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ORIGINAL ARTICLE

Sexual Dimorphism and Regional Difference in Size of Sacrum: A Study in Eastern India

Sibani Mazumdar[1*], Ansuman Ray[1], ArdhenduMazumdar[2], SudeshnaMajumdar[1], AbhikSinha[3] and SanjoyVasisht[2]

[1]Department of Anatomy, Calcutta National Medical College, Kolkata, West Bengal, India, [2]Department of Physiology, Institute of Post Graduate Medical Education & Research, Kolkata, West Bengal, India and [3]Department of Community Medicine, Calcutta National Medical College, Kolkata, West Bengal, India

Abstract: *Objective:* To study the sexual dimorphism and regional differences of the varied features of the sacrum in eastern India and record the significant anthropometric indices of the study. *Background*: In the determination of personal individuality from adult human skeletal remains, the pelvis affords the best marked and reliable characteristics for distinguishing sex in 90-95% subjects. Since the sacrum is an integral element of the axial skeleton and contributes to the functional differences of the pelvic girdle between the two genders, it has a distinct medico-legal importance in ascertaining the sex by means of the anthropometric measurements observed upon it. *Materials and Methods:* 250 normal human adult sacra were acquired from the Departments of Anatomy and Anthropology under the different medical & science colleges in Kolkata, West Bengal, during the years 2004-2009 for the study of anthropometric measurements and sexual dimorphism. The measurements included length, width, curved length of the sacra, antero-posterior and transverse diameter of the first sacral vertebrae, sacral index, corporo-basal index etc. Demarking points [DP] for these parameters were used for identification of the sex of the sacrum. *Results:* The results of the present study were compared with previous studies for regional differences. The sacral index (44.7%) was found to be the most useful criterion metric data for identification of the female sacrum followed by curvature index (26.8%) while in case of the male sacrum, corporo-basal index (23.6%) was found to be most useful, followed by sacral index (9.4%) in this study. *Summary and Conclusion:* To study sexual dimorphism in human sacrum, 127 male and 123 female sacra were studied from Kolkata District, West Bengal. This study may have importance in Anatomy, Anthropology and Forensic Medicine.

Keywords: Sacrum; Sexual dimorphism; Sacral anthropometry; Sacral Index.

Introduction

The sacrum is a large, triangular fusion of five vertebrae and forms the postero-superior wall of the pelvic cavity, wedged between the two innominate bones (Standring et al, 2008) [1]. The Sacrum (L. *sacer*: sacred) supports the erect spine, provides the strength and stability of the bony pelvis to transmit the body weight and also allows considerable mobility in childbearing. The bones of the body are the last to perish after death, next to the enamel of teeth. Sex determination of skeletal material is of concern to anatomists, anthropologists, paleoanthropologists, paleodemographers and forensic scientists. (*Mishra et al,2003* [2] & *Sachdeva et al, 2011*) [3].

Sexual dimorphic characters can be studied both morphologically and metrically [3]. In the determination of personal individuality from adult human skeletal remains, the pelvis affords the best marked and reliable characteristics for distinguishing sex in 90% - 95% subjects [4][5]. The sacrum has always enjoyed the attention of medico-legal experts for establishing the sex due to its contribution to the pelvic girdle and associated sex differences which are augmented due to reproductive functions, mainly influenced by sex hormones [3]. The female sacra are shorter and wider, providing a wider pelvic cavity [1].

Sacral width, as a percentage of length, yields a *Sacral index* [1]. On the basis of this index, the sacrum can be divided into three groups (vide Wilder's manual of Anthropometry) [6]:

i) Dolichohieric: sacral index < 100 (up to 99.99)
ii) Sub- plathyhieric: sacral index is in between 100 -106.
iii) Plathyhieric: sacral index > 106.

