

EFFICACY OF VARIOUS SACRAL INDICES IN IDENTIFYING THE SEX OF AN ADULT HUMAN SACRUM-A COMPREHENSIVE STUDY

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Abstract

Background: To study the accuracy and limitations of various sacral indices in identifying the sex of an adult human sacrum. **Materials & Methods:** In the present study, 120 sacra (70 male + 50 female) were studied from Maharashtra region. The sex determination of these bones was done using the different indices. **Results:** From the present study Sacral Index, Corporobasal Index, Kimura's Base Wing Index for Right and Left Wing of Sacrum, and Alar Index showed statistically highly significant difference between the means of male and female sacra. **Conclusion:** Amongst the indices, the Corporobasal Index, Sacral Index, Alar Index, Kimura's Base Wing Index for Right and Left Wing of Sacrum, are found to be more accurate in sexing the unknown samples of sacra.

INTRODUCTION

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. 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. Sexual dimorphism in this area is mainly due to the changes that occur during adolescence to meet the requirements of childbirth in females.^[1]

The exact establishment of identity of sex in archeological and medicolegal samples of bones, depends on the number of bones sent for examination. It was observed by Taylor in his book of Medical jurisprudence, that.^[2]

- | | |
|---------------------------|--------|
| a) Skull + Femur..... | 97.35% |
| b) Coccyx and Sacrum..... | 97.18% |
| c) Pelvis | 95.00% |
| d) Skull alone..... | 91.38% |
| e) Femur..... | 39.84% |
| f) Atlas vertebra..... | 31.18% |

However, Krogman (1962),^[3] has opined that the accuracy of sex identification based on the study of

complete skeleton was 100% and skull with pelvis 98%, pelvis alone 95%, skull alone 90% and long bones alone 80%. He subsequently made an estimate to reduce the above figures by 5-10% depending upon completeness of the material to be sexed. Both the above authors have worked on the sexing of the bones using the various statistical analysis.

Sacral width, as a percentage of length, yields a sacral index, the sacrum can be divided into three groups (vide Wilder's manual of Anthropometry).^[4]

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

Jit and Singh (1966),^[5] promoted the demarking point (D.P.), that identified sex with 100% accuracy. India is a vast country with intermixing of races, and pure ethnic groups are often difficult to get. However, Chand et al. (1995),^[6] suggested that India may be divided into four regions like north, south, west, and east for different study purpose on local population. The studies on sacral anthropometry are available from various other regions of the country, like, Jana et al (1988),^[7] in the Burdwan region of West Bengal, Singh and Raju (1980),^[8] from Varanasi, while Mishra et al (2003),^[9] undertook a study to determine the sex difference in the sacra of Agra region of Uttar Pradesh, India. Moreover, Singh and Gangarade (1968),^[10] have reported that

even within the same general population, mean value may be significantly different in bones from different zones.^[11]

Therefore, the present work was conducted on sacra of Maharashtra region to observe the sexual differences of male and female sacra and compare the findings with similar observations across India.

MATERIALS AND METHODS

The material for present study is comprised of 120 dry and clean adult human sacra of known sex but of unknown age. Complete developed sacrum without any deformity, fracture or damage were included while those of unknown sex, broken or those showing any fracture and pathological wear and tear were excluded from this study. The sacra were collected from Department of Anatomy of various Medical Institutes in Maharashtra.

Following indices were calculated.

$$\text{Sacral Index}^{[12]} = \frac{\text{Anterior straight breadth of sacrum}}{100} \times \text{Mid-ventral straight length of sacrum}$$

$$\text{Longitudinal curvature Index}^{[12]} = \frac{\text{Mid-ventral straight length of sacrum} \times 100}{\text{Mid-ventral curved length of sacrum}}$$

$$\text{3Corporo-basal Index}^{[5]} = \frac{\text{Transverse diameter of body of S1}}{100} \times \text{Width of sacrum}$$

$$\text{Kimura's Base-Wing Index}^{[13]} = \frac{\text{Width of wing} \times 100}{\text{Width of base}}$$

