SACRARTHROGENETIC TELALGIA

II. A Study of Sacral Mobility

BY HORACE C. PITKIN, M.D., AND HOMER C. PHEASANT, B.S., A.B.,
SAN FRANCISCO, CALIFORNIA

This article is the second of a series of five *. It is based upon additional analyses of the 506 records used in the first article and upon the records of 144 normal male students whom we studied as controls during their routine physical examinations for entrance to the University of California. Its scope is limited to a study of the mobility of the upper sacral joints, and its purpose is to show that sacro-iliac mobility is demonstrable *in vivo*, as well as in autopsy material.

In reviewing the literature, we have encountered very little difference of opinion in regard to the mobility of the sacrolumbar articulation. The sacrolumbar zygapophyses may resemble those between the adjacent dorsal vertebrae, or they may vary through 90 degrees of revolution [6] until they resemble those between the lumbar vertebrae. The type and extent of sacrolumbar motion must vary with the shape of the articular facets, but we have not found any author who doubts that the normal articulation is movable. Abnormal mobility may cause strain—that is, pathological tension—in the extra-articular sacrolumbar ligaments. In the first article of this series [11], we showed that such tension causes sacrarthrogenetic telalgia.

Despite arguments to the contrary, the normal sacro-iliac articulation is a diarthrosis. This fact has been established beyond all possibility of informed doubt by the anatomical and pathological studies of Meyer, Klein, Goldthwait and Osgood, Albee, Derry, Brooke, Sashin, and others. These authors have shown that the normal sacrum takes part in anteroposterior (flexion and extension) movements of the spine and that its average mobility in the cadaver is 4 degrees. Clinical records of sacro-iliac mobility are less easy to find. A few surgeons, like Ryerson, have demonstrated sacro-iliac mobility by manipulating these joints during surgical exposure. Chamberlain and others have determined sacro-iliac mobility by roentgenographic measurements of vertical mobility at the symphysis pubis, but these have been studies of abnormal joints, and we have not found in the literature any clinical measure of normal sacro-iliac motion. It is not difficult to demonstrate anteroposterior motion of the sacrum in two lateral roentgenograms taken with the subject recumbent and with the spine in the positions of acute flexion and hyperextension,

* Of the other four articles, one has been published under the same title [11]; the remaining three are now in preparation and deal with the following phases of the subject:

III. Alternating Scoliosis;
IV. Diagnosis;
V. Treatment.

but this method is not suitable for rapid examinations of large groups of normal subjects.

The axis of normal sacral motion usually is described as a line that parallels the plane of the base of the sacrum and passes through the body of the second sacral vertebra in the transverse plane of the trunk [7]. Such a line crosses each sacro-iliac joint among the interosseous ligaments close to the sacral tuberosity, and lies at the approximate center of the circle that would be formed by continuing the rough arc of the upper two-thirds of the auriculate articular cartilage (Fig. 1). Movements of the sacrum about this transverse axis are analogous to flexion and extension of the spine.

FIG. 1
Lateral view of the sacrum.

Despite the fact that the sacrum is a part of the vertebral column and, therefore, might be expected to take part in rotatory and lateral bending movements of the spine, we have not found any author who describes these types of sacral motion. The shapes of the sacro-iliac joints and their rough interlocking surfaces seem to deny the sacrum any movement about its longitudinal (rotation) or anteroposterior (lateral bending) axes.

In the presence of an intact symphysis pubis, all motions of the innominate bones about the transverse axis of the sacrum, or about the transverse axes of the hip joints, must be paired motions. Antagonistic

motions of this type would rupture the symphysis and are possible only when the symphysis is relaxed or torn. When the weight of the body is borne upon the lower extremities, the paired movements of the innominate bones are flexion and extension about the hip joints. In these movements the sacrum takes little part, since the weight of the trunk, acting through the lordotic lumbar spine, holds it almost continually in a position of flexion *. Movements of the pelvis, other than flexion and extension about the hip joints, are associated with unpaired, antagonistic motions of the innominate bones about a transverse axis that passes through the center of the symphysis pubis. This axis lies at the approximate center of the circle that would be formed by continuing the rough arc of the lower two-thirds of the auriculate cartilage (Figs. 1 and 2). We have checked this type of iliac motion by measurement of antero-posterior and lateral roentgenograms taken with the subjects in the standing position, but we have devised a much more convenient method of measuring it by means of an *inclinometer*.

