International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

An Anthropometric Analysis of Dry Human Sacrum: Gender Discrimination

Anil Kumar[1], Nitin Vishwakarma[2]

[1, 2] Department of Human Structure and Neurobiology, Oman Medical College affiliated with West Virginia University (USA), Sohar, Sultanate of Oman

Abstract: ***Sacrum is a part of axial skeleton and has long been held as a bone which is highly sexually dimorphic. In the present study 43 dry human sacra were subjected to anthropometric analysis to study the gender difference. The measurements taken were tabulated and analyzed statistically. Sacral index, Curvature index, Corpobasal index and Index of first sacral vertebra were calculated. The results of present study were compared with previous studies. The sacral index was found to most useful parameter to establish the sexual identity of the bone. The values obtained in the present study can be a useful guideline for sex identification in cases of forensic investigations.***

Keywords: Sacrum, Sacral Index, Anthropometry, Sexual dimorphism, Pelvic girdle.

1. Introduction

The sacrum meaning "sacred/ holy bone" is a part of the pelvic girdle, reflecting its sexual dimorphism[1,2]. The sacrum is a large, triangular fusion of five vertebrae and forms the posterosuperior wall of the pelvic cavity, wedged between the two innominate bones[3]. Neuroradiologists study the sacrum as a continuation of the spinal axis whereas pediatric radiologists evaluate the sacrum as part of the skeletal system and cross-sectional abdominal radiologists often assess the sacrum as a posterior border of the pelvis[4]. Morphometric estimation of sex from the pelvic bones becomes particularly important when dealing with incomplete or fragmented remains or cases where the morphology is ambiguous[5]. In forensic or archaeological context estimation of sex is a very important step in the identification of any human skeletal remains discovered. Taylor stated in his book of medical jurisprudence that the accuracy of estimating the sex from skeletal remains depends upon number of bones available. He reported accuracy of estimating the sex from Skull and Femur is 97.35%, Coccyx and Sacrum is 97.18 % whereas with the Pelvis 95 %, Skull alone 91.38 %, Femur 39.84 %, Atlas vertebra 31.18% [6].

Davivongs (1963) pointed out that as a general rule male bones are more massive and heavier than female bones[7]. The female sacra are shorter and wider, providing a wider pelvic cavity[3] .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. Numerous indices have been reported to determine sex of sacra but of it none have proved to effectively & singularly differentiate sex. Hence is advised to not rely on a single index but use maximum possible indices to determine sex of sacrum[8]. Several authors have studied sexual dimorphism wherein sacra of known sex were selected and the validity of the parameters was verified[8,9]. Morphometry in dry human sacrum is better than the radiograph because it eliminates measurement limitations of conventional radiographs, such as variability in the film–focus distance, rotation of the spine and parallax effect[10].

Though sacrum is often considered to be an important bone while dealing with sex differences in skeletal material, yet there is a dearth of information of metrical data available for this bone. The present study was undertaken to find out similarities and differences in the metrical values of different sacral parameters in males and females and also to highlight the best parameter that could be used to study sexual dimorphism of sacrum.

2. Material and Methods

In the present study, dry human sacra of known sex, were procured from the collection of human bones in the Department of Human Structure and Neurobiology, Oman Medical College. A total of 43 sacra were studied out of which 21 were of male and 22 of female. All the sacra were normal, fully mature, devoid of any fractures or damages. These sacra were subjected to a series of measurements following the procedures laid down in Wilder's Manual of Anthropometry[11]. A stainless steel sliding Vernier caliper with a sensitivity of 0.01 mm, was used for linear measurements and flexible steel tape was used for measuring curved ventral surface. The measurements were done twice at different times by both the authors separately to nullify the intra-observer error.

Following measurements were done as shown in Figure 1:

1) Mid-ventral straight length (AB): Maximum straight length was measured along the ventral mid-line, from the middle of sacral promontory to the middle of anterior margin of the last sacral vertebra (Figure 1a).
2) Ventral straight breadth (CD): It is the maximum linear distance across the ventral surface of first sacral vertebra between the margins of lateral wings (Figure 1a).
3) Mid-ventral curved length (EF): It was measured by using the flexible stainless steel tape along the ventral surface of sacrum from the midpoint of sacral promontory to the midpoint of the anterior margin of the last sacral vertebra (Figure 1b).
4) Transverse diameter of the body of the First sacral vertebra [S1] (GH): The maximum width of the body of the first sacral vertebra was measured by taking the

lateral most point on each side of the superior surface of the body of the 1st sacral vertebra (Figure 1C).
5) Antero-posterior diameter of the body of the First sacral vertebra [S1] (IJ): It is the distance between the sacral promontory and posterior border of body of first sacral vertebra in the midline (Figure 1c).
6) Transverse diameter of Base (KL): It is the maximum transverse width of the superior surface of sacrum, comprising the two alae (Figure 1d).

