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CT scan images for sex discrimination – a preliminary study on Gujarati population

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ABSTRACT

Objectives: Sex estimation of skeletal remains can lead the forensic anthropologist to the identification of the remains. Skull is one of the most encountered skeletal remains. Different craniofacial parameters have differing capacities to estimate the sex.
Materials and methods: In present study, volume rendered CT scan images of 143 adult living patients (66 female and 77 male) were studied. The criteria for inclusion were Gujarati origin and patients without fracture of the skull. The cranio-facial parameters studied were maximum frontal breadth, minimum frontal breadth, maximum cranial length, morphological facial height, nasion–prosthion length, bizygomatic breadth and bimaxillary breadth.
Results: Accuracy of sex estimation ranges from 61.3% to 88.7%, making the maximum cranial length and bizygomatic breadth best individual parameters with accuracy of 78.2%. The highest accuracy of 88.7% was obtained with combination of maximum cranial length, bimaxillary breadth and morphological facial height.
Conclusion: Discriminant function for identification of sex was obtained with satisfactory accuracy rates for the parameters under study. It indicates that the skulls of Gujarati population are dimorphic enough to identify the sex of unknown skulls obtained from crime scene.

1. Introduction

In recent years role of forensic anthropologists in crime investigation as well as in other kinds of investigations has been increased tremendously. An anthropologist assists the identification of human remains by creating a biological profile through the analysis of sex, ancestry, age, and stature. Sex estimation of these skeletal remains is one of the key functions of the forensic anthropologist as it lowers down the number of probable victims to the half. The accuracy of the sex estimation from skeletal remains varies according to bones and their fragmentary condition, intrinsic variability in the studied population and choice of method. The maximum accuracy of sex estimation is obtained when the whole skeleton is available for the purpose [1]. Several metric studies have claimed to obtain better classification accuracies using different parts of skeleton [2–11]. Study of morphological features of the skull includes determination of the presence or absence and the extent of the development of different features in both the sexes [12–14]. Sex can be determined with the accuracy level of more than 80% when morphological traits are studied [13]. But basic need for morphological examination is the judgement capacity and expertise of the examiner which makes the scope of method very limited. The alternate and more reliable approach is the metrical one which uses different linear and angular measurements of the skull, which are totally based on the pre-defined landmarks. Different parts of the skulls are used for measurements and the accuracy levels for sex estimation also vary with the part of the skull involved in the study [15–43,45–47]. Further, some populations are considered to be much dimorphic, e.g. African black.

The types of the samples used for different anthropological studies, conducted to estimate the sex, also vary. Generally, the dried skulls from the collection of particular origin are used as samples for the study which do have all the details regarding their identification like sex, age, stature and origin. Use of skulls, freshly extracted from dead bodies is also an alternate to these kinds of collections. Here, the pre-treatment is required to remove the flesh adhered to the subjected bone [48]. In the case of unavailability of any type of skulls with the required data, different radiographic techniques can be used. [37]. The cephalograms have been widely used in the field of forensic anthropology, including in the sex

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estimation [37–44]. The use of CT images for the purpose is also growing at a constant pace [45–47,49–54]. We have carried out the study of CT images of the neurocranium and face for the purpose of determining the origin from different cranio facial indices of Gujarati population [55]. This attempt of using CT images for anthropological studies provided us encouraging results which prompted us to use this technique for the purpose of the sex discrimination here in the present study. The accuracy rate of the anthropological studies by using the CT scan images is not less as compared to the use of the dry skulls [50].

The size and shape of skull are affected by external factors like culture, climatic condition, geographical conditions, food habits, and occupations along with the genetic factor [56,57]. In a country like India, where diversion of population is found to a great extent due to the diversion in all the external factors affecting the bone development and bone appearance, regional studies must be promoted [28]. Hence, the objective of present study is to examine the sex discriminating efficiency of cranial parameters which will provide a platform to evaluate the ability of selected parameters to determine the sex in forensic sample using CT scan images of Gujarati population.

Gujarat is a state in the North Western part of India. It is locally known as *the Jewel of the West*. In postcolonial Gujarat, the merchant culture and its values of purity and economical wealth have played important roles in shaping the present culture in Gujarat [58]. The climate of Gujarat involves diverse conditions, temperature ranges from 12 °C to 29 °C in the winters. The summers are extremely hot and dry with daytime temperatures around 49 °C and at night not lower than 30 °C. In terms of ancestry, Gujarat shares similar genes with the remainder of the Indian population, but exhibit a significant relationship with Western Asia. A 2004 Stanford study conducted with a wide sampling from India, found that over 33% of genetic markers in Gujarat were partially of West Eurasian origin [59]. The majority of Gujarat is are Hindus (89.53%) followed by 8.53% Muslims, 1.37% Jains, .03% Zoroastrians (Parsi), .39% Christians, .02% Buddhists, .07% Sikhs, 1.96% ‘other religions’ [60]. In addition, scheduled tribes (adivasis) constitute 14.22% of the total population of the state [60].

