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Assessment of indices used for sexual dimorphism of skull

Anant Dattatray Dhanwate[1], Dope Santoshkumar Ankushrao[2,*]

[1]Associate Professor, Govt. Medical College, Akola, Maharashtra, [2]Associate Professor, Dept. of Anatomy, Govt. Medical College, Latur, Maharashtra

***Corresponding Author:**
Email: drdopesantosh@yahoo.co.in

Abstract

Introduction: Skull is the preferred bone for identification of sex of the deceased as it resists decomposition, mutilation and fire. Cranial Index, Nasal Index and Orbital Index are commonly used for sexual dimorphism of skull. Previous studies present large variations in these indices due to genetic and environmental factors, racial and ethnic differences, different measurement methods and sample size. To know the reliability of these indices for sexual dimorphism of the skull, the present study was conducted.

Materials and Method: The study was performed on 98 adult Indian skulls consisting of 60 male and 38 female skulls of known age and sex. Parameters measured were Cranial Index (CI), Nasal Index (NI) and Orbital Index (OI) which were expressed in descriptive statistics i.e. mean, range and standard deviation. For all the three indices, 'identification points' and 'demarking points' were calculated and then percentage of skulls identified by these points were recorded. Results were compared with available literature.

Results- In the present study, mean CI in male and female skulls was 74.68±4.21 and 77.12±4.92 respectively while their NI was 50.76±5.61 and 56.86±6.65 respectively. In male skulls the mean OI was 87.47±8.09, while it was 87.88±5.55 in female skulls. The identification points and demarking points were calculated for all these three indices. Using identification points of CI and NI, 5% to 33% skulls were identified correctly as male or female. However, no sex could be determined from demarking points of three indices.

Conclusion: None of the three indices namely CI, NI or OI were promising individually in identifying sex as a very low percentage of skulls could be identified. The study concludes that the reliability of these three cranial indices is doubtful in sexual dimorphism of the skull.

Keywords: Cranial Index; Nasal Index; Orbital Index; Sexual dimorphism; Demarking points; Skull

Introduction

Morphometry of the skeletal remains for identification of sex is of great importance to anatomists, forensic experts and anthropologists. Skull is one of the most preferred bones for identification and sexual dimorphism because it resists fire, explosions, mutilations and decomposition. Sex of an individual can be identified accurately in 90% of cases using skull alone.[(1)]

Various natural and accidental circumstances may necessitate the use of anthropometry to identify the sex of a person. These include wars, road and train accidents and deliberate mutilation, disfigurement, pounding, or gauging of the body.[(1)] Several metrical parameters and indices have been used previously for sexual dimorphism of skull. Cranial Index (CI), Nasal Index (NI) and Orbital Index (OI) are commonly used for sexual dimorphism of skull and are considered to be reliable and are stated to determine the sex in a high percentage of skulls.[(2-15)] Previous studies present large variations in these indices due to genetic and environmental factors, racial and ethnic differences, different measurement methods and sample size. The prior knowledge of these indices is paramount to their successful application. Therefore, this study was done to assess the reliability of these indices to identify sex differences in skulls.

Materials and Method

The study material consisted of 98 adult skulls of known sex available in the Anatomy department of which 60 were male and 38 were female. Measurements were taken after putting the skull in Frankfurt's horizontal plane. Instruments used for the measurement were Vernier caliper, spreading caliper, scale and marker. Measurements were taken twice at different sittings and their average was taken.

All the skulls included in the study were dry, ossified, intact adult skulls free of any congenital deformity or artifacts.

Following parameters were measured in all the skulls-

1. Maximum cranial length- from glabella to the most posterior point in the mid-sagittal plane on occipital bone (opisthocranium).
2. Maximum cranial breadth- the greatest horizontal diameter of the cranium taken at the point above supramastoid crest perpendicular to median sagittal plane (euryon to euryon).
3. Cranial Index[(16,17)]- Calculated as Maximum cranial breadth X 100/Maximum cranial length
4. Nasal height- from nasion to the lowest tip of the nasal spine on the lower border of nasal aperture.
5. Nasal breadth- maximum breadth of nasal aperture.
6. Nasal Index[(18)] - Calculated as Nasal breadth X 100/Nasal height

