Indian Journal of Clinical Anatomy and Physiology 2022;9(4):236–240

Content available at: https://www.ipinnovative.com/open-access-journals

Indian Journal of Clinical Anatomy and Physiology

Journal homepage: https://www.ijcap.org/

Review Article

Morphometric study of sexual dimorphism in sacrum- A review paper

Stuti Srivastava[1], Gopal Sharma[1,*]

[1] *Jhalawar Medical College, Jhalawar, Rajasthan, India*

ARTICLE INFO

Article history:
Received 22-11-2022
Accepted 03-12-2022
Available online 12-01-2023

Keywords:
Sacrum
Sexual dimorphism
Morphometry
Sacral index

ABSTRACT

The accurate observations and measurable investigations to identify the sex is the intrinsic step in biological profile development of the sample. In such scenario, sacrum identifies unknown sex and associated sex related functional differences more precisely. In the past, studies have shown that the morphological features of the sacrum are influenced by the sex hormone secretion and its associated reproductive functions. There are several parameters that can be considered when the sacral dimorphism is considered. Along with the sacrum measurements, the subpubic angle of the individual can also be measured. Among all the parameters used, the breadth and curvature of the sacrum were reliable indicators of sex among these measures. Additionally, it was also reported that none of the criteria could completely determine the sex of the bones. Therefore, it can be said that in order to determine the sex of the sacrum with 100 percent accuracy, consideration of all the parameters should be done. Further, other factors associated with the environment, physical stress, and genetic factors also affects this measurement. Hence, a groundwork about the previous research, is required while evaluating the sexual dimorphism in sacrum.

1. Introduction

1.1. Sacrum

The sacrum, a wedge-shaped bone, formed due to joining of sacral vertebrae stands as the posterosuperior wall in the pelvic cavity and runs towards the lower end of the vertebral column.[1] The word sacrum is obtained from the Latin word ‘sacred’ notions to consider it as the ‘sacred bone’ augmenting the respect of human anatomical structure, where it lies in the lowest back of the body. In the sacrum, the basal part of it forms the superior portion whereas the edge portion of the wedge forms the inferior end. It has four surfaces and one sacral canal.[2]

1.2. Morphometry in sexual dimorphism

In medical science, the anatomical study is important specifically in anthropology. Each part and region of the human skeleton is used to determine sex. The success ratio of morphometry in sexual dimorphism is influenced by age, ancestral origin, and variation in morphology based on age.

The anatomical regions like skull, pelvic girdles, and elongated, long bones are the frequently investigating anatomical parts for sexual dimorphism. However, the accuracy and predictability ratio for using a skull ranges between 80 to 90 percent; for a pelvic girdle, it is stated to be around 90 to 95 percent.[3,4]

But studies say that the morphological features of the sacrum are influenced by the sex hormone secretion and its associated reproductive functions.[5] Hence, though female sacra are shorter, they are wider to render a wider and more supportive pelvic cavity.[6] Thus, greater morphological difference of sacrum and metrical analysis of sacrum

* *Corresponding author*.
E-mail address: drstutisri@gmail.com (G. Sharma).

https://doi.org/10.18231/j.ijcap.2022.050

provides greater accuracy.[1]

1.3. Why sacrum plays a crucial role in medical and health science?

The accurate observations and measurable investigations to identify the sex is the intrinsic step in biological profile development of the sample. In such scenario, sacrum identifies unknown sex and associated sex related functional differences more precisely; though, skull, pelvis, etc showed acceptable accuracy.[4,7] The association of the sacrum with the pelvic girdle is the major cause to determine it.[8] The spinal cord which is erect and the pelvic bone's strength and stability is also supported by the sacrum to transfer the body weight.[2]

Also, the adolescence period in females shows obvious sexual dimorphism in the female which facilitates the mobility levels of sacrum-pelvic cavity association to channelize childbirth.[9,10] Thus utilizing this quality of sacrum and pelvic cavity association, and using effective, relevant parameters based on the geographical location and race of the people renders observable and more efficient results.[7]

This was evident when tremendous gender variations of Chinese and Negroes population was identified[11] and when various species of animals like elephants, dogs, badgers, foxes, dogs, and felines was identified.[12] Thus sacral anatomical study predicts the uniqueness of sexual dimorphism, gender-associated characteristics, and functionalities in different species and individuals in depth.

2. Sacrum in Sex Determination

2.1. Parameters of morphometry of sacrum

To measure and scale the parameters, specific methods and manuals are followed: Based on the researcher's need, reference, and reliability, Wilder's manual of Anthropometry is used along with Vernier calipers and standardized ribbon tape. This is done to maintain the precision of the study.