(separately for Right & Left Wing)

(here, Width of base = transverse diameter of body of 1st sacral vertebra).

$$\text{Index of Body of S1 Vertebra}^{[1]} = \frac{\text{A-P diameter of body of S1}}{\text{Transverse dia. of body of S1}} \times 100$$

$$\text{Alar Index}^{[1]} = \frac{\text{Length of ala}}{\text{Transverse dia. of body of S1}} \times 100$$

From the above metrical data following details were obtained by using formulae. They were the range, mean, standard deviation (S.D.), 't' value and 'p' value by applying Unpaired 't' test, Identification Point, calculated range, Demarking Point and percentage of bones in which sex could be identified by demarking point for each parameter. The 'p' value <0.0001 is considered to be statistically highly significant while >0.05 is considered to be statistically not significant.

The calculated range was obtained by adding and subtracting (2 X standard deviation) to and from the mean value. The calculated range (mean \pm 2SD) thus obtained will cover upto 95% confidence limit. From the obtained values, demarking points (DP) were calculated on the lines of Jit and Singh (1966),^[5] and percentage of bones, thus identified were found out in relation to each parameter. Any single DP for any of the parameters, if crossed would detect the sex with 100% accuracy (Singh and Raju, 1977).^[8]

Thus for mid ventral straight length of sacrum, the calculated range for male is 8.472 to 11.848cm and for female is in between 7.768 to 11.636cm. thus the demarking point for ventral straight length of sacrum for males >11.636cm and for female is <8.472cm, it means that sacrum with mid ventral straight length measuring above 11.636cm is definitely a male and below 8.472cm is definitely a female.

Identification point (IP) is a limiting point of actual range of every measurable parameter in male and female.

Then each metrical parameter was tabulated in individual tables and graphs were plotted. Qualitative data was summarised in the form of proportions.

RESULTS

The mean value for males is 95.83 ± 8.82 % and for females is 105.30 ± 13.34 cm. The difference between genders is statistically highly significant. The range for male sacra is between 73.6 - 111.88% and for female sacra between 83.49 - 150.60 %. The Identification Point (IP) for male sacra is <83.49% and that for female sacra is >111.88%. The calculated range (mean \pm 2 S.D.) for male sacra is between 78.18 - 113.46 % and that for female sacra is between 78.32 - 131.99 %. The Demarking Point (DP) for male sacra is <78.32 % and for female sacra is >113.46 %. From this demarking point 4.28% male and 24% female bones can be identified respectively. [Table 1]

The mean value for males is 92.42 ± 3.65 % and for females is 91.61 ± 3.64 %. The difference between genders is statistically not significant. The range for male sacra is between 82.5 - 100 % and for female sacra between 82.87 - 99.19 %. The Identification Point (IP) for male sacra is >99.19 % and that for female sacra is <82.5 %. The calculated range (mean \pm 2 S.D.) for male sacra is between 85.11 - 99.73 % and that for female sacra is between 84.33 - 98.9 %. The Demarking Point (DP) for male sacra is >98.9 % and for female sacra is <85.11. From this demarking point 2.85% male and female bones can be identified respectively. [Table 2]

The mean value for males is 41.77 ± 3.81 % and for females is 36.35 ± 5.91 %. The difference between genders is statistically highly significant. The range for male sacra is between 33.05 - 50.50 % and for female sacra between 26.5 - 50 %. The Identification Point (IP) for male sacra is >50 % and that for female sacra is <33.04 %. The calculated range (mean \pm 2 S.D.) for male sacra is between 34.14 - 49.4 % and that for female sacra is between 24.51 - 48.19 %. The Demarking Point (DP) for male sacra is >48.19 % and for female sacra is <34.14 %. From this demarking point 10% male and 34% female bones can be identified respectively. [Table 3]

