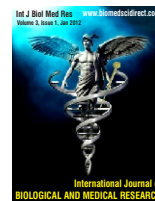Contents lists available at BioMedSciDirect Publications

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Original article

Morphometric study of Sexual dimorphism in adult sacra of South Indian population

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A R T I C L E   I N F O

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A B S T R A C T

Sex determination is the first step in the development of a biological profile in human osteology as methods to estimate other components of the profile depend on sex. In the present study certain morphometric parameters of sacrum viz Maximum length of sacrum, Maximum breadth (width) of sacrum, Mid-ventral curved length, Transverse diameter of the first sacral body, Antero-posterior diameter of the body of first sacral body, Length of ala, Maximum length of auricular surface were measured and indices viz Sacral index, Curvature index, Corporo-basal index, Alar index, Index of body of S1, Auricular index were calculated and statistically analyzed. Among the measurements recorded the parameters of Maximum breadth (width) of sacrum, Mid-ventral curved length, Antero-posterior diameter of the body of first sacral body, Length of ala, sacral index, alar index, were found to be statistically significant. Among these parameters the width of sacrum, curved length of sacrum were reliable for sex differentiation. It was also noted that no single parameter could identify 100% sex of the bones. Therefore, it can be concluded that for determination of sex of sacrum, maximum number of parameters should be taken into consideration for 100% accuracy.

1.Introduction:

Determination of sex is an integral first step in the development of the biological profile in human osteology. Sex determination is necessary to make age, ancestry and stature estimations, as the sex's age differently, exhibit some degree of variation in ancestry-related morphology and generally differ in height [1].

The accurate estimation of the sex of a skeletonized human is important to Forensic Anthropologists, Bio-archaeologists, and Anatomists [2, 3].

Nearly every region and element of the skeleton has been used to develop methods for sex estimation with varying degrees of success. The general anatomical regions used for sex determination are the pelvic girdle, skull and long bones, although other bones have also been utilized.

The skull is somewhat less reliable for use in determining sex, ranging between 80 and 90 percent accuracy [4]. The pelvic girdle is the most accurate area to determine sex and methods using the pelvic girdle tend to make successful predictions in 90 to 95 percent of individuals [5]. Sexual dimorphism in this area is mainly due to the changes that occur during adolescence to meet the requirements of childbirth in females [6].

The sacrum has always attracted the attention of the medico-legal experts for establishing its sex, because of its contribution to pelvic girdle and associated functional sex differences. Thus sacrum assumes applied importance in determining sex with the help of measurements carried upon it [7].

Though sacrum is considered to be an important bone for dealing with sex differences in skeleton, there is a real shortage of metrical data in the literature. The present study was undertaken to study the morphometric sex differences in the South Indian sacra and to provide a baseline data for the same.

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2.Material and Method:

The material for the present study consists of 81 adult intact human sacra of unknown sex. They were collected from the Department of Anatomy, Sri Venkateswara Institute of Medical Sciences, Tirupathi, Anthropology Department of S.V.University, Tirupathi, Sri Venkateswara Medical College, Tirupathi, Kurnool Govt. Medical College, Kurnool, Sri Sathya Sai Medical College& Research Institute, Chennai.

The measurements were done on intact parts of normal bones. Bones showing wear and tear, fracture or pathology and any variations were not considered. Instruments that were used in this study are measuring tape and Vernier sliding calipers. Each linear recording was taken to the nearest millimeter. The details of the parameters taken are as follows:

1. Maximum length: It measures the straight distance from sacral promontory in the mid sagittal plane to the corresponding lowest point on the anterior margin of the sacrum.

2. Maximum Width: This was measured by taking two points at the upper part of auricular surface anteriorly or lateral most part of alae of sacrum.

3. Curved length of sacrum (mid-ventral curve length) (CLS): Measured along the midline of the pelvic surface of the sacrum from middle of antero-superior margin of promontory to middle of antero-inferior margin of the last sacral vertebra with the help of a flexible steel tape.

4. Antero-posterior diameter of the body of first sacral vertebra (APD.S1): It is the maximum possible diameter of body of first sacral vertebra taking one point on the antero-superior border and other on the poster superior border.

