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Assessment of craniometric indices of adult human skulls of South Indian origin

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Abstract
Background: The determination of sex from human skeletal remains is of fundamental importance in any forensic, medico-legal investigations.
Aim: The aim of the present study was to measure the craniometric parameters of male and female adult human skulls of South Indian origin and calculate cranial, nasal, orbital, gnathic and upper facial indices. This study was undertaken to see the percentage relationship between different dimensions commonly used for sexual dimorphism of skull.
Material and Methods: This study was conducted in the Department of Anatomy, Osmania Medical College, Hyderabad, Telangana, India comprising of n=50 adult human skulls (19 female, 31 male) belonging to South Indian Origin. All the measurements were taken by using standard measuring devices and applying standard anthropometric techniques.
Results: The mean and SD of cranial indices in male was 75.32 ± 5.77, while in female (75.42 ± 5.52), nasal index in male was 52.19 ± 8.30 while in female 51.57 ± 5.11, orbital index in male 74.47 ± 9.21 while, in female 76.62 ± 11.59, gnathic index in male and female was 93.61 ± 5.25 and 93.01 ± 3.74 respectively, upper facial index in male 54.64 ± 5.85 and in female 46.14 ± 2.77. The data showed difference in male and female indices however, the differences were not statistically significant.
Conclusion: The minimal differences observed indicates less sexual dimorphism which could be due to smaller sample size (n=50) in our study. This study can be useful for sex differentiation of skeletal remnants.

Keywords: craniometry, indices, sexual dimorphism, skulls

Introduction

Forensic anthropometry is a scientific specialization that deals with identification of human skeletal remains with the help of metric techniques [1]. Craniometry is an important branch of anthropometry used for the measurement of various dimensions of skull bones useful for anthropologists, forensic experts, plastic surgeons, anatomists and oral surgeons for clinical as well as research purpose. Skull is one of the most preferred bones for identification and sexual dimorphism. Sex of an individual can be identified accurately in 90% of cases using skull alone [2].

Craniometry is employed in the measurement of cranial features to classify people according to race, criminal temperament, intelligence, and so forth. Several metrical parameters and indices have been used previously for sexual dimorphism of skull, to identify stature and race of the individual. Craniometric indices such as Cranial Index (CI), Nasal Index (NI), Orbital Index (OI), Gnathic Index (GI) and Upper Facial Index (UFI) are commonly used for sexual dimorphism of skull and are considered to be reliable. Several research studies stated to determine the sex in a high percentage of skulls [3-10].

Indices show the relationship between different dimensions (length and breadth) which can be expressed as ratios or percentages of comparison of two measurements and are important tools which may be used in categorizing human populations in different geological regions. The craniometric indices are also useful in the analysis and classification of fossil remains as well as study of living population. Indices can also demonstrate the degree of variations in different parts of human body caused by various disorders.

The general formula of index is the ratio of numerator (smaller measurement) to denominator (larger measurement) multiplied by hundred [11] and the ratios are often expressed as percentages.

Cranial index (CI) is ratio of the maximum breadth of the bare skull to its maximum length multiplied by hundred [11]. The skull is categorized into four types with a cranial index ≤ 74.9% as dolichocranic, 75 to 79.9% as mesocranic, 80 to 84.9% as brachycranic, 85 to 89.9% as hyperbrachycranic [12].

Nasal index (NI) is the ratio of maximum nasal width to its maximum length or height and the resultant factor multiplied by hundred. Nasal index has been classified as leptorrhine (slender nose) characterized by NI ≤ 46.9%, ranges between 47.0 and 50.9% as mesorrhine (moderate), between 51.0 to 57.9% as chamaerrhine (broad nose) and ≥ 58.0% as hyperchamaerrhine (very broad nose).

Orbital index (OI) is the ratio of greatest height of the orbital cavity to its greatest breadth multiplied by hundred. The skulls are categorized as chamaeconch (broad orbit) when OI is ≤ 75.9%, between 76.0 to 84.9% as mesoconch (moderate), ≥ 85.0% as hypsiconch (high orbit).