7. Orbital Breadth (OB)-from the *dacryon (d)* to the *ectoconchionec (ec).* (*dacryon d*- The point of frontal, lacrimal, and maxillary intersection on the medial border of the orbit; ectoconchionec- Intersection of the lateral border of the orbit with a line bisecting the orbit along its long axis).[19]
8. Orbital Height (OH)- the maximum vertical distance between the superior and inferior orbital margins
9. Orbital Index (OI)[7,18]- Calculated as Orbital Height X 100/Orbital Breadth

All the measurements were recorded in millimeters and were tabulated. The three indices CI, NI, and OI were calculated for each skull and their descriptive statistics i.e. mean, SD and Range were calculated in both the sexes. The differences of means between the male and female indices were compared for significance using the Student t-test. Confidence interval of 95% was assumed and the differences were considered significant at $P \leq 0.05$. Three indices were then subjected to "demarking points" (DPs) analysis as evolved by Jit and Singh (1966).[20] Demarkating points were calculated from mean ± 3 S.D. for each of the three indices. Percentage of the crania identified correctly as male or female by D.P. was then calculated.

Result

The range, mean, standard deviation (S.D.) and identification points (I.Ps) of CI, NI and OI in both sexes are presented in Table 1. In the present study, mean CI in male and female skulls was 74.68±4.21 and 77.12±4.92 respectively while their NI was 50.76±5.61 and 56.86±6.65 respectively. In male skulls the mean OI was 87.47±8.09, while it was 87.88±5.55 in female skulls. For all the three indices, 't' values indicated statistically significant differences between mean values of male and female skulls. Female values were always higher than males. There was statistically significant difference of means of CI and NI but not of OI between male and female skulls. This table also shows the identification point (I.P) and percentage of skulls identified with the help of I.P. With the help of this method the cranial index could identify only 5% male and 21% female skulls while nasal index could identify only 33.34% male and 5.26% female skulls.

Table 1: Descriptive Statistics and Identification point of Various Indices in Male and Female Skulls

		Cranial Index	Nasal Index	Orbital Index
Male	Range	66.11 – 79.81	42.03 – 62.15	71.51 – 102.99
	Mean	74.68	50.76	87.47
	SD	4.21	5.61	8.09
	Identification point	<67.87	<49.06	<72.88
	% Identified	*5.00*	*33.34*	*1.67*
Female	Range	67.87 – 87.12	49.06 – 79.86	72.88 – 104.65
	Mean	77.12	56.86	87.88
	SD	4.92	6.65	5.55
	Identification point	>79.81	>62.15	>102.99
	% Identified	*21.05*	*5.26*	*2.63*
	P value (Difference of Mean)	P<0.05	P<0.001	P>0.05

Demarking points (DPs) were calculated as mean±3SD for each index (Table 2).[20] Demarking point for CI was 62.36 in males and 87.31 in females. DP for NI was 36.91 in males and 67.59 in females. DP could not be calculated for OI due to high degree of overlap between male and female skulls. Percentage of the skulls identified by DP was then calculated. Using DP of NI, 5.26% of female skulls could be identified. Sex identification of skull was not possible from DPs of other indices.

Table 2: Calculated range and Demarking points for Various Indices in Male (60) and Female (38) Skulls

Sr. No.	Index	Sex	Calculated Range (Mean±3SD)	Demarking points	% Identified
1	Cranial Index	M	62.05- 87.31	<62.36	0.00
		F	62.36 – 91.88	>87.31	0.00
2	Nasal Index	M	33.93 - 67.59	<36.91	0.00
		F	36.91 – 76.81	>67.59	5.26
3	Orbital Index	M	63.2 – 111.74	<71.23	0.00
		F	71.23 – 104.53	-	-

Discussion

Human cranium is regarded as the best indicator of sex (next to pelvic bones).[21] Craniometry is the scientific measurement of the skull useful for anthropometry and forensic practice.[22] Many cephalic indices are widely used for racial and sex differences and they provide a system for metrical recording of sizes and proportions of cranial features.[23] Indices show the relationship between different dimensions (length and breadth) which can also be expressed as ratios or percentages. The general formula of index is the ratio of numerator (smaller measurement) to denominator (larger measurement) multiplied by hundred.[18] Since these indices yield a numerical expression, they are vital for identification and classification of races and sexes.[23,24]