The mean value for males is 75.58 ± 11.20 % and for females is 95.31 ± 21.91 %. The difference between genders is statistically highly significant. The range for male sacra is 50.98 –108.1% and for female sacra is 53.66 –138.7%. The Identification Point (IP) for male sacra is <53.66 % and that for female sacra is >108.1 %. The calculated range (mean \pm 2 S.D.) for male sacra is 53.18 –97.98% and that for female sacra is 51.49 – 139.13 %. The Demarking Point (DP) for male sacra is <51.49% and for female sacra is >97.98%. From this demarking point 1.42% male and 36% female bones can be identified respectively. [Table 4]

The mean value for males is 74.62 ± 10.49 % and for females is 95.06 ± 21.81 %. The difference between genders is statistically highly significant. The range for male sacra is between 50.98 –108.1% and for female sacra between 53.66 –138.7%. The Identification Point (IP) for male sacra is <53.66 % and that for female sacra is >108.1 %. The calculated range (mean \pm 2 S.D.) for male sacra is between 53.64 – 95.6 % and that for female sacra is between 51.44 – 138.68 %. The Demarking Point (DP) for male sacra is <51.44 % and for female sacra is >95.6%. From this demarking point 1.42% male and 36% female bones can be identified respectively. [Table 5]

Study of Index of Body of S1 Vertebra. The mean value for males is 69.74 ± 7.57 % and for females is 72.40 ± 9.69 %. The difference between genders is statistically not significant. The range for male sacra is between 50.98 – 86.11% and for female sacra between 56.1 – 90%. The Identification Point (IP) for male sacra is <56.1% and that for female sacra is >86.11%. The calculated range (mean \pm 2 S.D.) for male sacra is between 54.6 – 84.88% and that for female sacra is between 53.01 –91.79%. The Demarking Point (DP) for male sacra is <53.01% and for female sacra is >84.88. From this demarking point 2.85% male and 18% female bones can be identified respectively.

The study of Alar Index. The mean value for males is 75.10 ± 10.54 % and for females is 95.19 ± 21.82 %. The difference between genders is statistically highly significant. The range for male sacra is between 50.98 – 108.11% and for female sacra between 53.66 –138.71%. The Identification Point (IP) for male sacra is <53.66% and that for female sacra is >108.11%. The calculated range (mean \pm 2 S.D.) for male sacra is between 54.02 – 96.18% and that for female sacra is between 51.55 – 130.83%. The Demarking Point (DP) for male sacra is <51.55% and for female sacra is >96.18%. From this demarking point 1.42% male and 38% female bones can be identified respectively.

Table 1: Distribution of Sacral Index (%) in different gender

Sr. No.	Detailed measurements	Male	Female
1	Distribution of Sacral Index (%)	No. of Sacra	No. of Sacra
	73 – 98	46	20
	99 - 124	24	27
	125 - 151	00	03
2	Total no. of bones	70	50
3	Range	73.6 – 111.88	83.49–150.60
4	Mean	95.83	105.30
5	SD	8.82	13.34
6	Identification point	<83.49	>111.88
7	Calculated Range	78.18-113.46	78.32–131.99
8	Demarking point	<78.32	>113.46
9	% of identified bone	4.28	24

****t =4.68, p<0.0001 (Highly significant)**

Table 2: Distribution of Longitudinal Curvatural Index (%) in different gender

Sr. No.	Detailed measurements	Male	Female
1	Distribution of Longitudinal Curvatural Index (%)	No. of Sacra	No. of Sacra
	81 – 87	07	07
	88 – 94	36	24
	95 – 101	27	19
2	Total no. of bones	70	50
3	Range	82.5 – 100	82.87 – 99.19
4	Mean	92.42	91.61
5	SD	3.65	3.64
6	Identification point	> 99.19	< 82.5
7	Calculated Range	85.11–99.73	84.33 – 98.9
8	Demarking point	> 98.9	< 85.11
9	% of identified bone	2.85	2.85

****t = 1.21, p= 0.231, (Not significant)**

Table 3: Distribution of Corporo Basal Index (%) in different gender

Sr. No.	Detailed measurements	Male	Female
1	Distribution of Corporo Basal Index (%)	No. of Sacra	No. of Sacra
	26 – 33	01	17
	34 - 41	45	26