5. Transverse diameter of the body of first sacral vertebra (TD.S1): This was measured with the help of sliding calipers by taking a point on each side using the lateral most point on the superior surface of body of first sacral vertebra.

6. Length of alae (AL): It is measured on both sides by taking one point on lateral most point of superior surface of body of first sacral body and another point on lateral most point of ala. The mean of the length of two sides is taken as the length of ala of that vertebra and the measurement was taken using a sliding calipers.

7. Maximum length of auricular surface (ASL): This is the straight auricular length measured on lateral aspect of sacrum. For the purpose of recording this measurement, two points are plotted, one on the upper most part of auricular surface and another on its lower most part; these were marked and the measurement was taken using a sliding calipers.

The above measurements were used for calculating the following indices:

8. Sacral index: - $\dfrac{\text{Maximum width X 100}}{\text{Maximum length}}$

9. Curvature index: - $\dfrac{\text{Maximum length X 100}}{\text{Mid-ventral curved length}}$

10. Corpora-basal index: - $\dfrac{\text{TD.S1 X 100}}{\text{Width of sacrum}}$

11. Alar index: - $\dfrac{\text{Length of ala (AL) X 100}}{\text{TD.S1}}$

12. Index of body of S1: - $\dfrac{\text{APD.S1 X 100}}{\text{TD.S1}}$

13. Auricular index: - $\dfrac{\text{Length of auricular surface (ASL) X 100}}{\text{Width of sacrum}}$

Mean ± S.D. is given for quantitative variables, frequencies and percentage is given for qualitative variables. Two independent sample't' test was applied to check group mean differences. A p-value of <0.05 was considered as statistically significant.

3. Result

For all the studied parameters, the mean, standard deviation, range and 95% confidence intervals of mean in both the sexes are depicted in Table no 1. To this independent Student's t-test for equality of means was applied and "t" and "p"-values were calculated to find out the significant differences between the means for the two sexes.

While studying the mean values of all parameters of sacra, it was observed that Curved length of sacrum, T.D Of body of S1 are higher in males and A.P diameter of S1, length of sacrum, width of sacrum, length of auricular surface, length of ala of sacrum are higher in females. Among the indices sacral index, alar index and index of body S1 are higher in the females and curvature index, corpora-basal index, auricular index are higher in males. Comparison of mean values of males and females obtained in the present study were compared with those reported in the literature as shown in table 2.

4. Discussion

In the present study an attempt has been made to find the sex of 81 adult sacra of unknown sex with the available data in relation to the various parameters. The parameters have been selected from the literature available in the standard text-books of Anatomy and published articles. In these articles the study was on identification of validity of the parameters in the sacra of known sex. The values obtained in the present study on various sacral parameters were compared with those reported in the literature in Varanasi population of India [8], Agra population of India [9], North Indian population [10] and on Australian aborigines [11] in (table 2).

1. The mean length of male sacra obtained in the present study (Table.2) is higher than that reported in Australian aborigines [11] and lower than that reported in Northern part of India by various authors [8-10].The mean length of female sacra obtained in the present study is higher than that reported in Australian aborigines [11] and in North Indians [8-10].

