

THE INFLUENCE OF SEX ON THE POSITION AND COMPOSITION OF THE HUMAN SACRUM. By DOUGLAS E. DERRY, M.B., *Anatomical Department, University College, London.*

THE question of the cause of the variations so constantly found at the hinder end of the vertebral column, and notably in the sacrum, has given rise to extensive investigations having for their object the elucidation of this problem; and various hypotheses have been advanced to account for the remarkable variations which the human sacrum exhibits.

It is not my intention in this paper to discuss the different views which have been put forward, but rather to adduce evidence from a somewhat different direction, which to a large extent supports the views put forward by Professor Paterson (1) in his valuable monograph, "On the Human Sacrum," published in the *Scientific Transactions of the Royal Dublin Society* in 1893. In this memoir Professor Paterson discusses the views formulated by Rosenberg, Topinard, Regalia, Holl, and others, and then presents the results of his own investigations on a large number of sacra, including complete vertebral columns as well as isolated sacra.

In summing up the conclusions arrived at he says: "The consideration of a large series of vertebral columns compels one to discard the theory of 'intercalation' and 'excalation,' as failing to meet the case and to explain the variations met with in the number of vertebræ comprising the several regions of the human vertebral column. The hypothesis of inherent variability, of shifting of one region of the spine at the expense of a neighbouring region, fully and adequately accounts for all cases of individual variation."

This hypothesis, however, does not attempt to explain the reason of such inherent variability, nor why there should be a shifting of the different regions of the spinal column.

The object of this paper is to endeavour to explain, from a separate examination of the sacra of the two sexes, how such variability has come about—a variability which is, according to Professor Paterson, more frequent in man and the anthropoid apes than in the large majority of other animals.

The loss numerically in the sacra available for my purpose, owing to uncertainty as to the sex of the bones, was more than compensated for by the results obtained when only accurately sexed sacra were employed.

Sixty-three male bones with one or both hip-bones, and 34 female also with the corresponding hip-bones, were examined. This number is small, but, as will be shown, the definite sexual characteristics which this sharp classification reveals leave no doubt as to their reality and importance. One hundred and ninety-two isolated sacra have also been examined, but the results embodied in this paper are founded solely on the 97 of which the sex is known.

The special point which gave rise to this investigation was the observation that the articular surface of the female sacrum, while being obviously smaller than, and of a different shape from, that of the male, only extended over two sacral vertebræ in many cases, whereas that of the male almost invariably includes a part, and at times the whole, of the third. This was referred to in my paper on "Accessory Articular Facets between the Sacrum and Ilium," published in a recent number of this Journal (2).

In this connexion Professor Paterson says (p. 130): "The articulation is formed by means of three sacral vertebræ in the great majority of cases, by four vertebræ in very few, and by two vertebræ to an intermediate extent." He shows by a table that 250 sacra out of a total of 274 articulated by more than two pieces, and only 24 by two vertebræ alone. At first sight such a result would appear to be entirely at variance with my statement as to the difference in the number of sacral vertebræ included in the joint in the two sexes, as obviously Professor Paterson had more than 24 female sacra in his collection, for in another place (p. 156) he speaks of having 38 female bones. This apparent antagonism in our results is, however, in part explained by the following fact. In all female sacra in which an additional piece is incorporated with the bone—that is to say, in all six-pieced female sacra—the articular surface spreads on to the third sacral vertebra, and the condition which is normal in the male is taken on by the female. In the 34 female sacra which I have examined, there were 11 consisting of six pieces, *i.e.* 32·3 per cent., and in all of these the articular surface included a part of the third vertebra. On the other hand, of the remaining 23, in 20 the articular surface was confined to the upper two vertebræ; while of the last 3, in 1 the articular surface reached the third piece but only on the right side, 1 was doubtful, being on the boundary between the second and third pieces, and 1 showed the articular surface reaching the third sacral vertebra.

Of the 63 male sacra, the articular surface extended well on to the third vertebra in 52 cases, and in some instances nearly reached the fourth. In the remaining 11, 5 reached only to the second piece, 2 were doubtful owing to the presence of ligaments, 3 reached the second piece only on the left side but spread on to the third vertebra on the right, and

finally 1 articulated by only two vertebræ, but its first piece was released from articulation with the ilium, though still attached to the base of the sacrum.