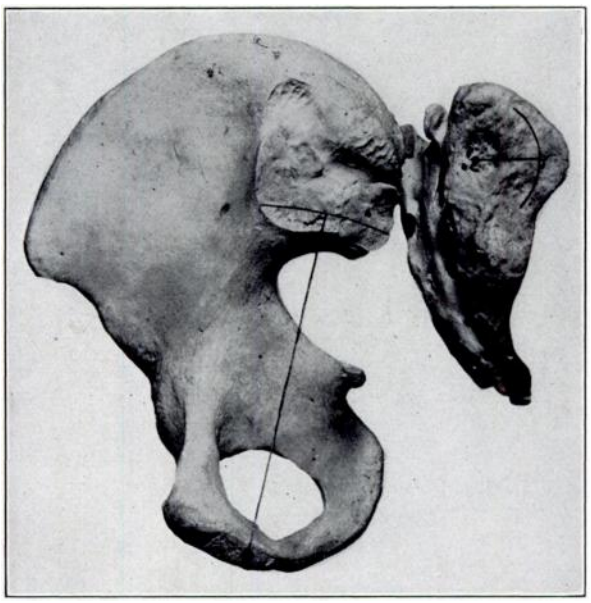

FIG. 2

The centers of sacro-iliac motion.

This instrument (Figs. 3 and 4) is made from a carpenter's calipers to which ball points, a small pendulum, and the scale of a transparent protractor have been fitted. The rod, upon which the protractor and pendulum are mounted, slides through the friction post and continually bisects the space between the arms of the calipers. Thus, the plane of the surface of the protractor always is parallel to a line that connects the tips of the calipers. The examiner applies one tip of the

* Six muscles act directly upon the sacrum. All others must act through the media of the spine and innominate bones. The erector spinae, the multifidus spinae, and the iliacus act as flexors. The gluteus maximus, the piriformis, and the coccygeus act as extensors. None of these muscles arises from the sacrum alone, but each takes an additional and usually a more extensive origin from the contiguous ilium. Only the gluteus maximus has sufficient strength or leverage to overcome the weight of the trunk and to cause the sacrum to extend. Its leverage is increased by flexion of the hips. Its power to act upon the sacrum alone is enhanced enormously by contraction of the flexors of the hips, since these muscles simultaneously immobilize both its iliac origin and its femoral insertion.

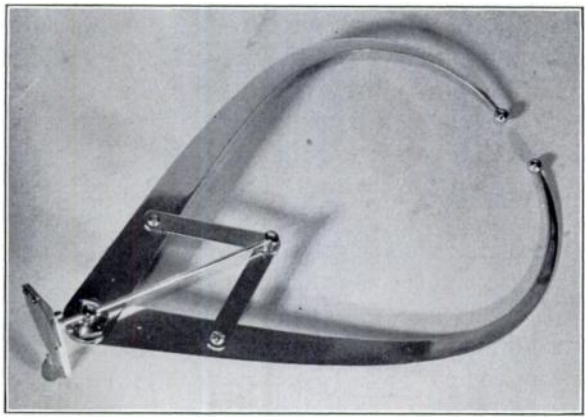

FIG. 3
Inclinometer.

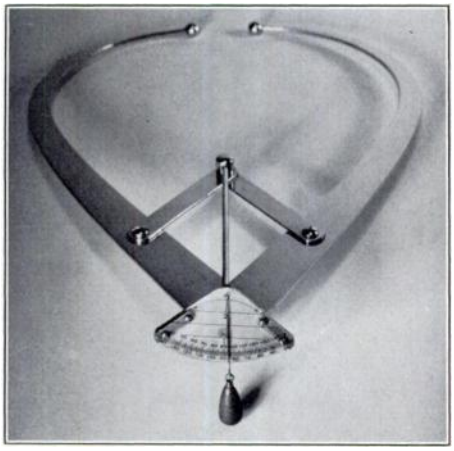

FIG. 4
Inclinometer.

calipers to the anterior-superior spine of one of the subject's ilia; he applies the other tip to the posterior-superior spine of the same ilium; and, finally, he brings the closed end of the calipers to a position such that the pendulum hangs free in the narrow space between the protractor and its back plate. In this position, the plane of the protractor is perpendicular to the plane of the floor, and the examiner may compute the "angle of inclination" of that ilium from the scale of the protractor.