Gnathic index (GI) is the ratio of basion - prosthion length to basion - nasion length multiplied by hundred. The skulls are classified as orthognathous when GI ≤ 98%, between 99 – 103% as mesognathous and > 103% as prognathous.

The upper facial index (UFI) is the ratio of nasion-prosthion height to bizygomatic breadth multiplied by hundred. The skulls are classified as hypereuryene (very broad) when UFI is ≤ 44.9%, ranges between 45.0 to 49.9% as euryene (broad), 50.0 to 54.9% as mesene (medium), 55.0 to 59.9% as leptene (narrow), ≥ 60.0% as hyperleptene.

Therefore, the present study was aimed to measure various parameters of the adult human skulls of South Indian origin obtained from three different Medical Colleges of Hyderabad. Using these parameters craniometric indices were calculated and compared with previous research studies to assess the reliability of these indices for sexual dimorphism in human skulls.

Material and Methods

The present study was conducted in the Department of Anatomy, Osmania Medical College, Hyderabad, Telangana, India. A total of fifty (n=50) adult human skulls (19 female, 31 male) were collected from the Departments of Anatomy and Forensic Medicine of three different Medical Colleges of Hyderabad viz., Osmania Medical College, Gandhi Medical College and Deccan Medical College. Ethical clearance was taken from the Institutional Ethical Review Committee before undertaking the study.

All the skulls used in this study were dry, ossified, intact adult skulls free of any congenital deformity or artifacts. The skulls were placed in Frankfurt's horizontal plane and the measurements were taken using the instruments such as vernier sliding caliper and spreading calipers.

The measurements of various parameters such as maximum cranial length (glabella to opisthion length, GOL), maximum cranial breadth (right angles to the median sagittal plane), nasal height (NLH), nasal breadth (NLB), orbital height (OH), orbital breadth (OB), basion - prosthion length (BPL) and basion - nasion length (BNL), upper facial height (nasion to prosthion), maximum bizygomatic breadth (ZYB) were taken following the guidelines of Das and Ranjan Deka [13]. Using these parameters cranial, nasal, orbital, gnathic and upper facial indices were calculated according to the standard formulae [14].

Following parameters were measured in all the skulls:

1. Maximum cranial length (Glabella-opisthion, GOL) - from glabella to the opisthion in the mid-sagittal plane on occipital bone (opisthocranium) (Fig. 1A).
2. Maximum cranial breadth (CB) - perpendicular to median sagittal plane (just above the supramastoid crests) (Fig. 1B).
3. Nasal height (NLH) - from nasion to the lowest tip of the nasal aperture on either side (Fig. 2A).
4. Nasal breadth (NLB) - maximum breadth between the two lateral margins of the nasal apertures (Fig. 2B).
5. Orbital Height (OH) - the maximum height between the upper and lower borders of the orbit (Fig. 3A).
6. Orbital Breadth (OB) - distance from ectoconchion to dacrion (approximating the longitudinal axis which bisects the orbit into upper and lower parts) (Fig. 3B).
7. Basion-prosthion length (BPL) - between basion and prosthion (Fig. 4A).
8. Basion-nasion length (BNL) - between basion and nasion (Fig. 4B).
9. Upper facial height (nasion-prosthion height) - from nasion to prosthion (Fig. 5A).
10. Maximum bizygomatic breadth (ZYB) - maximum breadth across the zygomatic arches, perpendicular to the median plane (Fig. 5B).