Another probable source of difference in the results obtained by Professor Paterson and myself in this respect is the opinion as to what actually constitutes articulation with the third sacral vertebra. A number of female bones show the articular surface touching the upper border of

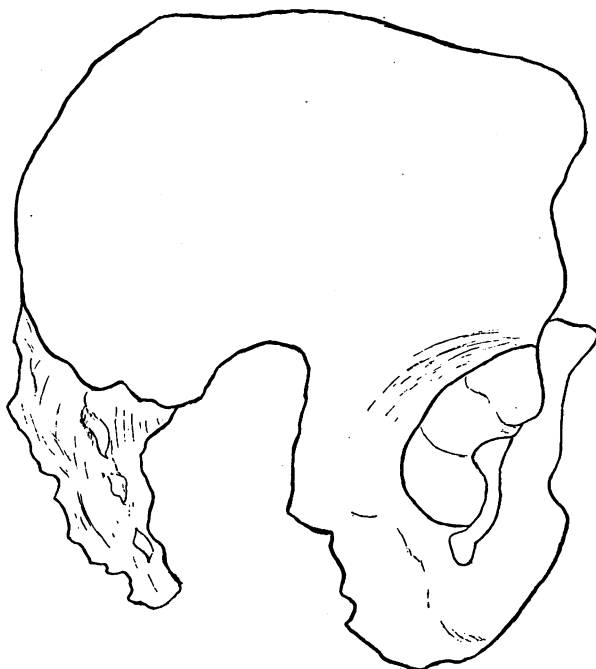


FIG. 1.—A normal male pelvis showing the position of the sacrum and the depth of the ilio-sciatic notch.

the third piece without actually articulating with it, and such cases are possibly those which Professor Paterson designates as 2+. There were 51 of this type in his series, so that it seems probable that had Professor Paterson known the sex of all his sacra he could have shown the marked difference in the extent of the articular surface which undoubtedly exists between the sexes. I have generally employed the lower border of the second posterior sacral foramen as indicating the lowest edge of the second sacral vertebra in those cases where the original line of junction is obliterated.

In the paper alluded to above I have already drawn attention to the

fact that the human female pelvis tends to preserve in some measure the position occupied by it in the lower mammals; that is to say, the plane of the brim forms a smaller angle with the horizontal than in the male and the ilia are not curved downwards posteriorly to the same extent, with the result that the sacrum projects more backwards than in the male and the ilio-sciatic notch is not nearly so deep (*cf.* figs. 1 and 2). I further stated that the peculiar form of the human pelvis is a direct result of the assumption of the erect attitude which has not only dragged the posterior ends of the



FIG. 2.—Normal female pelvis for comparison with fig. 1. Note the width and shallowness of the ilio-sciatic notch and the different position of the sacrum.

ilia downwards, but has caused a rotation of the sacrum on a transverse axis between the ilia, thereby allowing of a moving forward of the lower part and of a backward movement of the upper part. This, as was pointed out, has modified the shape of the articular surface in the human as compared with that in lower mammals, and has resulted in a more intimate connexion between sacrum and ilium in man than is the case in most pronograde mammals. In the majority of the carnivora as well as in ungulates the first piece of the sacrum with a small part of the second (in the cats the transverse process of the second sacral vertebra) form the complete articular surface, which is horizontally placed or even tilted with

the posterior end higher than the anterior, as compared with the articular surface of the human species, which slopes in an exactly opposite direction, tending, at least in males, to incline distinctly downwards posteriorly. It is therefore of great interest to find that women in part retain the more primitive condition in spite of their erect posture, owing to the necessity in this sex for greater space between the sacrum and pubic arch. As there has been no call for such modifications in the male, his sacrum has rotated further than has that of the female, and coming thus into more extensive apposition with the ilium, articulates therewith more frequently by its third piece than is the case in the female.

In some cases, however, the female sacrum shows, as already mentioned, a similar condition, and herein lies the interest of the investigation; for whenever such a sacrum, articulating by three vertebræ with the ilium instead of two, is examined, it is found to consist of six fused vertebræ instead of the accepted normal five. At the same time such sacra are seen to resemble those of males in other ways besides that of more extensive articulation, notably in their length and greater curvature, and also in their tendency to occupy a higher position with relation to the pelvic brim than is the case in the more normal female bone forming the high-standing promontory of Froriep. These cases further resemble the male in having frequently a deeper ilio-sciatic notch than is usual in females. The result of this general resemblance to the male type is to contract the pelvic outlet, and may therefore cause difficulties in parturition. A case of this sort is described by Dr Wood Jones (3) in the "Report on the Human Remains," *Archæological Survey of Nubia*, vol. ii. p. 248, where a pelvis with a six-pieced sacrum was found to contain a foetus which had apparently been unable to pass through the pelvic outlet.