The "angle of inclination" may be defined as the angle formed between the plane of the floor and the projection of a straight line that passes through the posterior-superior and anterior-superior spines of an iliac bone, when the subject is in the standing position. This angle increases with flexion at the hips and decreases with extension. In our series of 144 normal male college freshmen, the average angles of inclination in normal stance were: left, 9.5 degrees; right, 8.2 degrees; average, 8.8 degrees *. In the presence of an intact symphysis pubis, unpaired or antagonistic movements of the ilia must cause a change in the relation of the angles of inclination.

A concrete example of this type of motion is found in the test that we used in the examination of our group of students. Measurements were taken of the angles of inclination of the ilia in three positions. The examiner first requested each subject to place his right foot upon a block of wood, one and one-half inches in height, and then asked him to extend

* The average angles of inclination in our series of cases that showed sacrarthrogenetic telalgia were: left, 7.6 degrees; right, 9.6 degrees; average, 8.6 degrees. The relative positions of the ilia are reversed.

both knees. The latter instruction prevented compensation by flexion of the right knee. Examination of the subjects in this position disclosed the following changes in the relations of the skeleton:

1. The right acetabulum was raised,—that is, the pelvis was tilted toward the left.

2. The pelvis as a whole was shifted toward the right in relation to a point midway between the heels. This caused adduction and relative shortening of the long right leg and abduction and relative lengthening of the short left leg.

3. The left innominate bone was rotated sharply forward about the transverse axis of the symphysis. This caused an increase in the angle of inclination on the left and a tendency toward a further relative lengthening of the short left leg by elevation of the left sacro-iliac joint.

4. The right innominate bone tended to be rotated backward about the transverse axis of the symphysis pubis.

5. The rotation of the innominate bones, the abduction of the left hip, and the adduction of the right hip were not sufficient to correct the tilt of the pelvis toward the left. Thus the lumbar spine showed a scoliosis that was convex toward the left.

6. The lumbar lordosis usually was increased.

7. The vertebral bodies rotated toward the right side,—that is, toward the concavity of the scoliosis *.

8. The trunk, as a whole, tended to list toward the right. The lateral pelvic shift frequently corrected this tendency and sometimes overcorrected it.

9. The completed picture was that of the so called "functional scoliosis" [2].

Having noted the angles of inclination of the ilia in this position, the examiner next took corresponding measurements when the subject had both feet on the floor and, finally, when the subject's left foot alone was elevated upon the block. In this group of normal males, the average total antagonistic mobility of the two ilia was found to be 11 degrees; the greatest total antagonistic mobility was 19 degrees, and the smallest was 3 degrees.

The extra-articular, posterior, sacro-iliac, and sacro-ischial ligaments spread fanwise laterally from the crista sacralis lateralis and forward to their insertions (Fig. 5). The sacro-iliac ligaments oppose sacral hyperextension; the sacro-ischial ligaments oppose sacral hyperflexion. Conversely, in the case of unilateral iliac motion about the transverse axis of the symphysis, the sacro-iliac ligaments on that side

* This spinal rotation is due in part to the forward inclination of the sacrum and occurs even when both sacro-iliac joints are solidly ankylosed. If the sacrum were vertical, all of the pelvic tilt would be transmitted to the last lumbar vertebra as lateral bending toward the side of the shorter leg. Because the sacrum normally is inclined forward at an angle of 60 degrees with relation to the horizon, only two-thirds of the pelvic tilt is transmitted to the last lumbar vertebra as lateral bending; one-third of the tilt is transmitted as rotation of the body of the last lumbar vertebra toward the side of the longer leg.

