für Anat., 1892, 265.
4. Bibliography in
   RIEDINGER.—Morph. und Mech. der Skol., Wiesbaden, 1901.
   WULLSTEIN.—Die Skoliose, Stuttgart, 1902.

5. SCHULTHLESS.—Lunning and Schulthless Orth. Chir., Munich, 1901, p. 6.
VON HIRSCHBERG.—Zeit. f. Orth. Chir., VII, 1.
SCHMIDT.—Zeitsch. für Orth. Chir., 1903, XL, 2 (with bibliography).
OTTENDORF.—Zeitsch. f. Orth. Chir., 1903, XI, 4, 803.

6. WULLSTEIN.—Loc. cit., 172.

7. BRADFORD and LOVETT.—Orthopedic Surgery, 2nd Ed., New York, 1899, p. 96.

8. MEYER.—Virch. Archiv, 1865, Bd. 35.

9. ALBERT.—Die Mech. der Skol. Wirbelsaüle, Wien, 1899.

10. LOVETT.—Mechanics of Lateral Curvature. Boston Med. and Surg. Journal, June 14, 1900.

13.

THE AMERICAN JOURNAL OF ANATOMY.

THE AMERICAN JOURNAL OF ANATOMY is issued in quarterly numbers, each number of about 125 pages. A volume of four numbers will contain at least 500 pages, with plates and figures. The price per volume, *Postage Prepaid*, is five dollars ($5.00) to subscribers in the United States and Canada, and five dollars and fifty cents ($5.50) to subscribers in other countries. *Remit direct by Postal Money Order; mandat de poste; postanweisung. No discount to booksellers.*

Manuscripts may be sent to any of the editors. Subscriptions and all other communications should be sent to the **American Journal of Anatomy, Corner of Wolfe and Monument Streets, Baltimore, Md.**