The explanation of these conditions becomes very simple if it be supposed that the change in the direction of the sacrum which has contributed to the assumption of the upright posture in both sexes, but which is usually somewhat less marked in the female for the special purpose of child-bearing, has in the particular cases under consideration been carried further, so that the sacrum has rotated more forwards and thus been brought into closer union with the ilium, while at the same time the posterior part of the ilium itself has been pulled more downwards than in the normal female bone, so deepening the ilio-sciatic notch and lessening the size of the pelvic outlet.

This supposition affords an immediate explanation of the variations found in the sacrum as regards the number of vertebræ entering into its composition and also of the vexed question of the so-called shifting of the hip-bone on the vertebral column.

For if it be true that in standing erect the human sacrum has undergone some amount of rotation, it follows that the anterior part which moves backwards will also tend to rise out of the pelvis, while the hinder part will become more depressed between the ilia. This is precisely what has happened, for not only does the male, in whom the rotation has been carried to a greater degree than in the normal female, more frequently exhibit the high-standing promontory, but also it is the rule to find the sacrum more deeply placed between the posterior ends of the ilia in men than in women. Professor Paterson has pointed out that the first sacral vertebra tends to be released from the sacral mass more frequently in men than in women. On page 160 he says: "The male sacrum shows a certain (slight) tendency towards the formation of a second (false) promontory, through the separation of the first sacral vertebra from the rest." This is precisely what might be expected after what has been said in regard to the rotation of the sacrum; for as it rotates and the first piece is lifted out of the pelvis, this piece tends to lose its original important position as the principal bone of articulation with the ilium, and consequently all stages in this process may be found, from the complete and extensive articulation common in females, to the actual removal altogether of the bone from participation in the joint.

This, then, accounts for the so-called shifting of the pelvis, which has been variously described as moving in the cephalic and in the caudal directions. Professor Paterson is strongly against Rosenberg's view of a shortening of the vertebral column, and believes that the evidence tends to show a shifting of the whole sacrum caudalwards (p. 140). As I have attempted to show, there is in reality no shifting, as such, at all, but merely a change in the relative importance of the first sacral vertebra as an element in the joint, due entirely to an alteration in the position of the sacrum with regard to the ilium, owing to the rotation which has come about in association with the assumption of the erect posture.

There is, however, still a further point. As the first sacral vertebra tends to be released from the sacrum, so an additional vertebra tends to be taken in from the caudal series. As might be expected, this is commoner in men than in women, 46.6 per cent. of the male bones examined exhibiting the addition of a caudal vertebra, while, as mentioned earlier in this paper, 32.2 per cent. of the female sacra examined were six-pieced. It appears, then, that it is nearly as common for men to have six vertebræ in the sacrum as the generally accepted five. Paterson mentions in a note that Professor Cunningham had pointed out that Vesalius figures the sacrum as consisting of six pieces.

The reason for the taking up of a caudal vertebra is not so clear, but as it happens frequently in males, and regularly in females when the sacrum

simulates that of a male, it must be supposed that it is a direct result of the more intimate connexion of the sacrum and ilium, with loss of movement between the sacrum and coccyx, as suggested by Rosenberg.

The above statement as to the true cause of the variability found in the human sacrum is supported by all the evidence collected by the numerous observers who have given attention to this subject.

In the first place, Professor Paterson's observation in the case of the rat that variations of the spinal column in this animal are *extremely slight*, is what we should expect, and the same may be said of pronograde mammals generally. But an examination of the conditions in anthropoid apes should throw light on the problem, seeing that they hold to some extent an intermediate position between quadrupeds and man. In these animals, therefore, which have attained to a semi-erect posture, it is not surprising to learn that variations are "exceedingly frequent" (p. 196). There is, however, an important point in this connexion which must be discussed here. Professor Paterson finds great discrepancies between the three great anthropoids, gorilla, chimpanzee, and orang, showing, as he supposes, a tendency in the gorilla and chimpanzee towards abbreviation of the pre-sacral region, but in the orang towards elongation of the same region.

Now if the explanation given above for the changes in the position of the human sacrum be correct, it might be expected that similar influences have been at work in the case of the semi-erect apes.

Professor Paterson states that the formula for the *normal* vertebral column of the gorilla is

C. 7, T. 13, L. 4, S. 5, Co. 4 or 5.

In this he is perhaps following Flower (4), who gives seventeen as the united number of thoracic and lumbar vertebræ in the gorilla. In spite of this, however, Paterson's own series of eleven gorillas shows no less than nine *abnormal* spines, in seven of which the combined thoracic and lumbar vertebræ only number sixteen instead of the accepted normal seventeen.