Maximum length or Maximum straight length (measured in millimeters using vernier calipers): From the central point of the anterosuperior margin of the promontory to the central point of anteroinferior margin of the last sacral vertebra. Note: This measurement has to be taken along with the ventral mid-line of the sacrum.[4,10,13]

Maximum sacral width (measured in millimeters using vernier calipers): The maximum distance between the lateral most part of the left and right ala of the sacrum is measured.

Sacral mid-ventral curved length (measured in millimeters using ribbon tape): From the centrum of the sacral promontory to the centrum of the apex of the sacrum. Note: This measurement has to be taken along with the ventral concave median length.

Transverse diameter of the body of the First sacral vertebra [S1]: (measured in millimeters using ribbon tape): The maximum width of S1 measured from the sacral base towards the topmost superior surface of the whole body of S1 from its lateral side.

Antero-posterior diameter of the body of the First sacral vertebra [S1] (measured in millimeters): The diameter of 1st sacral vertebra has to be measured. For this, anterosuperior and posterosuperior borders of the 1st sacral vertebra are chosen as extremities.

$$Index\ of\ body\ of\ S1 : \frac{APD.S1\ X\ 100}{TD.S1}$$

Sacral index (measured using vernier calipers): Measure the length and breadth of the sacrum. The length is measured by placing the trunk of the caliper at the central point of promontory and midpoint of the anteroinferior border of the fifth sacral vertebra. Breadth is the measurement of the bone's lateral mass.

$$Sacral\ index\ = \frac{(Maximum\ width\ x\ 100)}{(Maximum\ length)}$$

To analyze and assess sexual dimorphism in humans or any specific population, the crucial parameter among various parameters of the sacrum is the sacral index. For instance, the male sacrum can be identified by sacral length and transverse diameter of the S1 portion.[14] Calculation using the formula, (mean ± 3SD) for a specific parameter, provides 100 percent assured results from the range. This limiting point is called as Demarking Point [D.P.] Also, the mean value of a chosen parameter differs for various regional studies and hence the calculation of DP should be performed for every unique region.[12] Thus, the calculation of DP for the parameters along with the sacral index improves sex identity with 100% accuracy for unknown sex.

$$Curvature\ Index : \frac{(Maximum\ length)\ x\ 100}{(Mid-ventral\ curved\ length)}$$

$$Corpora-basal\ index : \frac{(TD.S1)\ X\ 100}{Width\ of\ sacrum}$$

Length of alae (AL) (Measured using Vernier calipers): From the superior surface of the first sacral body to the lateral end of ala. Now, the mean of this is the length of alae.

Maximum length of auricular surface (ASL) (Measured using Vernier calipers): Measured from upper to lower part of auricular surface.

$$Alar\ index : \frac{Length\ of\ ala\ (AL)\ X\ 100}{TD.S1}$$

$$Auricular\ index : \frac{Length\ of\ auricular\ surface\ (ASL)\ X\ 100}{Width\ of\ sacrum}$$

Males showed higher levels of mean length, curved length, the transverse and anteroposterior diameter of S1 vertebrae, curvature, and corporo-basal indices (23.6%) as highest then females. Whereas the sacral index was found to be higher (44.7%) in females. This is because of its anatomy of being short and wide. Thus, sacral index serves as the greater option to identify the unknown sex.[6,10]

2.2. How can the sacral index be grouped and analyzed?

As discussed earlier, the contribution in measurements of human sacra varies based on the researcher's choice of geographical location and race of the population.[2] Hence, based on the sacral index, the sacrum can be divided into three groups: i) Dolichohieric: sacral index < 100 (up to 99.99) ii) Sub- plathyhieric: sacral index is between 100 -106. iii) Plathyhieric: sacral index > 106 for intensified analysis.

Samples with Dolichohieric index have a narrow sacrum, Hyplatyhieric index has a medium-sized sacrum and Platyhieric indexed samples have a broad sacrum. The mean sacral index groups are under the Dolichohieric group. The study population of (Jana et al., 1988; Singh et al., 1988) groups under Plathyhieric group with narrow and broad sacrum respectively.[9,15] This helps to easily broadcast the observation with the prior records of the earlier researchers to understand the sex-associated characteristics.

3. Analysis of Data

3.1. Comparative analysis of male and female prior records about the obtained results

The research reports of the following authors can be used to undergo the study:

Martin (1928) Grays Anatomy (1954) Davivong (1963) Flander (1978) White Black Raju et al. (1980) Budge (1981) Vinod Kumar et al (1984) Jana et al. (1988) Singh et al. (1988) S.S. Dapate (1997) Kanika et al. (2011) Mishra et al. Agra (2003) Shilaja C Math (2006), Gulbarga Aurora et al. (2010), Amritsar Patel et al.(2005).