Cranial Index: Cephalic index also called as cranial index is one of the important parameter to differentiate between different human races. It was defined by Swedish professor of Anatomy Anders Retzius (1796–1860) and first used in physical anthropology to classify ancient human remains found in Europe.[25] The ratio of the cranial vault breadth to the glabellomaximal length multiplied by 100 gives the cranial index.[26] The CI is an important feature that is influenced by the shape of the head. It determines how close or apart the orbits appear to be.[1] This index has been known to be higher in females than in males and shows racial and ethnic variations.[27,28]

According to Williams et al (2000) the skulls are divided into four types based on cranial index as follows, Dolicocephalic (CI<74.9), Mesocephalic (CI=75 to 79.9), Brachycephalic (CI=80 to 84.9), Hyperbrachycephalic (CI=85 to 89.9).[23]

In the present study, mean CI in male skulls was 74.68±4.21 and in female skulls was 77.12±4.92 with statistically significant difference. These results support prior findings in which the CI was found to be significantly higher for the female crania than for the male crania (Table 3).[4,9,27-30] A few researchers, however, found higher CI in males than females.[6,8,31,32]

Table 3: Comparison of means of Cranial Index of Males and Female skulls

Sr No.	Name and year of the study	Study Sample (No. of skulls)	Male	Female	Study population	Mean CI	Mean CI	Significance
						Males	Female	(p Value)
1	Present Study (2016)	98	60	38	Indian	74.68	77.12	p<0.05 (S)
2	Shanthi et al. (2013)[29]	100	66	34	South Indian	69.75	71.48	p<0.05 (S)
3	Vidya et al. (2012)[3]	80	41	39	South Indian	78.40	79.13	p=0.622 (NS)
4	Kumar and Nagar (2015)[4]	80	45	35	North Indian	73.75	75.22	p<0.001 (S)
5	Salve and Chandashekhar (2012)[30]	210	150	60	Mumbai Indian	73.19	76.84	p=0.000 (S)
6	Mahajan and Gandhi (2011)[6]	62	40	22	North Indian	72.64	72.06	p>0.05 (NS)
7	Jeremiah et al. (2013)[7]	150	80	70	Kenyan	71.04	72.37	p=0.095 (NS)
8	Adejuwon et al. (2011)[8]	85	56	29	Nigerian	72.97	71.72	p>0.05 (NS)
9	Sangvichien et al (2007)[9]	101	66	35	Thai	83.07	85.84	p=0.003 (S)

Though the differences of CI in male and female skulls in the present study were statistically significant by t test, only 5% of male and 21% of female skulls could be identified from the Identification points (Table 1). When subjected to demarking point analysis, no sex difference was possible from CI (Table 2). Not many previous studies have subjected CI to demarking point analysis for comparison.

Nasal Index: Nasal index is a ratio of the greatest width of the nasal aperture to the height of the nasal skeleton multiplied by 100.[23,33] It has been a useful tool in Forensic Science as it exhibits sexual dimorphism.[31,34,35] Various studies have been conducted in the past on nasal aperture measurements and nasal index to determine sex and in distinguishing racial and ethnic differences.[36-39] Based on the index, the nose has been classified into leptorrrhine or fine nosed (≤69.9), mesorrhine or medium nosed (70.0-84.9) and platyrrhine or broad nosed (≥85.0).[40]

The mean nasal index calculated using the nasal aperture measurements in the present study was 50.76±5.61 in male and 56.86±6.65 in female skulls with statistically significant difference. These results corroborates with previous studies in which the NI was found to be significantly higher for the female crania than for the male crania as in studies by Kotian et al. (2015) on south Indian, by Orish and Ibeachu (2016) on Nigerian and by Mahakkanukrauh et al. (2015) on Thai skulls (Table 4).[10-12] However, findings of Vidya et al. (2012) and Oladipio et al. (2010) differed with slightly higher NI in males than females.[3,41]

Table 4: Comparison of means of Nasal Index of Male and Female skulls

Sr No.	Name and year of the study	Study Sample	Male	Female	Study population	Mean NI	Mean NI	Significance
						Males	Female	(p Value)
1	Present Study (2016)	98 Skulls	60	38	Indian	50.76	56.86	p<0.001 (S)
2	Vidya et al. (2012)[3]	80 Skulls	41	39	South Indian	49.38	49.24	p=0.930 (NS)
3	Kotian et al. (2015)[10]	150 MDCT 2D Radiographs	84	66	South Indian	66	66.97	p=0.465 (NS)
4	Orish and Ibeachu (2016)[11]	100 Skulls	78	22	Nigerian	53.67	59.11	--
5	Mahakkanukrauh et al. (2015)[12]	200 Skulls	100	100	Thailand	50.50	52.48	--

Though the differences of NI in male and female skulls in the present study were statistically significant by t test, only 33% of male and 5% of female skulls could be identified from the Identification points (Table 1). When subjected to demarking point analysis, no male skull could be identified and only 5% of female skulls could be identified from NI (Table 2). Not many previous studies have subjected NI to demarking point analysis for comparison.