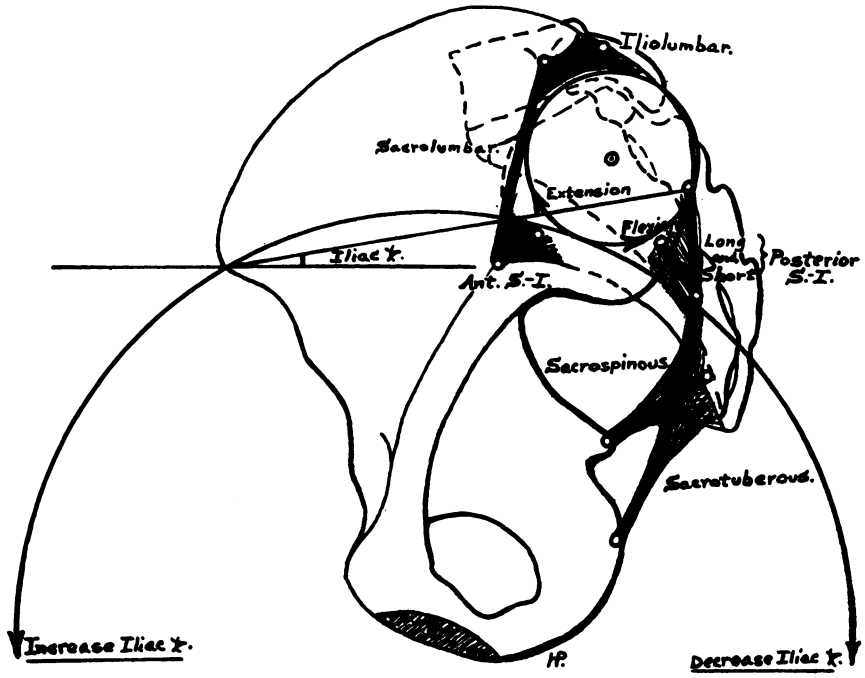

FIG. 5

The extra-articular ligaments of the upper sacral joints.

immediately oppose any attempt to increase the angle of inclination, and the sacro-ischial ligaments immediately oppose a decrease. However, flexion of the sacrum will relax the sacro-iliac ligaments and allow the ilium to rotate forward; extension of the sacrum will relax the sacro-ischial ligaments and allow the ilium to rotate backward. When antagonistic mobility of the two ilia occurs, it thus creates a need for flexion of the sacrum on the side of increasing iliac inclination, and a need for extension of the sacrum on the decreasing side. The sacrum obviously cannot flex and extend simultaneously; it can do only one of these acts, and the weight of the trunk tends to hold it in flexion. Thus, as we have noted in the summary of our examinations of normal males, the ilium that is being rotated forward usually shows a greater excursion than the one that is being rotated backward, and the increased lumbar lordosis reflects the increased flexion of the sacrum.

When an ilium rotates forward about the symphysis pubis as a center, its articular surface, which is slightly behind the center of motion, travels on a rising arc and is carried somewhat upward, as well as forward. Similarly, rotation of the ilium backward causes the articular surface to be translated backward and downward. When antagonistic iliac mobility occurs, the sacrum cannot remain suspended in mid-air, but is forced by gravity to follow any *downward* or *forward* motion of the ilia. Therefore, the articular surface of the sacrum, on the side of the ilium that is rotating

forward, accompanies the articular surface of that ilium in its *forward* and upward movements. The opposite side of the sacrum, in a like manner, accompanies the ilium that tends to rotate backward and *downward.* Thus, the sacrum is caused to bend laterally and to rotate away from the side on which the angle of inclination is increasing. The antagonistic movements of the ilia and the associated movements of the sacrum can be demonstrated quite easily by measurements of roentgenograms, and we have checked our inclinometric figures by this method.

From the foregoing, it is apparent that we must divide sacral mobility into two types:

1. Flexion and extension, in which the sacrum is the moving member and the ilia are fixed.

2. Lateral bending and rotation, in which the ilia are the moving members and the sacrum follows passively.

It should be emphasized that *lateral bending and rotation normally do not occur alone, but as correlated movements,* and that in this respect the sacrum does not differ from the rest of the presacral vertebrae, perhaps excepting the atlas and axis. We have found, by inclinometric and other measurements, that this second type of sacro-iliac motion regularly accompanies all lateral bending and rotatory movements of the trunk (Table I). Because the volitional element is greater in these movements than in the reflex compensation for a lengthened leg, we have not used them for routine tests *.