The mean curvature index in male sacra observed in the present study is lower than that reported in Australian aborigines and in North Indian population. 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, Australian aboregeions and higher than North Indian population. The mean corpora-basal index in male sacra observed in the present study is lower than the values of Australian aboregeions, Varanasi and Agra populations, and higher than the values of North India. The mean corpora-basal index in female sacra observed in the present study is higher than that reported in Australian aboregeions, North Indian population. The mean index of S1 in male and female sacra observed in the present study is higher than that reports in Australian aborigines and in Agra and Varanasi regions of India.[16]

For instance, the mean corpora-basal index of the sacrum of males in the population observed by Kothapalli et al., was lower when compared to the values of Australian aboregeions obtained by Davivongs (1963). Also, the mean corpora-basal index for female samples was higher when compared to the values of Australian aboregeions. This similar variation is also observed in the male samples of Varanasi and Agra when observed by (Mishra SR et al., 2003; Davivongs V, 1963).[16,17] But in contrast, the obtained values of both male and female samples were higher than the values of North India.[18] As expected, in the study of Kothapalli et al the mean index of S1 in both gender is higher than the values of Australian aborigines as observed by Davivongs and Agra samples observed by Mishra SR et al.[16] Thus, as the results differ for various discussed factors, using the reports of these researchers will serve as the reference tool or baseline data.[10]

The data published can be used as standards to compare the similarities and differences in the metrical values of different parameters of sacra of both genders used for the current research. This may also provide statistical data for identifying the sexing of a specific geographical population and identifying the best parameter suitable for each region.

3.2. Statistical analysis for validation

Tests that can be performed between the chosen population:

Independent t-test or Mann–Whitney U test: to test the differences or Z-tests to test the significance.

Pearson or Spearman coefficient: to test the correlation (Triwidodo et al., 2021).

Chi-square test: to compare proportions between qualitative parameters.

Mean and S.D. calculations (quantitative data); frequencies and percentages (qualitative variables).

4. Discussion

4.1. Steps to improve the result efficiency

Along with the sacrum measurements, the subpubic angle of the particular individual can also be measured. Now, the difference and association of the results can be compared with the results of the same measurements of the two different male and female known sample's sex. This is inferred based on the study of the Egyptian population performed by (Mahmoud and Fadaly, 2019) where the mean value of sub-pubic angles of the female is higher than males. Thus, the gender of the pelvis associated with the sacrum can be identified. Sub-pubic angle is less than ninety in males usually whereas the female possess the angle more than ninety degrees to facilitate child birth.[13] Thus, this angular measurement of pelvis in association with sacra can also be an indicator to identify the unknown sex.[8] This is inferred by the result of higher accuracy of male sex determination of bone samples (66.4%) and female sex determination of bone samples (58.4%) only by using the sub pubic angle measurement.[19]

The strict followings of Wilder (1920), Davivongs (1963), and Flander (1980) manuals and reports which are followed by most researchers ensure a platform for higher accuracy results.

Spinopelvic parameters and their impact on the sacral prosthesis.

The study of the spinopelvic parameters (pelvic incidence (PI), pelvic tilt (PT), Sacral slope (SS), and Lumbar lordosis (LL) Computed tomographic images, showed that lumbar lordosis was found to be significantly greater in females.[20,21] A strong positive correlation between LL and SS provides the idea of analyzing LL and SS together in sexual dimorphism. This study also led to the development and launching of sacral prosthesis based on the sacral body curved length and total curved length based on sacral amputation.[20] Studies by (Kothapalli et al., 2012) suggest that the length of the auricular surface and ala of the sacrum are higher in females. Generally, the studies of sacra are performed by manual measurements, and intact parts of undamaged or non-fractured, normal bones are usually chosen for effective results.[5,22] But pathological studies which show wear and tear symptoms or fractures in the bones can be analysed using CT for specific intensive research on sacra.[3]

5. Conclusion

Though various parameters like the width of the sacrum, curved length of sacrum, sacral index, length of ala, and demarking point are explained; analyzing maximum parameters based on the study is required. Based on the review of the research performed by different researchers, it is evident that demarking point help in sex identification using sacrum, with high accuracy. For instance, ventral straight length measurement shows lesser accuracy compared to the auricular index. Also, corporo-basal indices and sacral index stand as the most important and necessary parameters for studying sexual dimorphic characters. Using CT images of the study samples may provide the minute details of the chosen parameter in some populations. The certainty to use only a single parameter for 100% accurate results cannot be justified. Choosing statistically significant parameters along with the additional parameters serves the real purpose of the study. This is because the results vary based on factors related to the environment, physical stress, and genetic factors, and thus the mean, range, S.D., DP, and correlation values differ. Hence, a groundwork about the previous research, and study sample is necessary to provide certainty in sexual dimorphism and its associated functions.