India is a vast country with intermixing of races, and pure ethnic groups are often difficult to get. However, *Chand et al*. (*1995*) [7] suggested that India may be divided into four regions like north, south, west, and east for different study purpose on local population. Though, studies on the sacral anthropometry are available from other regions of the country, there is hardly any population specific data from the eastern part, except that by *Jana et al (1988)* [8] in the Burdwan region of West Bengal. Moreover*, Singh and Gangrade (1968)* [9] have reported that even within the same general population, mean value may be significantly different in bones from different zones. Therefore, the present work was conducted on the sacra of Kolkata district of West Bengal to observe the sexual and regional differences of the local population and compare the findings with similar observations across India.

Material and Methods

The sex classification of a bone is possible with a degree of certainty only when it can be compared to a series of bones of known sexual dimorphism [3]. *127 male and 123 female adult human sacra* were procured from the Department of Anatomy and Department of Anthropology under the different medical & science colleges in Kolkata, West Bengal, during the years 2004-2009 and studied for anthropometric measurements and sexual dimorphism. All the selected sacra were normal, fully mature and ossified, and devoid of any fractures or pathological changes. The methods of measurements, calculation of indices and statistical methods applied were same as used by *Raju et al.* (*1980*) [10]. The measurements included length, width, curved length, antero-posterior and transverse diameter of the first sacral vertebrae, sacral index, curvature index, corporo- basal index and alar index.

The Demarking Points [D.P.] suggested by *Jit and Singh (1966)* [11] were used for identification of sex of sacrum with 100% accuracy. For identification of male sacrum, the D.P. of a particular measurement was more than 3 S.D of the female mean value. Similarly, for identification of female sacrum, the D.P. of the same measurement was less than 3 S.D. of the male mean value.

The metrical data was recorded from each sacrum according to the method demonstrated in Wilder's manual of Anthropometry [6]. Vernier calipers and standardized flexible ribbon tape were used to measure the parameters to the precision of the nearest millimeter.

1. *Maximum length:* Maximum straight length was measured in millimeters up to the first decimal with the help of vernier calipers along the ventral mid-line of the sacrum from the middle of the antero-superior margin of promontory to the middle of antero-inferior margin of the last sacral vertebra.

2. *Maximum sacral width:* The maximum distance was noted in millimeters with the calipers by taking two points between the lateral most part of left and right ala of sacrum.

3. *Sacral mid-ventral curved length:* It was measured in millimeters by using the flexible ribbon tape along the ventral concave median length from the midpoint of sacral promontory to the midpoint of the apex of sacrum.

4. *Transverse diameter of the body of the First sacral vertebra [S1]:* The maximum width of the body of the first sacral vertebra was measured in millimeters with the measuring tape from the base of the sacrum, by taking the lateral most point on each side of the superior surface of the body of the 1st sacral vertebrae.

5. *Antero-posterior diameter of the body of the First sacral vertebra [S1]:* The maximum possible antero-posterior diameter of 1st sacral vertebra was measured in millimeters by taking one point on antero-superior border and another point on the postero-superior border of 1st sacral vertebral body.

6. *Sacral index:* Sacral index was calculated by assessing the breadth and length of individual sacrum with the help of vernier calipers and adopting the method demonstrated in practical Anthropometry. The stem of caliper was applied to the middle of promontory and middle of antero-inferior border of fifth sacral vertebra for the length and measurement of maximum breadth was taken across the greatest expanse of lateral masses of the bone.

$$\text{Sacral index} = \frac{\text{Sacral width}}{\text{Sacral ventral straight length}} \times 100$$

7. *Curvature Index:*

$$\text{Curvature Index} = \frac{\text{Ventral straight length}}{\text{Mid - ventral curved length}} \times 100$$

8. *Index for body of first sacral vertebra (S1):*

$$\text{S1 index} = \frac{\text{Antero-posterior diameter of body of S1}}{\text{Transverse diameter of body of S1}} \times 100$$

9. *Corporo-basal index:*

$$\text{Corporo-basal index} = \frac{\text{Transverse diameter of body of S1}}{\text{Width of sacrum}} \times 100$$

The Demarking Points [D.P.] of all the above parameters were calculated following the work of *Jit and Singh (1966)* [11] and percentage of bones identified by each parameter was worked out.