The problem of measuring separately the mobility of either sacro-iliac joint, when both joints are movable, has proved to be an insoluble one to date. In cases of bilateral sacro-iliac ankylosis, the measurements of iliac mobility regularly have shown less than 2.0 degrees of total antagonism (which establishes the maximum error inherent in this method). In cases of unilateral sacro-iliac ankylosis, antagonistic mobility of the ilia has been found to be identical on the two sides, or to have differed by less than 2.0 degrees. In our group of normal males, the average antagonistic mobility of the left ilium was 4.8 degrees, while that of the right

* The relation of the dominant hand and eye to iliac mobility is interesting and perhaps important. When we made our measurements of iliac mobility in the group of normal students, we also made records of their handedness and eyedness by Quinan's method [12] and discovered the following facts:

1. The dominant eye, primarily, and the dominant hand, secondarily, are associated with a decrease in the iliac inclination on the same side in normal stance.
2. Unilateral double dominance is associated with:
   a. The largest difference between the two angles of inclination in normal stance, the doubly dominant side tending to show the smaller angle;
   b. The largest excursion of one ilium, usually the one on the doubly dominant side when that side is lowered;
   c. The largest net change in the inclination of the pelvis as a whole, since the less mobile ilium frequently follows rather than opposes the motion of the more mobile one.
3. Right-eyedness is associated with the largest total antagonistic mobility of the two ilia.
4. Left-handedness is associated with the largest discrepancy between the individual excursions of the two ilia.
5. The largest net change in the inclination of the pelvis as a whole is associated with the smallest total antagonistic mobility of the two ilia, and *vice versa.*

TABLE I

NORMAL MECHANICS OF THE PELVIS AND SPINE IN THE ERECT POSITION
(FLEXION AND EXTENSION ARE NOT INCLUDED BECAUSE THEY DO NOT CAUSE TORSION OF THE PELVIS)

Effect Upon	Short Right Leg, or Lift under Left Foot	Short Left Leg, or Lift under Right Foot	Bending of Trunk to Left, and Shifting of Pelvis to Right	Bending of Trunk to Right, and Shifting of Pelvis to Left	Rotation of Trunk to Left, and of Pelvis to Right	Rotation of Trunk to Right, and of Pelvis to Left
Left Acetabulum	Up	None	Up	Down	(Down)	(Up)
Right Acetabulum	None	Up	Down	Up	(Up)	(Down)
Pelvic Tilt	Right	Left	Right	Left	Left	Right
Pelvic Shift	Left	Right	Right	Left	(Left)	(Right)
Left Iliac Inclination	(Decreased)	Increased	Increased	(Decreased)	(Decreased)	Increased
Right Iliac Inclination	Increased	(Decreased)	(Decreased)	Increased	Increased	(Decreased)
Sacral Motion—Longitudinal Axis	Left rotation	Right rotation	Right rotation	Left rotation	Left rotation	Right rotation
Sacral Motion—Anteroposterior Axis	Left lateral bend	Right lateral bend	Right lateral bend	Left lateral bend	Left lateral bend	Right lateral bend
Lumbar Curve Convexity	Right	Left	Right	Left	Left	Right
Rotation of Pelvis—Longitudinal Axis	Left	Right	Right	Left	(Right)	(Left)
Dorsal Curve Convexity	Right	Left	Right	Left	Right	Left
Rotation of Shoulder Girdle—Longitudinal Axis	Left	Right	Right	Left	Left	Right
List	(Left)	(Right)	Left	Right	Right	Left

The parentheses in the above columns indicate weak actions that always are present, but that may be neutralized or overcome by the dominant actions.

ilium was 6.2 degrees. This represents a total antagonistic mobility of 11.0 degrees. In our group of cases that showed sacrarthrogenetic telalgia, the antagonistic mobility of the ilia was found to be increased; its average measurement was 7.0 degrees for the left ilium, 7.6 degrees for the right ilium, and the total was 14.6 degrees *. A comparison of the two groups shows that in the group with sacrarthrogenetic telalgia the average mobility of the left ilium was increased by 2.2 degrees, or 46.0 per cent.; that of the right ilium was increased by 1.4 degrees, or 23.0 per cent.; and the average total mobility was increased by 3.6 degrees, or 33.0 per cent. If one will imagine the effect of an increase of 33.0 per cent. in the mobility of any joint with which he is completely familiar, he will recognize the possibilities of strain that such abnormal mobility entails.

The ilium on the side of maximum pain may show an increased mobility or a decreased mobility, but, when we consider that in this series the average increase in mobility of the left ilium was 23.0 per cent. greater than that of the right, the following figures become significant. Tenderness of the posterior sacro-iliac ligaments was 14.0 per cent. more frequent on the left side than on the right. The patients complained of telalgia originating in the left sacro-iliac joint 17.0 per cent. more often than in the right. Prone-knee flexion [10] was more limited on the left side 37.0 per cent. more often than on the right. Supine straight-leg raising was more limited on the left side 41.0 per cent. more often than on the right.