Using the above measurements, three indices were calculated using the following formulae:
1) Sacral Index = Ventral straight breadth X 100/ Mid-ventral straight length
2) Curvature Index= Mid-ventral straight length X 100/ Mid-ventral curved length
3) Corporobasal Index = Transverse diameter of body of S1 X 100/ Transverse diameter of base
4) Index of body of first sacral (S1) vertebra= Antero-posterior diameter of body of S1X 100/ Transverse diameter of body of S1

All the data was collected, tabulated and subjected to statistical analysis. Data was analyzed using SPSS 17.0 program. The mean, standard deviation, standard error and 95% confidence intervals of means were calculated for all the parameters. Unpaired't' test was used as the test of significance to test the difference in means between males and females at an alpha of 0.01. The t-value and p-value were calculated to know the significance of difference of means.

3. Result

For all the studied measurements, the range, mean, standard deviation, t-value and p-value are shown in the Table 1. It was found that mean values of all measurements were higher in males except ventral straight breadth and transverse diameter of base. The difference of means for mid-ventral straight length, ventral straight breadth, transverse diameter of base were found to be extremely significant, while for mid-ventral curved length was very significant (P- value = 0.0019). The differences of means for transverse and antero-posterior diameters of body of S1 were not statistically significant (Table 1).

The indices of sacrum were calculated on the basis of measurements and standard deviation, t-value and p-value were calculated (Table 2). It was found that for all the indices the difference of means is extremely significant except index of first sacral vertebra (S 1) which is statistically non-significant as shown in the Table 2.

4. Discussion

The various parameters of the sacrum have been studied and attempt has been made to become useful to anesthesiologist in caudal epidural anesthesia, orthopedic surgeries to do the screw fixation surgeries in different cases by knowing the anatomical variation in the parameters taken in this study. The present study showed that most of the values for parameters like sacral index, index of first sacral vertebra, ventral straight breadth and transverse diameter of base of sacrum were higher in female whereas other parameters like mid-ventral straight length, mid-ventral curved length of sacrum and diameters of first sacral vertebra were higher in male. It was found in this study that both Curvature index and Corpobasal index of the sacrum were more in males in all the population groups. Hence comparison of parameters and indices of sacrum for present study with the studies of other authors has been shown in Table 4 and 5 which clearly depict the existence of regional and racial difference in the parameters and indices of sacrum.

Devivongs (1963) in his study of Australian aboriginal sacra has reported comparatively less mean mid-ventral length of sacrum than the present study, which indicates there is a regional and racial difference in the length of sacrum[7]. Comas & Charles (1960) reported a wide sexual dimorphic variation of sacra in the Chinese, Negroes and Bushmen[27]. Snell reported that sacrum of females is usually wider in proportion to its length than that of males[28]. According to Frazer (1933), female bone is broader than the male and shows a different curve anteriorly; in females, it is marked sharply at the lower part but in males, the curve is more or less uniform from above downward[29]. Reduced sacral curvature, along with posterior angulation of the sacrum, serves to enlarge the female pelvic outlet for childbirth. Therefore, the posterior angulation of the sacrum might be a reliable indicator of sex[30]. The range of the mid-ventral curved length of female sacra falls within the male range in the present study. Similar findings were seen in the sacra studied by Davivongs (1963), Raju et al (1980), Singh et al (1988), Mishra et al (2003), Sachdeva et al (2011). The sacrum is more curved in men than in women[31].

In modern Greeks, dimensions of the sacrum, including its anterior length, anterior straight breadth and maximum mid ventral breadth of first sacral vertebra (S1) were not very dimorphic[32]. Hegazy (2013) observed in his study that the body of the first sacral vertebra (S1) is a good bone for sex assessment[33]. In the present study, the mean transverse diameter of body of S1 of male was higher than that of females. Also the first sacral vertebra (S1) was shown to be sexually dimorphic in all of the investigated dimensions and indices but the mean difference between the sexes was statistically non-significant. Similar findings reported by Flander (1978), Mishra et al (2003) and Poornima et al (2012) who demonstrated that the body of S1 is significantly wider in males than in females. Başaloğlu et al, in their study on dry bones, reported a slight difference ($P > 0.05$) in anteroposterior diameter measurements between males (mean: 32mm) and females (mean: 30mm). This small difference is consistent with that recorded in the present study, males (mean: 30.6mm) and females (mean: 30.5mm) [34]. Present study showed that index of first sacral vertebra was higher in females compared with males whereas Snell reported it was lower in females compared with males[28].