	42 - 51	24	07
2	Total no. of bones	70	50
3	Range	33.05 – 50.50	26.5 – 50
4	Mean	41.77	36.35
5	SD	3.81	5.91
6	Identification point	> 50	< 33.05
7	Calculated Range	34.14 – 49.4	24.51 – 48.19
8	Demarking point	> 48.19	< 34.14
9	% of identified bone	10	34

****t = 6.09, p< 0.0001, (Highly significant)**

Table 4: Distribution of Kimura's Base Wing Index for Right (Rt) wing of sacrum (%) in different gender

Sr. No.	Detailed measurements	Male	Female
1	Distribution of Kimura's Base Wing Index for Rt. wing (%)	No. of Sacra	No. of Sacra
	50 – 79	44	12
	80 – 109	26	27
	110 – 140	00	11
2	Total no. of bones	70	50
3	Range	50.98 – 108.1	53.66 – 138.7
4	Mean	75.58	95.31
5	SD	11.20	21.91
6	Identification point	<53.66	>108.1
7	Calculated Range	53.18 – 97.98	51.49 – 139.13
8	Demarking point	< 51.49	>97.98
9	% of identified bone	1.42	36

****t=6.45, p<0.0001, (Highly significant)**

Table 5: Distribution of Kimura's Base Wing Index of Left (Lt) Wing of Sacrum in different gender

Sr. No.	Detailed measurements	Male	Female
1	Distribution of Kimura's Base Wing Index for Lt. wing (%)	No. of Sacra	No. of Sacra
	50 – 79	44	13
	80 – 109	26	26
	110 - 140	00	11
2	Total no. of bones	70	50
3	Range	50.98 – 108.1	53.66 – 138.7
4	Mean	74.62	95.06
5	SD	10.49	21.81
6	Identification point	<53.66	>108.1
7	Calculated Range	53.64 – 95.6	51.44 – 138.68
8	Demarking point	<51.44	>95.6
9	% of identified bone	1.42	36

****t =6.81, p< 0.0001,(Highly significant)**

DISCUSSION

Sacral Index

As noted in table -11, in the present study, the mean value for sacral index in male is 95.83% and in female 105.30%. The Mean value of female is higher than male.

The sacrum having mean sacral index below 78.32% is definitely a male and above 113.46% is definitely a female. 4.28% male and 24% female bones do not overlap.

the mean sacral index of male bone (95.83%) in present study falls under dolichohieric group (sacral index <100) which is similar to the observations of Mishra et al,^[9] and Math SC et al.^[1]The mean sacral index of female bone (105.30%) in present study falls under sub- plathyhieric (sacral index between 100 – 106) which is falling a short from plathyhieric group (sacral index >106) just by a short difference of 1% which is observed by the rest all workers in above mentioned table. The reason for this may be explained like that the female sacra from present study are more longer and less wider than the female

sacra from the rest all above mentioned studies as discussed in earlier part of discussion. This could be attributed to differences in various factors like environmental, geographical, regional and genetic. However, its importance in sex determination cannot be decreased as the difference between male and female mean is statistically highly significant.

1. Longitudinal Curvature Index

As noted in table- 12, the mean value for Longitudinal Curvature Index in present study is 92.42% in males and 91.61% in females.

Sacrum with mean Longitudinal Curvature Index measuring above 98.9% is definitely a male and below 85.11% is definitely a female. 2.85% male and female bones do not overlap. The mean value for males is higher than females.

the findings of present study agrees with findings of Sachdeva K et al,^[12] and Davivongs.^[30]The mean value is higher in males than in females in these studies, thus supporting the Davivongs (1963),^[14] view that the higher values of this index in males is indicative of a more pronounced anterior surface of female sacrum. However, the mean difference in present is statistically insignificant.

2. Corporobasal Index

As noted in table- 13, the mean value for Corporobasal Index in present study is 41.77% in males and 36.35% in females.