Craniometric indices were calculated using the standard formulae

$$\text{cranial index} = \frac{\text{maximum cranial breadth}}{\text{maximum cranial length}} \text{ X } 100$$

$$\text{nasal index} = \frac{\text{nasal breadth}}{\text{nasal length}} \text{ X } 100$$

$$\text{orbital index} = \frac{\text{orbital breadth}}{\text{orbital length}} \text{ X } 100$$

$$\text{gnathic index} = \frac{\text{basion} - \text{prosthion length}}{\text{basion} - \text{nasion length}} \text{ X } 100$$

$$\text{upper facial index} = \frac{\text{nasion} - \text{prosthion height}}{\text{bizygomatic breadth}} \text{ X } 100$$

A comparative study of these indices was done with those of the previous studies of various authors who worked on the skulls from different regions of India. All the indices such as CI, NI, OI, GI and UFI were calculated for each skull and their descriptive statistics i.e. mean, standard deviation (SD) and range were calculated in both the genders. The differences of means between the male and female indices were compared for significance using the Student t-test. The differences with a probability level less than 0.05 ($p \leq 0.05$) was considered as statistically significant.

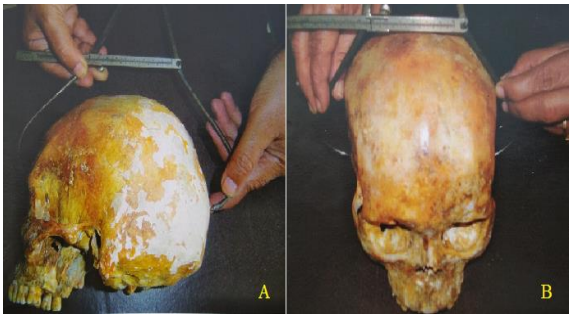

Fig 1.A: Glabella-occipital length, B- Maximum cranial breadth

Fig 2.A: Nasal height, B- nasal breadth

Fig 3.A: Orbital height, B- orbital breadth

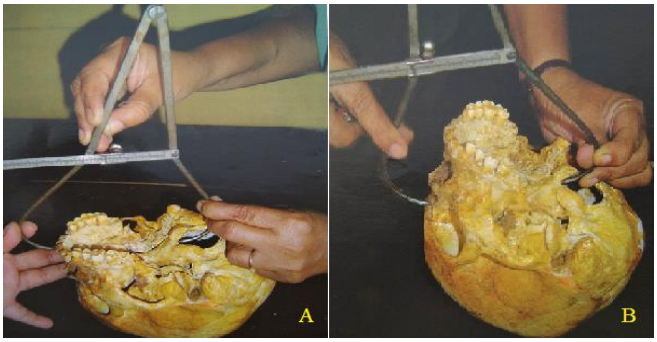

Fig 4.A: Basion-prosthion length, B- basion-nasion length

Fig 5.A: Nasion-prosthion height, B- bizygomatic breadth

Results and Discussion

Various craniometric measurements like cranial length (Fig. 1A), breadth (Fig. 1B); nasal height (Fig. 2A), breadth (Fig. 2B); orbital height (Fig. 3A), breadth (Fig. 3B); basion - prosthion length (Fig. 4A), basion - nasion length (Fig. 4B), upper facial height (Fig. 5A), bizygomatic breadth (Fig. 5B) were measured in fifty (n=50) adult human skulls which included n=31 male and n=19 female subjects. These measurements were taken in millimeters and converted to centimeters. Craniometric indices viz., cranial index, nasal index, orbital index, gnathic index and upper facial index were calculated using the above parameters.

Table 1: Means ± SD, maximum, minimum, sexual dimorphism ratios of craniometric parameters of male (n=31) and female (n=19) skulls in the present study