6. Source of Funding

None.

7. Conflict of Interest

None.

References

1. Shingare AK, Masaram NB, Dhapate SS. Morphometric analysis of human sacra. *MedPulse Int J Anat*. 2017;3(2):34–7.
2. Bajpai SR, Maiyyar A. Sexual Dimorphism in Sacrum- A Morphometric Study of Nasik Population. *Indian J Appl Res*. 2016;6(8):633–5.
3. Williams GJ, Rogers A. Rationale and standards for the systematic review of qualitative literature in health services research. *Qual Health Res*. 2006;8(3):341–51.
4. Krogmann WM. The Human Skeleton in Forensic medicine. vol. Vol. 5. U. S. A: Charles C Thomas; 1962. p. 35.
5. White T, Folkens P. The Human Bone Manual. United States: Elsevier Academic Press; 2005.
6. 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 J Med Sci*. 2012;5(3):298–307.
7. Patel MM, Gupta BD, Singel TC. Sexing of Sacrum by Sacral Index& Kumra's Base- Wing index. *J Indian Acad Forensic Med*. 2005;27(1):5–9.
8. Shreekrishna HK, Yatiraj S, Vijayakumari N. Credibility of Various Indices of Sacrum in Identification of Sex of Sacrum. *Int J Med Toxicol Forensic Med*. 2013;3(2):58–63.
9. Singh H, Singh J, Bargotra RN. Sacral index as observed anthrpometrically in the region of Jammu. *J Anat Soc India*. 1988;37:1–13.
10. Kothapalli J, Subhadradevi V, Varalakshmi D, Roshan Z. Morphometric study of sexual dimorphism in adult sacra of South Indian population. *Int J Biol Med Res*. 2012;3(3):2076–81.
11. Comas J, Charles C. Manual of Physical Anthropology. USA: Charles C Thomas; 1961. p. 415–6.
12. Abbasabadi BM, Hajian O, Rahmati S. Investigating the Morphometric Characteristics of Male and Female Zell Sheep Skulls for Sexual Dimorphism. *Anatomical Sciences Journal*. 2020;17(1):13–20.
13. Klepinger LL. Assignment of sex. In: Fundamentals of Forensic Anthropology. United States: John Wiley & Sons Inc; 2006. p. 25–41.
14. Raju PB, Singh S, Padamnabhan R. Sex determination and sacrum. *J Anat Soc India*. 1981;30:13–5.
15. Jana TK, Koley TK, Saha SB, Basu D, Basu SK. Variation and sexing of adult human sacrum. *J Anat Soc Ind*. 1988;37:2–3.
16. Mishra SR, Singh PJ, Agrawal AK, Gupta RN. Identification of sex of sacrum of Agra region. *J Anat Soc Ind*. 2003;52(2):132–6.
17. Davivongs V. The pelvic girdle of the Australian aborigines-sex difference and sex determination. *Am J Phys Anthropol*. 1963;21(4):443–55.
18. Sachdeva K, Singla RK, Kalsey G, Sharma GK. Role of Sacrum in Sexual Dimorphism-A Morphometric Study. *J Ind Acad Foren Med*. 2011;33(3):206–11.
19. Mahmoud SF, Fadaly NMA. A Morphometric and Statistical Study for Determination of Sex from Certain Bony Pelvic Parameters in Assiut Governorate by Using Plain X-Ray Films. *Egypt J Hosp Med*. 2019;76(5):4068–76.
20. Triwidodo A, Rahyussalim AJ, Yulisa ND, Pandelaki J, Huraiby LS, Hadi I, et al. Sacrum morphometry and spinopelvic parameters among the Indonesian population using computed tomography scans. *Medicine (Baltimore)*. 2021;100(47):e27955.
21. Krogmann WM. The Human Skeleton in Forensic medicine. USA: Charles C Thomas; 2012.
22. Wilder HH. The pelvic skeleton including hipgirdle and sacrum (Part I: Osteometry, the measurement of the bones). In: A laboratory manual of anthropometry. Philadelphia: P. Blakistons Sons & Co; 1920. p. 114–9.

Author biography

Stuti Srivastava, Resident

Gopal Sharma, Senior Professor & Head

Cite this article: Srivastava S, Sharma G. Morphometric study of sexual dimorphism in sacrum- A review paper. *Indian J Clin Anat Physiol* 2022;9(4):236-240.