Table.1: Mean, SD and Discriminant functions of different variables

Parameters	Sex	Range	Mean	Sd	T – value	P – value
AP Diameter Body S1(mm)	Male	24-34	2.95	0.22	2.1891	0.0315*
	Female	21-41	3.11	0.42		
Transverse Diameter Body S1(mm)	Male	34-55	4.46	0.52	1.9134	0.0593
	Female	33-62	4.72	0.71		
length of sacrum	Male	34-55	9.85	1.14	0.5947	0.5538
	Female	75-129	10.01	1.22		
Width of sacrum	Male	91-116	10.11	0.48	6.9222	0.0001**
	Female	95-115	10.82	0.43		
Curved length of sacrum	Male	87-134	11.25	1.18	1.7295	0.0001**
	Female	95-118	10.52	0.51		
Length of auricular surface	Male	45-68	5.37	0.59	1.7318	0.0872
	Female	42-78	5.63	0.77		
Length of ala of sacrum	Male	45-20	3.19	0.44	2.9065	0.0047*
	Female	20-53	3.59	11.53		
Sacral index	Male	81-136	104.08	16.50	3.7310	0.0004*
	Female	85-146	115.72	13.64		
Curvature index	Male	82-106	90.56	5.01	1.7841	0.0783
	Female	77-95	88.66	4.45		
Corpobasal index	Male	37-55	44.15	5.31	0.1059	0.919
	Female	30-58	44.00	7.41		
Alar index	Male	47-93	71.31	12.10	2.3878	0.0193*
	Female	35-112	80.21	20.97		
Index of body of S1	Male	55-81	66.79	7.31	0.0223	0.9823
	Female	41-86	66.75	8.83		
Auricular index	Male	44-89	55.82	8.71	1.5916	0.1141
	Female	40-76	52.77	8.31		

Table.2: Comparison of means for various parameters of sacrum reported in the literature.

Parameters	Sex	Davivongs (1963) Australian Aborigines	Mishra et al (2003) Agra	Singh et al (1972) Varanasi	Kanika et al (2011) North India	Present study
AP Diameter Body S1(mm)	Male	29.7	30.04	30.30	31.5	29.50
	Female	27.5	29.29	27.63	28.5	31.19
Transverse Diameter Body S1(mm)	Male	47.4	49.12	47.33	47.6	44.62
	Female	44.1	42.81	42.18	45.5	42.27
length of sacrum	Male	96.52	107.53	104.96	104.1	98.53
	Female	88.12	90.58	92.72	91.8	100.16
Width of sacrum	Male	99.92	105.34	105.33	103.1	101.13
	Female	101.24	105.79	103	101.7	108.13
Curved length of sacrum	Male	104.3	119.56	112.75	113.5	112.51
	Female	97.1	100.95	104.81	104.5	105.25
Length of auricular surface	Male	-	62.54	-	-	53.75
	Female	-	54.57	-	-	56.38
Length of ala of sacrum	Male	-	28.38	-	33.5	31.95
	Female	-	31.67	-	30.0	35.97
Sacral index	Male	104.16	98.21	100.85	100.24	104.08
	Female	115.49	117.84	113.39	111.74	115.72
Curvature index	Male	92.46	95.72	92.77	91.59	90.56
	Female	90.80	90.72	88.51	87.87	88.66
Corpobasal index	Male	47.42	46.54	44.94	43.42	44.15
	Female	43.62	40.47	40.96	43.84	44
Alar index	Male	-	62	-	-	71.39
	Female	-	62	-	-	71.39
Index of body of S1	Male	63.03	61.73	64.42	-	65.75
	Female	62.84	68.60	65.52	-	69.33
Auricular index	Male	-	59.78	-	-	55.82
	Female	-	51.69	-	-	52.77

Table.3: Comparative study of sacral index between male and female sexes in present study with previous studies.

| Investigators | Male | | | | Male | | | | S.S.D. |
	No	mean	Range	S.D.	No	mean	Range	S.D.	P.
Martin (1928)	-	112.14	-	-	-		-	-	-
Grays Anatomy (1954)	-	105	86.9-123.2	8.93	50	115.49	96.2-140	10.39	<0.001
Davivong (1963)	50	104.16	86.9-123.2	8.93	50	115.49	96.2-140	10.39	<0.001
Flander (1978)									
White	50	106.49	-	10.40	50	108.69	-	13.59	N.S.
Black	50	106.17	-	10.36	50	112.35	-	11.03	<0.01
Raju et al (1980)	33	100.85	74.72-126.9	8.71	11	111.39	88.38-134.4	7.67	<0.001
Budge (1981)	65	94.75	80.2-114	7.15	30	112.05	90.8-133.3	10.9	<0.001
Vinod Kumar et al (1984)	-	91.27	-	-	-	103.89	-	-	-
Jana et al (1988)	-	91.27	83.3-(1987)	-	-	103.89	89.61-115.7	-	-
Singh et al (1988)	26	94.32	76.3-110.94	-	12	104.81	95.77-113.85	-	-
S.S.Dapate (1997)	117	94.58	77.27-118.42	6.96	83	104.27	85.0-136.36	10.675	0.05
Kanika et al (2011)	40	100.24	78.04 -149.56	12.54	10	111.74	88.79 -140.48	14.6	0.016*
Mishra et al Agra (2003)	74	98.21	90-108	4.89	42	117.84	103-131.25	7.00	<0.001
Shilaja c math (2006),	190	94.24	53.57-152	11.78	64	113.19	91.89- 146.15	10.26	<0.001
GulbargaAurora et al. (2010),	20	93.69	58.9-128.38	11.57	20	125.35	90.94- 159.76	11.47	<0.001
Amritsar	32	96.25	90.5-106	4.6	32	113.25	104.8- 131	5.74	<0.001
Patel et al(2005), Jamnagar									
Present study	81	104.84	81-136	16.50	64	115.72	85-146	13.64	<0.0004