Sacrum with Corporobasal Index measuring above 48.19 % is definitely a male and below 34.14 % is definitely a female. 10% male and 34% female bones do not overlap.

The mean value for males is significantly higher than females.

the findings of present study agrees with the findings of Mishra et al,^[9] and Mazumdar S et al,^[11] as in these studies including our study the difference between the means of male and female is statistically significant. However, the mean corporobasal index for males in present study is lower than those studied by Mazumdar S et al,^[11] and Mishra et al,^[9] the same trend is observed for female sacra also.

This parameter is more accurate in identifying female sacra (34%) than male sacra (10%) from present study.

3. Kimura's Base Wing Index for Rt. Wing of Sacrum

As noted in table- 14, the mean value for Kimura's Base Wing Index for Rt. Wing of sacrum in present study is 31.19% in male and is 33.424% in female. The mean value for female sacra is significantly greater than that for male sacra. This mean value for male and female sacra of present study is found to be lesser than that observed by Patel et al (2005),^[38] in the study from Jamnagar region having mean value 61.55% in male and 79.5% in females. However, in both the studies the difference between male & female mean is statistically significant.

Patel et al (2005),^[13] in their study, the percentage of male and female bones identified by using demarking point were equal in both i.e. 18.75%, but in present study the accuracy for female sacra (16%) is more than that for male sacra (10%).

Very few individual sexual dimorphic study on the Kimura's Base Wing Index for Rt. And Lt. Ala of sacrum has been done up till now. In present study we found statistically highly significant difference between male and female on Right side.

Thus this parameter can be used for sexual dimorphism individually.

4. Kimura's Base Wing Index for Lt. Wing of Sacrum

As noted in table- 15, the mean value for Kimura's Base Wing Index for Lt. Wing of sacrum in present study is 30.85% in male and in female it is 33.331%. The mean value for female sacra is significantly greater than that for male sacra. This mean value for male and female sacra of present study is found to be lesser than that observed by Patel et al (2005),^[38] in the study from Jamnagar region having mean value 62.15% in male and 79.5% in females. However, the difference between male & female mean is statistically significant in our study but it was insignificant in the study of Patel et al (2005).^[13]

Patel et al (2005),^[13] in their study, the percentage of male and female bones identified by using demarking point were equal in both i.e. 18.75%, but in present study the accuracy for female sacra (28%) is more than that for male sacra (12%).

Similar to the above parameter, very few individual sexual dimorphic studies has been done till date on the Kimura's Base Wing Index for Lt. Ala of sacrum. In present study we found statistically highly significant difference between male and female on Left side.

Thus this parameter can be used for sexual dimorphism individually.

5. Index of Body of 1st Sacral Vertebra

As noted in table- 16, in the present study the mean value for Index of Body of 1st Sacral Vertebra in males is 69.74% and in females 72.40%.

The demarking point for male is <53.012% and for females is >84.882%.

2.85% male and 18% female bones do not overlap.

the findings of present study are similar with the findings of Raju et al (1980) [8] from Varanasi region that is the mean value is higher in females than in males being statistically insignificant.

6. Alar Index

As noted in table- 17, in present study the mean value for Alar Index in males is 75.1% and in females 95.19%. The mean value for females is significantly higher than for males.

The demarking point for males is <51.55% and for females is >96.18%.

1.42% male and 38% female bones do not overlap.

The mean value for male in present study is found to be greater than that observed from Agra region by Mishra et al (2005),^[9] and from South Indian population as observed by Kothapalli J et al (2012).^[11] The similar pattern is observed for female sacra of present study. But the difference between means of male and female was statistically significant as observed by Mishra et al (2005), Kothapalli J et al (2012) including the present study. This parameter is found to be more accurate in identifying female sacra (38%) than the male sacra (1.42%) in the present study.

CONCLUSION

Amongst the indices, the Corporobasal Index, Sacral Index, Alar Index, Kimura's Base Wing Index for Right and Left Wing of Sacrum, are found to be more accurate in sexing the unknown samples of sacra.

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