In this study the curvature index was more in males as compared to females; similar findings are reported in all the population groups shown in table 5. The mean difference in the present study was statistically significant. Davivongs (1963) stated that the higher values of this index in males are indicative of a more pronounced anterior surface of female sacrum[7].

Corpobasal index was more in males as compared to the females in the present study, which is supported by the previous studies compared in table 5. Corpobasal index is directly proportional to transverse diameter of body of S1, and inversely proportional to the transverse diameter of base of sacrum, thus mounting to higher values for the index in males of the present study.

Baptist et al (2008) stated that the well-known method for determination of male or female type of sacrum has always ideally been the Sacral Index method[35]. The present study showed that the difference between male and female average Sacral Index was extremely statistically significant ($p<0.001$). It has been observed that sacral index in females is more than in males among different races (Table 5). Sacral index can be used with 95% accuracy in identification of sex [40]. Hence sacral index stands as reliable and important criteria for sex determination of sacrum.

5. Conclusion

The present study indicates significant sexual dimorphism exist in these parameters. These parameters should be taken into consideration during surgical procedures. Morphometric analysis of Sacrum can be used as supportive findings in estimation of sex of fragmented, incomplete or damaged dry human skulls. The knowledge of morphometry of sacrum is important for Neurosurgeons, Anesthetist, Radiologist, Forensic scientist, Paleoanthropologist as well as Paleodemographers. Data were available to test the validity of the parameters studied to identify the sex of sacra. The authors recommend future studies with larger sample size.

6. Conflict of Interest

None of the authors has conflict of interest to declare. No source of support in form of grants.

7. Ethical Approval

This study was approved by the Institutional Review Board (IRB) of Oman medical college. The Institutional Review Board (IRB) registration number is OMC/IRRB/2015/006/C

8. Acknowledgement

We acknowledge and thankful for the support provided by the Oman Medical College, Al- Tareef, Sohar, sultanate of Oman.