Table. 4: Grouping of sacra by sacral index

Classification	Range	Male	Female
Dolichohierisch (narrow)	<99.9	17	7
Hyplatyhierisch (medium)	100-105.9	10	3
Platyhierisch (broad)	>106	18	26

2. The mean width of male and female sacra obtained in the present study is (Table.2) is higher than that reported in Australian aborigines [11] and lower than that reported in North Indians [8-10]. The difference between the sexes is lower and some values are higher in the present study when compared to that of Agra population and North Indian populations where the difference was minimal between the male and female sexes (Table. 2).

3. The mean curvilinear length for male sacra obtained in the present study (Table.2) was low compared to the Agra region and minutely lower than Varanasi region and north Indian population and higher than that of the Australian aborigines [11].The mean curvilinear length for female sacra in the present study is (Table 2) high when compared to the North Indian population and Australian aborigines. This difference is also highly significant, statistically (p<0.01).

4. The mean T.D of S1 for male sacra in the present study (Table 2) is lower and that of female sacra is higher when compared to the values in the Australian aborigines [8], and in North Indian population [8-10].

5. The mean AP diameter of S1 in male sacra observed in the present study is slightly in conformity with the Australian aborigines [11] and Agra, Varanasi, North Indian studies [8-10] (table 2).The mean AP diameter of S1 in female sacra observed in the present study were high compared to the Australian aborigines [11] and Agra, Varanasi, North Indian studies [8-10] (table 2).

6. The mean alar length in male sacra in the present study is high compared to the Agra region [9], low compared to the North Indian population [10] (table 2). The mean alar lengths in female sacra observed in the present study are higher than that reported in North Indian population [9,10]. Statistically also these parameter are highly significant. (p<0.05).

7. The mean length of auricular surface of male sacra in the present study (Table 2) is low compared to the Agra region [9]. The mean length of auricular surface in female sacra in the present study is high when compared to the Agra region [9].

8. The mean sacral index in male sacra observed in present study are compared with those reported in the literature by various authors in different populations is represented in table.3. The values observed in the present study are higher than that of values reported in the literature of Patel et al [7], Mishra and Singh in Agra and Varanasi regions [8,9], Kanika et al [10], Raju et al [12], Vinod Kumar et al [13], Jana et al in region of Burudhwan [14], Depate et al

[15], Budge [16], Shailaja c Math [17], Aurora et al [18], and minutely lower than that of Australian aborigines [11], Flander in whites and in blacks [19], lower than that reported in text-books Gray's Anatomy [20], Martin [21]. Sacra with sacral index <100 are considered to be grouped as Dolichohierisch group and if >106 they belong to platyhieric group (Table.4).

The comparison of values of sacral index in male in the Patel et al [7], Mishra in Agra [9], Vinod Kumar et al [13], Jana et al in region of Buderdhwan [14-18], comes under Dolichohierisch group (value is <100), Flanders in Whites and Blacks [16] comes under Hyplatyhierisch group [between 100-105.9] and in Davivongs in Australian aborigines [11], Kanika et al [10], Raju et al [12]and present study comes under Platyhierisch group[>106] (Table.3).