Orbital Index: Metric parameters of skull including orbital height, breadth and index are useful for identification and sex determination. Patnaik et al. (2001) stated that in each orbital cavity, the width is usually greater than the height; the relation between the two is given by the orbital index.[42] The orbital index (OI), the proportion of the orbit height to its breadth multiplied by 100, is determined by the shape of the face and varies with race, regions within the same race and periods in evolution.[43] Using the OI, Orbits are classified into three types: Megaseme (OI >89) for the Orientals (except the Eskimos) where the orbital opening is round, Mesoseme (89>OI>83) for the Caucasians and Microseme (OI≤83) for the Africans where the orbital opening is rectangular.[42,44] In the present study, the mean OI was 87.47 placing the study population in Mesoseme category.

In the present study, the mean OI in male skulls was 87.47±8.09 and in female skulls was 87.88±5.55 (Table 1). Higher OI in female skull, however, was statistically not significant to warrant the use of the OI in sexual dimorphism of skulls in Indian population. The higher OI in females has been reported in previous studies conducted among different populations (Table 5).[7,14,15,43] However, Sangvicichien et al. (2007) observed significantly higher OI in female than male skulls of thai population.[9]

Table 5: Comparison of means of OI of Male and Female skulls (Right and Left together)

Sr No.	Name and year of the study	Study Sample (No. of skulls)	Male	Female	Study population	Mean OI	Mean OI	Significance
						Males	Female	(p Value)
1	Present Study (2016)	98	60	38	Indian	87.47	87.88	p>0.05 (NS)
2	Biswas et al (2015)[13]	53	31	22	Indian (Bengali)	86.89	90.31	p=0.07 (NS)
3	Mekala et al (2015)[14]	200	105	95	Indian (South)	84.62	85.46	p=0.104 (NS)
4	Jeremiah et al. (2013)[7]	150	80	70	Kenyans	82.57	83.48	p=0.472 (NS)
5	Fetouh & Mandour (2014-2013)[15]	52	30	22	Egyptian	82.27	83.5	p=0.175 (NS)

6	Sangvichien et al. (2007)[9]	101	66	35	Thai	83.5	86.61	p=0.027 (S)

Thus, from above discussion, it is clear that the sex differences in CI and NI are significant by 't' test but by D.P. method a very few crania if any could be sexed correctly (Table no. 2). It was observed that there was a lot of overlap in the values of male and female crania. So by D.P. method, neither of CI, NI or OI was found helpful in determining the sex of cranium.

Conclusion

1. In the present study the mean CI in male and female skulls was 74.68±4.21 and 77.12±4.92 respectively placing the Indian study population in Mesocephalic group.
2. Though the differences of CI in male and female skulls were statistically significant by t test, only 5% of male and 21% of female skulls could be identified from the Identification points. When subjected to demarking point analysis, no sex difference was possible from CI.
3. In the present study the mean NI in male and female skulls was 50.76±5.61 and 56.86±6.65 respectively placing the Indian study population in Leptorrrhine group.
4. Though the differences of NI in male and female skulls were statistically significant by t test, only 33% of male and 5% of female skulls could be identified from the Identification points. When subjected to demarking point analysis, no male skull could be identified and only 5% of female skulls could be identified from NI.
5. In the present study the mean OI in male and female skulls was 87.47±8.09 and 87.88±5.55 respectively placing the Indian study population in Mesoseme group.
6. Though the OI was less in male skulls than the female skulls, the differences were statistically insignificant excluding their role in the sexual dimorphism of the skull.
7. Thus, though the sex differences of CI and NI are significant by 't' test, none of the three cranial indices i.e. CI, NI and OI are reliable for sexual dimorphism of skull in general population as proven by demarking point analysis.

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