References

[1] Sugar O. How the sacrum got its name. JAMA. 1987; 257(15):2061-3.
[2] Gómez-Valdés JA, Ramírez GT, Molgado SB, Sain-Leu PH, Caballero CJL, Sánchez-Mejorada G. Discriminant function analysis for sex assessment in pelvic girdle bones: Sample from the contemporary Mexican population. J Forensic Sci., 2011; 56(2):297–301.
[3] Standring S, Newell RLM, Collins P, Healy JC, Mahadevan V. In The Back & Pelvic Girdle, Gluteal Region and Thigh. In: Gray's Anatomy, The Anatomical Basis of Clinical Practice. 40th Edition. Spain, Churchill Livingstone Elsevier. 2008; 724 & 1349.
[4] Jack Diel, Orlando Ortiz, Richard A. Losada, Donald B. Price, Michael W. Hayt, Douglas S. Katz. The Sacrum: Pathologic spectrum, multimodality imaging, and subspecialty approach. Radiographics. 2001; 21(1):83-104.
[5] Patriquin ML, Steyn M, Loth SR. Metric analysis of sex differences in South African black and white pelvis. Forensic Sci. Int., 2005; 147:119–27.
[6] Math Shailaja C, Nandyal VB, Shetty Vinay B, Pawar Jayashree D, Rajkumar KR. Study of sexual dimorphism in human sacrum-in North Karnataka. Indian journal of forensic medicine and pathology. 2010; 3(1):13-19.
[7] Davivongs V. The pelvic girdle of the Australian Aborigine; sex differences and sex determination. Am J Phys Anthropol., 1963; 21:443-56.
[8] Raju PB, Singh S, Padmanabhan R. Sex determination and sacrum. Journal of anatomical society of India. 1980; 30(1):13-15.
[9] Krogmann W. M. In the Human Skeleton in Forensic medicine. Thomas Springfield (Ellinois); 1962.
[10] Cyteval C, Thomas E, Picot MC, Derieffy P, Blotman F, Taourel P. Normal Vertebral Body Dimensions: A new measurement method using MRI. Osteoporos Int., 2002; 13:468–73.
[11] Wilder, H.H. A laboratory manual of anthropometry. P. Blakistons sons & Co. Philadelphia. 1920: 193.
[12] Krogmann W. M. In the Human Skeleton in Forensic medicine. Thomas Springfield (Ellinois); 1962.
[13] Arora AK, Gupta P, Mahajan S, Kapoor SS. Significance of sacral index in estimation of sex in sacra of cadavers in Punjab. J. Indian Acad Forensic Med., 2010; 32(2): 104- 107.
[14] Sachdeva K, Singla RK, Kalsey G, Sharma G. Role of sacrum in sexual dimorphism – A morphometric study. J Indian Acad Forensic Med., 2011; 33(3):206-210.
[15] Mazumdar S, Ray A, Mazumdar A, Majumdar S, Sinha A, Vasisht S. Sexual dimorphism and regional difference in size of sacrum: a study in eastern India. Al Ameen Journal of Medical Sciences. 2012; 5(3):298-307.
[16] Nisha Yadav, Kopal Saini, Kalpana Patil. Determination of sex using dry adult human sacrum- a morphometric study. Int J Cur Res Rev., 2015; 7(3):22-28.
[17] Flander LB. Univariate and multivariate methods for sexing the sacrum. Am.j. Phys.Anthrop., 1978; 49: 103-110.
[18] Jana TK, Koley TK, Saha SB, Basu D, Basu SK. Variation and Sexing of Adult Human Sacrum. Journal of anatomical society of India. 1988; 37:11-20.
[19] Singh H, Singh J, Bargotra RN. Sacral index as observed anthropometrically in region of jammu. Journal of anatomical society of India. 1988; 30:13-15.
[20] Patel MM, Gupta BD, Singel TC. Sexing of sacrum by sacral index and Kimura's base-wing index. J. Indian Acad Forensic Med., 2005; 27(1):5-9.
[21] Kothapalli J, Velichety SD, Desai V, Zammer MR. Morphometric study of sexual dimorphism in adult

sacra of south Indian population. Int J Bio Med Res., 2012; 3(3):2076- 2081.
[22] Mamatha H, Sandhya , Sushma RK, Suhani S, Naveen Kumar. Significance of various sacral measurements in the determination of sex in South Indian population. Int J Cur Res Rev., 2012; 4(20):112–18.
[23] Poornima Janipati, Jyothinath Kothapalli, Shamsunder Rao V. Study of sacral index: comparison between different regional populations of India and abroad. Int J Anat Res., 2014;2(4):640-44.
[24] Shree Krishna HK, Yatraj S, Vijaya Kumari. Credibility of various Indices of sacrum in identification of sex of sacrum. International journal of medical toxicology and forensic medicine. 2013; 3(2):58-63.
[25] Vasantha Maddikunta, Ravinder M. Role of morphometrical data of sacrum in determination of sex. Int J Biol Med Res., 2014; 5(1):3785-3792.
[26] Sushma K Kataria , Pravesh Kulhari , Kaushal Raj Kataria , Pushpa Potaliya . A study of the sacral index in Western Rajasthan population in comparison with other races. Int J Anat Res., 2014; 2(2):383-85.
[27] Comas J., Charles C., Manual of Physical anthropology (revised and enlarged English edition) Thomas Springfield, Illinois, USA, pp. 415-416 (1961).
[28] Snell RS. Clinical Anatomy by Regions, 9th ed. P. 244-251, Lippincott Williams & Wilkins. 2012.
[29] J.E. Frazer. Anatomy of human skeleton 3rd Edition, 1933; 43.
[30] Tague R. Do big females have big pelves? Am J Phys Anthropol., 2000; 112:377–393.
[31] Steyn M, Işcan MY. Metric sex determination from the pelvis in modern Greeks. Forensic Science International. 2008; 179:86-89.
[32] Plochocki, JH. Sexual dimorphism of anterior sacral curvature. J Forensic Sci., 2011; 56(1):161-164.
[33] Abdelmonem Awad Hegazy. Sex assessment of the first sacral vertebra, MRI study. Journal of american science. 2013; 9(10):146-150.
[34] Başaloğlu H, Turgut M, Taşer FA, Ceylan T, Başaloğlu HK, Ceylan AA. Morphometry of the sacrum for clinical use. Surg Radiol Anatomy. 2005; 27:467–71.
[35] Baptist M, Sultana F, Farzana F. Sex differences in sacra in the Punjab region. Biomedica. 2008; 24(23):152-57.