The mean sacral index in female sacra in Agra region [9] is 117.84, by Singh [6] is 104.81, in Varanasi region is[8] 104.8, in Australian aborigine[8] is115.49, by Gray's Anatomy [20] is 115.49, by Flanders [19] in whites is 108.69 and in blacks is 112.35, by Raju et al [12] is 113.39, by Budge [16] is 112.05, by Vinod Kumar et al [13] is 103.89, by Jana et al [14] is 103.89, by S.S.Dapate [15] is 104.27 and by Kanika et al [10] is 111.74. Whereas in the present study it is 115.72 (Table 2 and 3) that were low compared to the Mishra in Agra region [9] and Aurora et al [18]. But, it is higher than that reported in the Patel et al [7], Australian aborigines [11], Varanasi region of Indian population [8], Kanika et al [10] Raju et al [12], Vinod Kumar et al [13], Jana et al in region of Buderdhwan [14], S.S Depate et al [15], Flanders in Whites and Blacks [19], by Gray's Anatomy [20] and Shailaja c Math [17]. The male sacra show a mean sacral index of 104.08 that is low when compared to female sacra that show a mean sacral index of 115.72 in the present study. Even in the present study the difference between male and female values is very significant (p<0.04).

In females Singh et al [6], Vinod Kumar et al [13], Jana et al in region of Buderdhwan [14], S.S Depate et al [15] comes under Hyplatyhierisch group (values in the range of 100-105.9). Patel et al [7],[9-12],[16-19] and present study comes under Platyhierisch group(>106) (Table 3).

9. The mean curvature index in male sacra observed in the present study is lower than that reported in Australian aborigines [11] and in North Indian population [8,9] (Table 2).The mean curvature indices in female sacra in the present study are slightly coinciding with the observations in the Varanasi region and lower to the values of Agra region [8], Australian aboregeions [11] and higher than North Indian population [10].

10. The mean corpora-basal index in male sacra observed in the present study is lower than the values of Australian aboregeions [11], Varanasi and Agra populations [9, 10], and higher than the values of North India [10]. The mean corpora-basal index in female sacra observed in the present study is higher than that reported in Australian aboregeions [11], North Indian population [8-10].

11. The mean index of S1 in male and female sacra observed in the present study (Table 2) is higher than that reports in Australian aborigines [11] and in Agra and Varanasi regions [8,9] of India.

12. The mean alar index of male and female sacra observed in the present study is higher than the result of Varanasi region [8] (Table 2). This is statistically highly significant (p<0.05).

13. The mean auricular index in male sacra observed in the present study is lower than the values noted in the Agra region [9].The mean auricular index of female sacra in the present studyis higher than that of values in Agra region [9]. The male sacra show a mean auricular index of 55.82 that is higher compared to the female sacra that show a mean of 52.77 in the present study.

5. Summary and Conclusion

Sacrum is one of the bones that exhibit sex differences, hence used in identification of sex from skeletal remains. In these studies sacra of known sex were selected and parameters noted. Then the validity of these was tested by various measures. In the present study an attempt has been made to test the validity of parameters in sacra of unknown sex. In the present study on sacra, various parameters have been taken and elaborately analyzed to find the significance of the parameters in identifying sex of an unknown sacrum. Some of these parameters have been found very useful which include maximum anteroposterior diameter of body of S1, width of sacrum, curvilinear length, length of ala, sacral index, and alar index. They are also statistically significant. Some more methods and parameters have to be studied so that identification in unknown sacra is easier.

The important conclusions that can be drawn are as follows:

1. In a typical sacra sex could be identified with 95% accuracy using maximum anteroposterior diameter of first sacral vertebra, width of sacrum, curved length of sacrum, length of ala, sacral index, alar index and auricular index.

2. Among the remaining parameters the accuracy is less than 90%. They are not statistically significant.

3. The range and mean of most parameters coincide or correlates with values of previous Studies by other authors.

4. For 100% accuracy of the estimation of sex, some more parameters are needed.

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