Figure-1: Maximum sacral width is being measured.

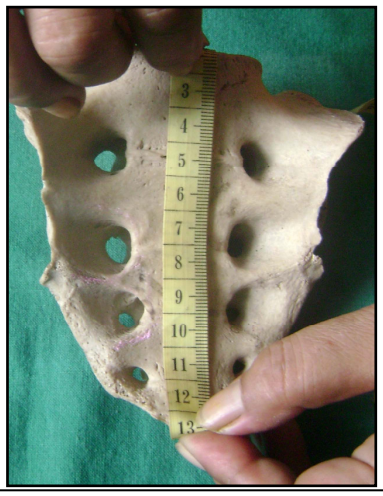

Figure-2: Sacrum midventral curved length is being measured.

Results

The mean, estimated range (Mean ± 3S.D), Demarking Points of various anthropometric parameters and the percentage of bones in which sex could be identified are shown in Table 1. The mean length, curved length, transverse and antero-posterior diameter of S1 vertebrae, curvature and corporo-basal indices were significantly higher in males as compared to that of females, while the width and the S1 index were comparable in both sexes. However, the sacral index was significantly higher in females as the female sacra are shorter and wider.

Table-1: Metric data of sacrum and the demarking points for The Various parameters for identification of sex in the present study

Parameter	Sex (N)	Degree Mean ± SD	Estimated Range	Demarking Point (DP)	Values beyond DP Number of cases %	
1	2	3	4	5	6	
Length (mm)	Male (127)	100.8 ± 11.5	66.3 – 135.3	>109.5	10/127	7.9
	Female (123)	87.3 ± 7.4	65.1 – 109.5	<66.3	0	0

1	2	3	4	5	6	
Width (mm)	Male (127)	96.3 ± 7.4	74.1 - 118.5	>112.7	0	0
	Female (123)	95.6 ± 5.7	78.5 - 112.7	<74.1	0	0
Curved Length (mm)	Male (127)	108.2 ± 6.7	92.0 -1 24.4	>119.4	4/127	3.1
	Female (123)	99.3 ± 7.4	79.2 - 119.4	<92.0	16/123	13
Transverse Diameter of S1(mm)	Male (127)	41.6 ± 8.5	16.1 – 67.1	>55.3	5/127	3.9
	Female (123)	39.7 ± 5.2	24.1 – 55.3	<16.1	0	0
Antero-posterior Diameter of S1(mm)	Male (127)	29.4 ± 3.8	18.0 - 40.8	>36.0	6/127	4.7
	Female (123)	27.9 ± 2.7	19.8 – 36.0	<18.0	0	0
Sacral Index	Male (127)	94.9 ± 4.8	80.5 – 109.3	<87.9	12/127	9.4
	Female (123)	109.8 ± 7.3	87.9 – 131.7	>109.3	55/123	44.7
Curvature Index	Male (127)	94.0 ± 2.7	85.9 – 102.1	>100.5	1/127	0.8
	Female (123)	87.9 ± 4.2	75.3 – 100.5	<85.9	33/127	26.8
S1 Index	Male (127)	71.6 ± 9.1	44.3 – 98.9	>88.1	3/127	2.4
	Female (123)	70.7 ± 5.8	53.3 – 88.1	<44.3	0	0
Corporo-Basal Index	Male (127)	43.8 ± 9.1	16.5 – 71.1	>51.6	30/127	23.6
	Female (123)	41.7 ± 3.3	31.8 – 51.6	<16.5	0	0

In this study the sacral index (44.7%) was found to be the most useful criterion for identification of female sacrum followed by curvature index (26.8%) and the curved length (13%). In the identification of male sacrum, corporo-basal index (23.6%) was found to be most useful, followed by the sacral index (9.4%) and length of the sacrum (7.9%).