Figure legend

Figure 1: Showing measurements of various parameters of sacrum

1a: Mid-ventral straight length (AB), ventral straight breadth (CD). 1b: Mid-ventral curved length (EF),
1c: Transverse diameter of the body of the First sacral vertebra [S1] (GH), Antero-posterior diameter of the body of the First sacral vertebra [S1], 1d: Transverse diameter of Base (KL)

Table 1: Showing metric data of sacrum for the various parameters of present study

Parameter	*Sex*	*Range*	*Mean± S.D*	*S.E.*	*t-value*	*p-value*	*95% C.I. of difference*
Mid-ventral straight length (AB)	M	09.75-10.97	10.27±0.49	0.11	5.29	<0.0001 ES*	0.57-1.27
	F	07.67-10.23	9.35±0.64	0.14			
Mid-ventral curved length (EF)	M	11.10-12.20	11.64±0.40	0.09	3.32	0.0019 VS*	0.22-0.91
	F	09.70-12.20	11.07±0.67	0.14			
Ventral straight breadth (CD)	M	09.04-11.00	9.99±0.73	0.16	5.42	<0.0001 ES*	1.30-0.59
	F	10.03-11.33	10.95±0.37	0.08			
Transverse diameter of Base / width (KL)	M	09.95-11.28	10.68±0.55	0.12	5.48	<0.0001 ES*	1.40-0.65
	F	09.96-12.35	11.71±0.67	0.14			
Transverse diameter of body of S1 (GH)	M	04.85-5.76	5.30±0.33	0.07	1.91	0.0632 NS*	0.01-0.34
	F	04.71-5.29	5.14±0.22	0.05			
Antero-posterior diameter of body of S1 (IJ)	M	02.88-3.36	3.06±0.14	0.03	0.07	0.9476 NS*	0.068-0.073
	F	02.79-3.13	3.05±0.09	0.02			

*ES= Extremely significant, *VS= Very significant, *NS=Normal significant, M=Male, F= Female

Table 2: Showing gender comparison of various indices of sacrum

Index	*Sex*	*Range*	*Mean*	*S.D.*	*t-value*	*p-value*
Sacral Index	M	83.74-109.73	97.51	8.15	9.28	<0.001 ES*
	F	110.70-130.77	117.35	5.72		

Curvature Index	M	82.17-93.19	88.31	3.63	3.96	0.0003 ES*
	F	79.07-88.82	84.44	2.72		
Corporobasal Index	M	47.50-51.06	49.60	1.44	9.75	<0.0001 ES*
	F	38.11-47.82	43.93	2.26		
Index of body of 1st Sacral vertebra	M	52.08-63.36	57.94	4.38	1.46	0.1518 NS*
	F	57.11-66.2	59.63	3.11		

*ES= Extremely significant, *NS=Normal significant, M=Male, F= Female

Table 4: showing comparison of various parameters of sacrum (in centimeters) of present study with other studies

Authors and Years	Gender	Mid-ventral straight length	Mid-ventral curved length	Ventral straight breadth	Transverse diameter of Base	Transverse diameter of body of S1	Antero-posterior diameter of body of S1
Davivongs et al[7] (1963)	Male	09.65	-	-	09.99	04.74	02.98
	Female	08.81	-	-	10.12	04.41	02.76
Raju et al[8] (1980)	Male	10.50	-	-	10.50	04.73	03.3
	Female	09.27	-	-	10.30	04.21	02.76
Mishra et al[12] (2003)	Male	10.70	08.61	-	10.53	04.91	03.00
	Female	09.05	06.62	-	10.51	04.28	02.92
shailaja et al[6] (2010)	Male	11.00	-	-	10.42	-	-
	Female	09.45	-	-	10.60	-	-
Arora et al[13] (2010)	Male	10.97	-	-	10.14	-	-
	Female	09.12	-	-	11.41	-	-
Sachdeva et al[14] (2011)	Male	10.41	11.35	10.31	11.18	04.76	03.15
	Female	09.18	10.45	10.17	10.44	04.55	02.85
Mazumdar et al[15] (2012)	Male	10.08	10.82	-	09.63	04.16	02.94
	Female	08.73	09.93	-	09.56	03.97	02.79
Yadav et al[16] (2015)	Male	10.47	-	-	10.20	04.84	02.91
	Female	09.26	-	-	10.47	04.07	02.69
present study (2015)	Male	10.27	11.64	09.99	10.68	05.30	03.06
	Female	09.35	11.07	10.95	11.71	05.14	03.05