In the first article of this series, we showed that sacrarthrogenetic telalgia in the lower extremities is caused by pathological changes in the tension of the extra-articular ligaments of the upper sacral joints. At that time we omitted all consideration of sacro-iliac mobility. The parallelism between the incidence of sacrarthrogenetic telalgia, abnormal mobility of the ilia, tenderness of the sacro-iliac ligaments, the patient's opinion of the source of his pain, and the results of those tests which tend to increase the tension of the sacro-iliac ligaments is too striking to be fortuitous. We feel that abnormal sacro-iliac mobility is not only a regular concomitant, but also a potent cause of the abnormal ligamentous tension that produces sacrarthrogenetic telalgia.

CONCLUSIONS

1. Sacro-iliac mobility can be demonstrated *in vivo* by measuring the movements of the ilia.

2. In the standing position, all motions of the trunk, with the exception of flexion and extension, normally are associated with unpaired, antagonistic movements of the ilia about a transverse axis that passes through the center of the symphysis pubis.

* Only the males were considered in computing this average, in order to make the figures more accurately comparable. The average age of the individuals in this group was considerably greater than in the normal group, so that, all other factors being equal, the mobility in the normal group should have been the greater [3].

3. Rotation and lateral bending of the sacrum normally do not occur alone, but as correlated motions that are coincidental to antagonistic movements of the ilia.

4. The positions of the ilia in normal stance, as well as their relative mobility, are affected by the dominant eye and hand.

5. The average antagonistic mobility of the male ilia is found to be increased 33.0 per cent. above normal in those subjects who complain of sacrarthrogenetic telalgia.

6. Abnormal sacro-iliac mobility is a potent cause of the abnormal ligamentous tension that produces sacrarthrogenetic telalgia.

REFERENCES

1. Albee, F. H.: A Study of the Anatomy and the Clinical Importance of the Sacro-Iliac Joint. J. Am. Med. Assn., LIII, 1273, 1909.
2. Brewster, A. H.: Nelson Loose-Leaf Living Surgery, III, 165. New York, Thomas Nelson & Sons.
3. Brooke, R.: The Sacro-Iliac Joint. J. Anat., London, LVIII, 299, 1923–1924.
4. Chamberlain, W. E.: The Symphysis Pubis in the Roentgen Examination of the Sacro-Iliac Joint. Am. J. Roentgenol., XXIV, 621, 1930.
5. Derry, D. E.: The Influence of Sex on the Position and Composition of the Human Sacrum. J. Anat. and Physiol., London, XLVI, 184, 1911–1912.
6. Goldthwait, J. E.: The Lumbo-Sacral Articulation. An Explanation of Many Cases of "Lumbago", "Sciatica", and Paraplegia. Boston Med. and Surg. J., CLXIV, 365, 1911.
7. Goldthwait, J. E., and Osgood, R. B.: A Consideration of the Pelvic Articulation from an Anatomical, Pathological and Clinical Standpoint. Boston Med. and Surg. J., CLII, 593, 634; 1905.
8. Klein, G.: Zur Mechanik des Ileosacralgelenkes. Ztschr. f. Geburtsh. u. Gynäkol., XXI, 74, 1891.
9. Meyer, G. H.: Der Mechanismus der Symphysis sacro-iliaca. Arch. f. Anat. u. Physiologie (Leipzig), I, 1, 1878.
10. Pitkin, H. C.: Prone Knee Flexion: In Differential Diagnosis of Low Back Pain. California and West. Med., XXXVIII, 51, 1933.
11. Pitkin, H. C., and Pheasant, H. C.: Sacrarthrogenetic Telalgia. I. A Study of Referred Pain. J. Bone and Joint Surg., XVIII, 111, Jan. 1936.
12. Quinan, Clarence: The Handedness and Eyedness of Speeders and of Reckless Drivers. Arch. Neurol. and Psychiat., XXV, 829, 1931.
13. Ryerson, E. W.: Surgical Treatment of Low Back Disabilities. J. Bone and Joint Surg., XIV, 154, Jan. 1932.
14. Sashin, David: A Critical Analysis of the Anatomy and the Pathological Changes of the Sacro-Iliac Joints. J. Bone and Joint Surg., XII, 891, Oct. 1930.