Table 2 reflects the statistically significant gender differences in the present study. The length of the sacrum, antero-posterior diameter, sacral and curvature indices are highly significant in the determination of sex of the sacrum. Of these, the sacral index is of greatest significance and hence singularly most pertinent in the identification of the sex of the male and female sacra. In contrast, the width of the sacrum and SI index are non significant and hence least relevant in the sexual dimorphism of sacrum.

Table-2: Gender comparison of the different indices of sacrum		
Parameter	**Z Value**	**p Value**
Sacral Length	11.00	<0.001[HS]
Sacral Width	0.84	0.404[NS]
Curved Length (mm)	9.97	<0.001[HS]
Transverse Diameter of S1(mm)	2.12	0.035[S]
Antero-Posterior Diameter of S1(mm)	3.59	0.001[HS]
Sacral Index	19.13	<0.0001[HS]
Curvature Index	13.7	<0.001[HS]
S1 Index	0.93	0.35[NS]
Corporo-Basal Index	2.84	0.02 [S]
HS: Highly Significant S: Significant NS: Not Significant		

Discussion

In the present study, the maximum differences between the male and female sacra were observed in the measurements like curved length and length of the sacrum followed by the antero-posterior and transverse diameter of S1. Amongst the indices, the best was sacral index followed by curvature and corporo-basal index. Corporo-basal index was most useful for male bones while the sacral index was the best parameter for identification of female bones in this study. The present study showed that only 9.4% of male sacra and 45% of female sacra were identified by using the sacral index method, whereas 23.6% of male sacra and no female sacrum could be identified by using the Corporo-basal index [Vide table 1]. In males, the corporo-basal index was significantly lower in this study (43.8 ± 9) than the observations of *Chand et al, 1995* (45.8 ± 5.9) [7] and *Mishra et al, 2003 (*46.54 ± 3.17) [2] while it was comparable to that of *Raju et al*, *1980* (44.9 ± 4.6) [10].

The present study thus suggested that the sacral bones from the eastern part of the country were smaller among Indian sacral bones irrespective of the sex. The sacral index was significantly lower only in males while in females it was comparable to the North Indians values. According to *Raju et al,* the mean sacral index was 100.85 among males and it was 111.39 among females [10] whereas according to *Mishra et al,* the mean sacral index was 98.21 among males and it was 117.84 among females [2] in north India. The mean sacral index of the male sacra of the present series being 94.9 falls under Dolichohieric group (narrow sacrum with sacral index up to 99.9). Similar observations were reported by *Jana et al. (1988)* [8] in their study of sacra in Burdwan region of West Bengal and *Singh et al, 1988* [12] in the Jammu region. The mean sacral index of the female bone of the present series being 109.8 falls under Plathyhieric group (broad sacrum), which is similar to the observations of *Raju et al, 1980* [10] and *Davivongs, 1963*. [13] [Vide table 3]. All these measurements were taken in millimeters.

Table 3 shows a comparative analysis of the sacral index by independent researchers while Table 4 shows the comparative figures of two studies for the bones identified on the basis of Demarking Points. According to *Raju et al, 1980* [10], the length of the sacrum and the transverse diameter of S1 were the convincing parameters on the basis of which 43% and 40% of the male sacra could be identified. The figures were significantly higher than the figures of the present study where only 7.9% and 3.9% of the male sacra could be identified using the same parameters.

To be certain in identification, a calculated range is considered, which is worked out by adding and subtracting 3 X Standard Deviations (S.D) to and from the mean of any parameter [11]. *Jit and Singh* called the limiting point of such calculated range as Demarking Points [D.P.] [11] which can identify sex with 100% accuracy *(Rao,1962)* [14] from any given region *(Raju et al.1981)* [15]. *Mishra et al (2003)* conducted a study on sacrum in Agra region [2] and observed that 71.6% of male sacra and 80.1% of female sacra could be identified by Demarking Points of the parameters mentioned above. The Demarking points of various parameters, if crossed by any sacrum will identify the sex with certainty, which is of paramount importance in medico-legal cases [2].