2. Materials and methods

2.1. Materials

The samples for anthropological measurements were the CT scan of the neurocranium and face of 143 adult patients (77 male and 66 female), age ranging from 21 years to 60 years, arriving at Department of Radiology, Sheth V. S. Hospital, Ahmedabad, Gujarat. The subjects suffering from any fracture in neurocranium or face were not included in the study. All the subjects included in the study were having the Gujarati origin, which was confirmed by confirming the history of their forefathers.

2.2. Methods

The computed tomography scan was done with the machine Philips Brilliance 16 Slice MDCT. The technical features of the machine include current of 250 mA and potential difference of 120 kV. The thickness of slice was 1 mm. The pitch is .688 and collimation is 16 × .75. The workstation namely Philips Brilliance Workspace can show the volume rendered image on the computer screen as it is evinced in the Fig. 1. The landmarks were identified and located along the volume rendered image present on the computer screen manually, according to the definitions given in the citation. The workstation has a facility to give distance between two points. Different measurements are also predefined according to the reference and thus distance between two landmarks was measured by this kind of facility. Craniofacial measurements named maximum frontal breadth, minimum frontal breadth, maximum cranial length, morphological facial height, nasion–prosthion length, bizygomatic breadth and bimaxillary breadth were measured at the workstation for all the subjects. The intra-observer variability was checked by conducting one way ANOVA test and the result is shown in Table 1. The discriminant function analysis was done with the use of SPSS 22.00 to find out the ability of all these parameters to differentiate between sexes.

The measurements were taken according to Martin and Saller and Singh and Bhasin [61,62]. The landmarks are identified as shown in Fig. 1.

Maximum frontal breadth (MAXFB): It is the straight distance between two coronalia (co–the most laterally placed points on coronal sutures).

Minimum frontal breadth (MINFB): It is the straight distance between two fronto temporalia (ft – the most projected and the inward point of the superior temporal line).

Maximum cranial length (MAXCL): It is the straight distance between glabella (g – the point which lies at the root of the nose and between the supra-orbital ridges on the forehead) and opisthocranion (op – the most posteriorly projecting point in the mid-sagittal plane, lying mostly on the external occipital protuberance).

Morphological facial height (MFH): It is the straight distance between nasion (n – the point where the frontonasal suture meets the mid-sagittal plane) and gnathion (gn – the lowest point on the lower margin of the lower jaw in the mid-sagittal plane).

Nasion–prosthion length (NPL): It is the straight distance between nasion (n – the point where the frontonasal suture meets the mid-sagittal plane) and prosthion (pr – the point which lies on the alveolar margin of the upper jaw in the mid-sagittal plane).

Bizygomatic breadth (BZB): It is the straight distance between two zygia (zy – the most laterally placed points of the zygomatic bone).

Bimaxillary breadth (BMB): It is the straight distance between two zygomaxillaria (zm – the deepest point on the zygomaxillary suture).

3. Results

Table 1 shows the result of one way ANOVA test conducted to check the intra-observer variability. The result shows that there is no significant difference in three observations of each parameter. Table 2 describes means and standard deviations along with the results of univariate ANOVA for each independent variable and their predictive accuracies. All the measurements were significantly higher ($p < .0001$) in males than in females, as shown by t-values. The highest sexual dimorphism index (SDI) is calculated for BMB i.e. the female measurement of BMB is 7.79% smaller than males in Gujarati population. Average classification accuracies for studied variables range from 61–78.2%.

The results of stepwise analysis are displayed in Table 3. Of the seven variables entered into the function, three variables, MAXCL, MFH and BZB were selected to provide maximum classification of sex. The Wilk's lambda shows the percent contribution of each measurement, and determines the order of variables to enter the function. Lambda ranges between 0 and 1. The values close to 0 indicate that the means of two groups are different, and values close to 1 indicate that there is no difference between the two means. Here, the MAXCL is the first measurement to be selected by stepwise discriminant analysis.

Once the variables that provide maximum discrimination were obtained, various other functions were generated by using direct discriminant analysis. This was done keeping in mind the various fragmentary conditions of skull encountered in forensic anthropology