Parameters	Sex	Mean ± SD	Maximum (cm)	Minimum (cm)	Sexual dimorphism ratio*	$p \leq 0.05$
Cranial length	M	17.92 ± 0.6	19.1	17.1	1.12	> 0.05
	F	17.1 ± 0.77	18.4	15.8		
Cranial breadth	M	13.4 ± 0.96	15.0	11.2	1.08	> 0.05
	F	12.9 ± 0.46	13.9	10.4		
Nasal length (height)	M	4.9 ± 0.30	5.4	4.1	1.04	> 0.05
	F	4.7 ± 0.34	5.3	4.0		
Nasal breadth	M	2.58 ± 0.28	2.9	1.5	1.17	> 0.05
	F	2.4 ± 0.12	2.6	2.2		
Orbital height	M	3.15 ± 0.36	3.6	2.1	0.97	> 0.05
	F	3.3 ± 0.19	3.8	3.0		
Orbital breadth	M	4.2 ± 0.28	4.7	3.4	1.02	> 0.05
	F	4.1 ± 0.24	4.4	3.6		
Basion-prosthion length	M	9.5 ± 0.50	7.0	5.6	1.08	> 0.05
	F	9.03 ± 0.51	7.0	5.3		
Basion-nasion length	M	10.2 ± 0.40	10.9	8.5	1.05	> 0.05
	F	9.72 ± 0.59	11.0	8.7		
Upper facial height	M	6.5 ± 0.39	7.0	5.6	1.08	> 0.05
	F	6.0 ± 0.43	7.0	5.3		
Bizygomatic breadth	M	5.47 ± 0.52	13.0	10.2	1.02	> 0.05
	F	4.97 ±,0.33	12.8	10.6		

Sexual dimorphism ratio* = Male mean / Female Mean

Table 2: Maximum, minimum, Mean ± SD of craniometric indices (%) of male and female skulls in the present study

Parameters (%)	Male (n=31)			Female (n=19)			M+F (n=50)
	Max	Min	Mean±SD	Max	Min	Mean±SD	Mean±SD
Cranial index	81.76	59.77	75.32±5.77	78.82	69.66	75.42±5.52	75.21±5.72
Nasal index	62.22	36.58	52.19±8.30	61.90	45.28	51.57±5.11	51.95±7.20
Orbital index	85.63	55.26	74.47±9.21	89.19	54.61	76.62±11.59	75.30±10.11
Gnathic index	99.02	84.62	93.61±5.25	97.87	85.86	93.01±3.74	93.41±4.70
Upper facial index	66.7	46.3	54.64±5.85	57.20	45.10	46.14±2.77	52.81±5.95

Max- maximum, min- minimum

Table 3: Classification of skulls based on percentages of craniometric indices in the present study

Indices	Indices (%)	Male	Female	Total skulls (%)	Type of skull
Cranial index	Upto 74.9	14	7	21 (42)	Dolichocranic
	75.0 – 79.9	12	12	24 (48)	Mesocranic
	80.0 – 84.9	5	-	5 (10)	Brachycranic
Nasal index	Upto 46.9	5	1	6 (12)	Leptorrhine
	47.0 – 50.9	5	9	14 (28)	Mesorrhine
	51.0 – 57.9	17	8	25 (50)	Chamaerrhine
	≥ 58.0	4	1	5 (10)	Hyperchamaerrhine
Orbital index	Upto 75.9	19	5	24 (48)	Chamaeconch
	76.0 – 84.9	10	11	21 (42)	Mesocconch
	≥ 85.0	2	3	5 (10)	Hypsiconch
Gnathic index	≤98	28	18	46 (92)	Orthognathous
	98 – 103	4	-	4 (8)	Mesognathous
	>103	-	-	-	Prognathous
Upper facial height index	Upto 44.9	3	5	8 (16)	Hypereuryene
	50.0 – 54.9	11	11	22 (44)	Mesene
	55.0 – 59.9	6	2	8 (16)	Leptene
	≥ 60.0	10	2	12 (24)	Hyperleptene

The mean cranial length in male and female skulls was 17.66cm (range 15.8 -19.1cm), in male skull it was 17.92cm (range 17.1-19.1cm) and female skulls 17.1cm (15.8-18.4cm) (Table 1). The mean cranial breadth in male and female subjects was 13.2cm (12.2-15.0cm), in males and females it was 11.2cm (11.2-15.0cm) and 12.9cm (10.4-13.9cm) respectively.

Cranial indices (CI) give numerical expression to certain features of the skull, which can be difficult to describe otherwise. The mean cranial index in male skulls was 75.32% (59.77-81.76%) and in females 75.42% (69.66-78.82%) (Table 2). As reported in our [15] previous study the differences in cranial indices of male and female skulls were not significant (p>0.05) in confirmation with similar findings of Adejuwon *et al.* [8] and Williams *et al.* [16]. Our results are contradictory to the findings in which the CI was significantly higher for female crania than male [10]. Mahajan and Gandhi [9] and Adejuwon *et al.* [8] observed higher CI in males than females. These studies were carried out on different Indian population from different regions, which may be reason for difference in cranial index.