Table-3: A Comparison of Sacral Index by Independent Researchers

Sl. No	Researcher (Year)	Male				Female				p value
		Sample Size	Mean	Range	S.D	Sample Size	Mean	Range	S.D	
1	2	3	4	5	6	7	8	9	10	11
1.	Martin [16] (1928) [Europe]	-	112.14	-	-	-	-	-	-	-
2.	Davivongs [13] (1963) [Australian Aborigines]	50	104.16	86.9-123.2	8.93	50	115.49	96.2-140	10.39	<0.001
3.	Flander [17] (1978) [American Blacks]	50	106.17	-	10.36	50	112.35	-	11.03	<0.01
	[American Whites]	50	106.49	-	10.40	50	108.69	-	13.59	Not Significant
4.	Raju et al. [10] (1980) [Varanasi]	33	100.85	74.72-126.9	8.71	11	111.39	88.38-134.4	7.67	<0.001
5.	Jana et al.[8] (1988) [Burdwan, WestBengal]	27	91.27	83.3-112.5	-	27	103.89	89.61-115.7	-	-
6.	Singh et al. [12] (1988) [Jammu]	26	94.32	76.3-110.94	-	12	104.81	95.77-113.85	-	-

1	2	3	4	5	6	7	8	9	10	11
7.	Mishra et al [2] (2003) [Agra]	74	98.21	90-108	4.89	42	117.84	103-131.25	7.00	<0.001
8.	Patel et al. [18] (2005) [Jamnagar]	32	96.25	90.5-106	4.6	32	113.25	104.8 - 131	5.74	<0.001
9.	Shilaja C.Math [5] (2006) [Gulbarga]	190	94.24	53.57-152	11.78	64	113.19	91.89-146.15	10.26	<0.001
10.	Aurora et al. [19] (2010) [Amritsar]	20	93.69	58.9-128.38	11.57	20	125.35	90.94-159.76	11.47	< 0.0001
11.	Present study [Kolkata, West Bengal]	127	94.9	80.5-109.3	4.8	123	109.8	87.9-131.7	7.3	<0.0001

Table 4: Comparative number and percentage of bones in which sex could be identified using demarking points as the parameter

Parameter	Sex	Present Study [Kolkata, West Bengal]	Raju Et Al.[1980] [Varanasi]
Sacral Length	M	10/127 [7.9%]	14/33(42.4%)
Sacral Width	M	00/127 [0.0%]	03/33(9.1%)
Transverse Diameter Of S1	M	05/127 [3.9%]	13/33(39.4%)
Antero-Posterior Diameter Of S1	M	06/127 [4.7%]*	0/33(0.0%)
S1 Index	M	03/127 [2.4%]	0/33(0.0%)
Sacral Index	M	12/127 [9.4%]***	0/33(0.0%)
	F	55/123 [44.7%]***	0/11(0.0%)
Corporo-Basal Index	M	30/127 [23.6%]**	02/33(6.1%)

Statistical comparison: Z test. *p< 0.05 **p < 0.01 ***p< 0.001

Except sacral index, no other parameter was useful in identifying female sacrum.

Summary and Conclusion

To study sexual dimorphism in human sacrum, 127 male and 123 female sacra were studied from the Kolkata District, West Bengal. The observed parameters and indices were subjected to standard statistical methods, and compared with other similar regional studies, to principally conclude that the sacral bones from the eastern part of the country were smaller irrespective of the sex. The maximum differences between the male and female sacra were observed in the measurements like curved length and length of the sacrum followed by the antero -posterior and transverse diameters of S1.

Amongst the indices, the sacral index was the best parameter for identification of female bones while corporo-basal index was most useful for male bones in this study. Regional studies are constructive in the observation of the anthropometric trends that may be influenced by environmental, racial and genetic factors of the region and have immense importance in Forensic Medicine and Anthropology in addition to Anatomy.

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*All correspondences to: Prof. Sibani Mazumdar. C-29 Green Park, 151, North Purbachal Road, Kolkata-700078, West Bengal. E mail: drsibanimazumdar@gmail.com