I have also examined the spines of 10 gorillas, 3 in the British Museum, 6 in the museum of the Royal College of Surgeons, and 1 in the Zoological Museum at University College. Most of these have probably already been included in Professor Paterson's series. Of these 10, no fewer than 7 have only sixteen thoracic+lumbar vertebræ, thirteen thoracic and three lumbar; while of the remaining 3, 1 has its so-called fourth lumbar vertebra partly sacralised on the right side where it articulates independently with the ilium, and each of the two last cases with four lumbar vertebræ has a pair of lumbar ribs attached to the first lumbar

vertebra. Practically, therefore, 8 out of 10 are abnormal according to the received formula for the gorilla. This of itself is sufficiently remarkable, and suggests that the so-called abnormal spines are in reality the normal ones. Examined in this light we find that, supposing the normal number of lumbar vertebræ in the gorilla to be three instead of four, then the cases in which four lumbar vertebræ are present resemble those cases in the human subject in which the first sacral vertebra has been released and added to the lumbar series. On the theory advanced in this paper of a rotation of the sacrum, with consequent lifting out of the pelvis of the first sacral vertebra, this condition in the gorilla is explained. For if the skeleton of the gorilla is examined, it will be noticed that this animal exhibits the high-standing promontory referred to above in a remarkable degree, the first piece of the sacrum standing up well out of the pelvis, and in a condition to be released from the articulation altogether. Apparently this has happened in those cases where the gorilla exhibits four lumbar vertebræ, and this is further borne out by finding that the normal six-pieced sacrum is reduced to five pieces in these instances.

In the case of the chimpanzee, in which four lumbar vertebræ are much more frequently the regular number than in the gorilla, it may be said that this has become normal, and that the occasional instances of only three lumbar vertebræ are a reversion to the original shorter condition such as still exists most commonly in the gorilla.

An interesting case has just been published by Dr Barclay-Smith of "Multiple Anomaly in a Vertebral Column." The spine is that of an ancient Egyptian woman, and it exhibits, amongst other things, a six-pieced sacrum of which the first piece is only attached to the general sacral mass on the right side, and has ceased to articulate with the ilium altogether. The pre-sacral region has the normal number of thoracic and lumbar vertebræ, so that the non-articulating first sacral piece is evidently derived from the sacrum. Dr Barclay-Smith suggests that, from the shape of the sacrum, "the pelvic brim was more or less circular in outline," and hazards a guess "that the pelvis was of an infantile type." It has already been shown in this communication that the six-pieced sacrum in women is frequently associated with characters which belong more commonly to the male, so that this case and the suggestion made in regard to the pelvis form an interesting contribution to the evidence already adduced to explain the cause of the variations in this region of the spinal column.

If the theory of Rosenberg—that a shortening of the vertebral column is going on—were correct, then we should expect to find frequently a six-pieced sacrum with only four lumbar vertebræ, the fifth having been taken up by the sacrum. But this is very uncommon as compared with the

number of cases of six-pieced sacra. In eleven male spines where I have noted the sacrum as consisting of six pieces, only two are recorded as being short of a lumbar vertebra, and one of these was a negro. In women, on the other hand, the reduction in the number of lumbar vertebræ is of more frequent occurrence. Dr Wood Jones has recorded two cases in Archaic Nubian women, and I have found three such cases in my notes, one of whom was a negress, and two belonged to an ancient race of Nubian people whom we know to have been strongly negroid.

I regard these cases as instances of reversion to an originally shorter condition of the lumbar region as illustrated in the anthropoids, and it is noteworthy that such an anomaly should be so much more frequent in women, in whom, as I have endeavoured to show, there has been less disturbance of the more primitive conditions, in assuming the erect attitude, than in men.

Struthers (5), in an examination of 17 adult gorillas, 13 males and 4 females, found that the so-called fourth lumbar vertebra was fused to the sacrum in 7 males and 1 female, while it was free in 6 males and 3 females. He speaks of the fusion as a synostosis, but it must be remembered that it is something very different from an ordinary synostosis such as may occur between vertebræ as the result of age or disease. This is evident from the whole character of the bone in question, which in these cases is not a lumbar vertebra fused to the sacrum, but a sacral vertebra in process of being released from the sacral mass and with all the characters of one of that series.

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