Based on cranial index the skulls were classified according to Ashley Montagu [14] and listed in Table 3. In our earlier report, n = 21 (42%) skulls were dolicocranic, n = 24 (48%) mesocranic and n = 5 (10%) brachycranic. In the present study, we have categorized male and female skulls based on the mean cranial index, n = 14 (28%) male and n = 7 (14%) female skulls belonged to dolicocranic (long head), n = 12 (24%) each of male and female to mesocranic (medium size head), n = 5 (10%) male skulls to brachycranic (short head) and no skull (n = 0) belong to Hyperbrachycranic (very short head) group. Hence, in this study dolicocranic and mesocranic were the commonest head shapes.

However, Dhall and Gopinath [17] observed most of the North Indian skulls belong to dolicocranic group. Jayasingh and his associates [18] reported 57.3% skull belong to dolicocephalic contradictory to our study findings of Samata Roshini and Nausheen [15]. Human knowledge of paleontology and available data suggest that early man was generally dolicocephalic. Brachycephaly developed later as a result of repeated mutation and various other factors.

It is interesting to note that cranial index varies significantly among populations in different geographical zones [19] and in different ethnic groups [20]. Bharati *et al.* [19] reported dolichocephalic head form in tropical zones, but in temperate zones mesocephalic or brachycephalic form. The genetic factors may also influence the cranial shape.

The mean nasal height in male and female was 4.8cm (Table 2). The mean nasal height was 4.9 and 4.7cm in male and female respectively and the differences were not statistically significant (p > 0.05). The mean nasal breadth in male and female was 2.5cm. The mean nasal breadth in male and female was 2.8 and 2.4cm respectively and the differences between male and female were not statistically significant (p > 0.05). Vidya *et al.* [21] reported nasal breadth 2.36 ± 0.26 and 2.23 ± 0.24cm, nasal height 4.79 ± 0.57 and 4.54 ± 0.35cm for male and females respectively similar to our observations. Kranioti and Iscan [22] reported higher nasal breadth and height in male than female subjects contradictory to our findings.

Nasal index (NI) has been a useful tool in Forensic Science as it exhibits sexual dimorphism [23]. The mean nasal index in male and female was 51.95% (ranges 36.58 - 62.22%). The mean nasal index in male was 52.19% (36.58-62.22) and in female 51.57% (45.28-61.9%) exhibiting no statistically significant differences between male and females. The present study results are in supportive with the findings of Vidya *et al*, [21], Chaturvedi and Hameja [24] in Indian skulls, Jaya Singh *et al.* [18] in Uttar Pradesh skulls, Sree Latha [25] in Andhra Pradesh skulls. However, contradictory observations were reported in the studies made by Kotian *et al.* [2] on south Indian skulls, by Orish and Ibeachu [3] in Nigerian, Mahakkanukrauh *et al.* [4] on Thai skulls in which the NI was found to be significantly higher in female than male crania.

In the present study, 6 (12%) skulls belong to Leptorrhine (slender nose), 13 (26%) skulls to mesorrhine (moderate), 26 (52%) to Chamaerrhine (flat) and 5 (10%) to Hyperchaemarrhine (very flat). Most nasal indices analysis shows that sexual dimorphism exist between tribes. Nasal index which is a physical characteristic of a race appears to show a marked relation to climate, broad nose being associated with hot moist

climate and narrow noses with cool dry conditions.