Table 5: Showing comparison of genders in the indices of dry human sacrum

Authors and Years	Gender	Sacral index	Curvature index	Corpobasal index	Body of 1st sacral vertebrae index
Davinvongs[7] (1963)	Male	104.16	92.46	47.72	63.03
	Female	115.49	90.80	43.62	62.84
Flander[17] (1978)	Male	106.49	-	-	-
	Female	112.85	-	-	-
Raju et al[8] (1981)	Male	100.85	92.77	44.94	64.42
	Female	111.39	88.51	40.96	65.52
Jana et al[18] (1987)	Male	91.27	-	-	-
	Female	103.89	-	-	-
Singh et al[19] (1988)	Male	100.85	92.77	44.94	64.42
	Female	113.39	88.51	40.96	65.52
Mishra et al[12] (2003)	Male	98.21	95.72	46.54	61.73
	Female	117.84	90.72	40.47	68.6
Patel et al[20] (2005)	Male	96.25	-	-	-
	Female	113.25	-	-	-
Grays anatomy[3] (2008)	Male	105.00	-	-	-
	Female	115.00	-	-	-
Shailaja et al[6] (2010)	Male	94.24	-	-	-
	Female	113.19	-	-	-
Arora et al[13] (2010)	Male	93.69	-	-	-
	Female	125.35	-	-	-
Sachdeva et al[7] (2011)	Male	100.24	-	-	-
	Female	111.14	-	-	-
Kothapalli et al[21] (2012)	Male	-			66.79
	Female	-			66.75
Mamatha et al[22] (2012)	Male	115.92	-	-	-
	Female	125.20	-	-	-
Poornima et al[23] (2012)	Male	104.08	-	-	-
	Female	115.72	-	-	-
Mazumdar et al[15] (2012)	Male	94.90	94.00	43.80	71.60
	Female	109.8	87.90	41.70	70.70
shreekrishna et al[24] (2013)	Male	99.21	94.72	47.76	64.33

	Female	119.94	91.20	40.90	69.40
Vasantha and Ravinder[25] (2014)	Male	91.80	-	-	-
	Female	116.30	-	-	-
Kataria et al[26] (2014)	Male	120.01	-	-	-
	Female	117.56	-	-	-
Present study (2015)	Male	97.51	88.31	49.60	57.94
	Female	117.35	84.44	43.93	59.63

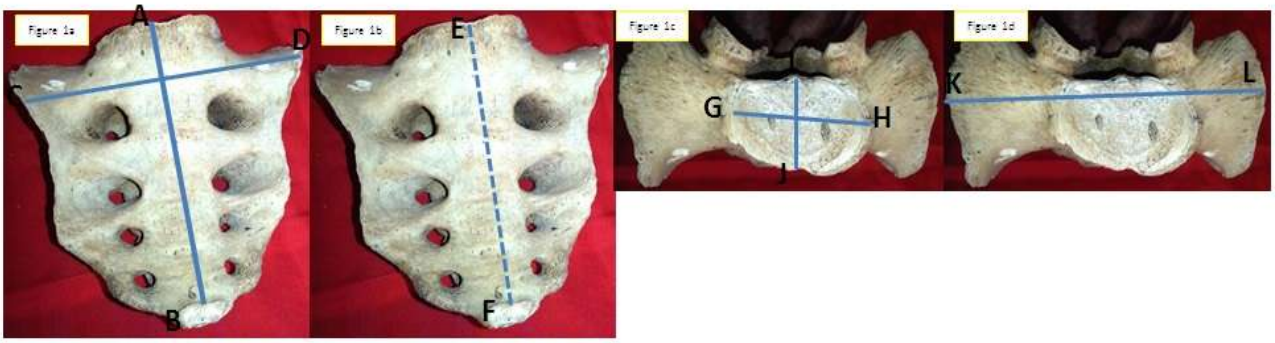

Figure 1: Showing measurements of various parameters of sacrum
1a: Mid-ventral straight length (AB), ventral straight breadth (CD).
1b: Mid-ventral curved length (EF),
1c: Transverse diameter of the body of the First sacral vertebra [S1] (GH),
Antero-posterior diameter of the body of the First sacral vertebra [S1],
1d: Transverse diameter of Base (KL)