The mean orbital height in male and female is 3.2cm (ranges 2.1 - 3.8cm). The mean orbital height in male was 3.2cm (2.1-3.6cm) and in female 3.3cm (3.0-3.8cm). The mean orbital breadth in male and female was 4.2cm (3.4 to 4.7cm). The mean orbital breadth in male was 4.2cm while in female 4.1cm. The data shows that the orbital breadth was higher than height which can be attributed to racial differences. Our results are similar to the observations made in previous studies by Gosavi *et al*. [26] in central Indian skulls, Kaur *et al*. [27] in North Indian skulls and Ebeye and Otikpo [28] in Nigerian skulls.

The orbital height and breadth showed no statistically significant differences between male and female in the present study in confirmation to the previous studies [10] exhibiting no significant difference between the two genders. The minimal differences observed could be due to environmental and genetic factors or due to a smaller sample size in our study (n=50).

The mean orbital index (OI) in male and female was 75.30% (ranges 55.26 - 89.19%). The mean orbital index in male and female was 74.47% (55.26-85.36%) and 76.62% (54.61-89.19%) respectively. Ebeye and Otikpo [28] in their study observed orbital index 78.15% which is slightly higher than our observed findings (74.47 and 76.62%) for male and female respectively. However, several research studies on Indian population reported orbital index 81.65% [28] (Kaur *et al*., 2012), Deepak Howale *et al*. [29] 86.4%, Mekala *et al*. [5] 85.8% which were much higher than our results (75.30%).

The orbit with larger width than height will have smaller orbital indices and have broad faces while, the orbital index vice versa will have narrow faces. The OI is determined by the shape of the face and varies with race, regions within the same race and periods in evolution.

Though, the orbital index in female was slightly higher than in male skulls, the differences were however, not statistically significant to warrant the use of OI in sexual dimorphism of skulls in the present study South Indian population. However, Sangvicichien *et al*. [10] observed significantly higher OI in female than male skulls of Thai population.

In the present study, 24 (48%) skulls were categorized as chamaeconch (broad orbit), 21 (42%) mesoconch (moderate) and 5 (10%) as hypsiconch (high orbit) (Table 3). The mean orbital index (75.30%) recorded in this study was slightly lower than previous study observations [18, 24, 25].

The mean basion-prosthion length (BPL) in male and female was 6.3cm (7.0 to 8.2cm). The mean BPL in male and female was 6.5cm (5.6-7.0cm) and 6.0cm (5.3-7.0cm) respectively. The mean basion-nasion (BNL) in male and female was 10.02cm (8.5 to 11.0cm). The BNL in male and female was 10.2cm (8.5-10.9cm) and 9.7cm (8.7-11.0cm) respectively. The mean BPL and BNL showed no significant differences between male and female skulls contradictory to the results reported by Deshmukh and Devershi [30].

The mean gnathic index in male and female was 93.41% (ranges 84.62 - 99.0%). The mean gnathic index in male was 93.61% (84.62-99.02%) and in female 93.01% (85.86-97.87%) in supportive to the findings of earlier studies [18, 24].

The mean upper facial height in male and female was 6.3cm (ranges 5.3 to 7.0cm). The mean upper facial height in male was 6.5cm (5.6-7.0cm) and in female it was 6.0cm (5.3-7.0cm). The mean bizygomatic breadth in male and female was 11.6cm (10.2 to 13.0cm). The mean bizygomatic breadth in male was 11.9cm (10.2-13.0cm) and in female it was 11.7cm (10.6-12.8). The mean upper facial index (UFI) in male and female was 52.8% (45.1 to 66.6%). The UFI in male was 54.64% (46.3-66.7%) and in female 46.0% (45.1-57.2%) which was significantly higher than male UFI. According to the classification, 9 (18%) skulls were grouped as Hypereuryene (very broad), 22 (44%) to mesene (medium), 7 (14%) as leptene (narrow) and 12 (24%) as Hyperleptene.

Conclusion

The result of present study showed slightly higher cranial, nasal gnathic, upper facial indices of male than female skulls and orbital index was slightly higher in female compared to male. However, the differences were not statistically significant indicating less sexual dimorphism in this study. More studies need to be conducted with large sample size and in different population groups. Knowledge of craniometric indices will be helpful for forensic experts with respect to classification of races and sexes and for clinical and research purpose.

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