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SHORT COMMUNICATION

Estimation of stature from cranial sutures in a South Indian male population

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Abstract The aim of this study was to investigate the possibility of estimating height from length of coronal and sagittal sutures of the skull for the positive identification of the height in forensic investigations concerned with fragmentary skeletal remains. The study was conducted on 87 male bodies subjected to medicolegal autopsy in the Department of Forensic Medicine, Kasturba Medical College, Manipal, South India and the Department of Forensic Medicine, Kasturba Medical College, Mangalore, South India. Length of coronal suture was measured from left pterion at the junction of sphenoparietal with the sphenofrontal suture, along the coronal plane, over the coronal suture to the pterion on the right side. Length of sagittal suture was measured from bregma along the sagittal plane over the sagittal suture to the lambda. The data collected were subjected to statistical methods. Significant correlation was found between height and coronal suture length in males, when compared to sagittal suture. The correlation coefficient between height and coronal suture was 0.363. The correlation coefficient between height and sagittal suture was 0.090. Linear regression equations for stature estimation were derived from coronal suture length in male population. Coronal suture length gives more accurate results in estimating stature than sagittal suture. However, in cases where identification is required by means of only skull, this method could prove useful.

Keywords Stature · Skull · Coronal suture length · Sagittal suture length · Linear regression equation · Identification

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Introduction

The living has responsibilities for the dead and, in particular, civilized societies recognize the need for identity both during life and death [1]. In medicolegal investigations, identification of a person or dead body is important as it helps in connecting the criminal to the crime [2]. In both diagnostic fields, a two-stage strategy is recommended to use “field” methods that are quick and easy but more imprecise and then “ laboratory” methods that are time consuming but are more precise. For sexing and ageing nonadults, the field methods are tooth mineralization, long bone length, epiphyses development, morphological skull, and pelvis characteristics. The advanced laboratory method for sexing and ageing adults is molecular biology and aspartic acid racemization, respectively [3]. In cases of advanced decomposition, skeletal examination may help in identification, since bone resists decomposition for a long time [4]. Along with sex, age, and race, stature is one of the biological entities that can be estimated from the skeleton long after the death of an individual. Studies have shown that stature can be estimated from length of long bones, bone fragments, spine, foot dimensions, metacarpal and metatarsal lengths, scapula, and from somatometry of the skull [5–11]. Estimation of living stature of an individual from various body parts is considered as an important tool in personal identification. This is based upon the definite biological relationship of stature with all body parts like extremities, head, trunk, vertebral column, etc [12]. In the last few decades, forensic scientists along with anthropologists used foot dimensions and shoe size to estimate body size, sex, and stature [13, 14]. Knussmann and Sperwien [15] studied interindividual correlations between androgen hormone levels and anthropometric features in healthy young men. The total testosterone and dihydrotestosterone were found to have a number of significant correlations with the various body measures and factors, while the free testosterone did not yield any significant findings [15]. Numerous studies have shown that regression equations derived for stature estimation from intact long bones of the upper and lower extremities are accurate and are population and sex specific. Since intact long bones are not always available for forensic analysis, other researchers have used fragments of long bones for stature estimation with various degrees of success [16].

In certain medicolegal cases, where only head and face are available for examination, it becomes difficult for a forensic specialist to identify the deceased [17–20]. When a skull of unknown origin is found and no other means of identification is possible due to decomposition, then the ability to determine sex, age, population affinity, and stature from the skull is of great value. A few studies have been conducted in the past by Introna et al. [21], Chiba and Terazawa [10], and Patil and Mody [22] which focus on the determination of stature from cephalofacial and craniofacial material. Van der Lugt et al. [23] established a relationship between person's stature and the height of an ear print from the floor and explained its usefulness in forensic cases. Krishan and Kumar [12] estimated stature from cephalofacial dimensions in Koli male adolescents of North India and tested the reliability and accuracy of regression formulae in the same population and mixed population of North India. It is therefore the aim of this preliminary study to assess the usefulness of the measurements of the length of skull sutures and derive linear regression equation for estimation of stature for the indigenous South Indian male population group.

Materials and methods

The present study was conducted at the Department of Forensic Medicine, Kasturba Medical College, Manipal, South India and the Department of Forensic Medicine, Kasturba Medical College, Mangalore, South India from March 2004 to June 2005. The study material comprised of 87 male autopsy cases of South Indian origin aged between 20 and 60 years. The age of the individuals was retrieved from the inquest documents furnished by the police, hospital records, and legal heirs. The bodies that were decomposed, charred, mutilated, and with physical anomalies, skulls with premature obliteration of sutures, and the presence of epipteric ossicles between the parietal and sphenoid bone were excluded from the study.

The body was placed in supine position on the flat hard surfaced autopsy table, with the knee and hip joints extended, and the neck and feet in a neutral position. The cadaver length (stature) was measured from the vertex of the head to the base of the heel using a steel measuring tape according to the technique described by Nagesh and Kumar [4]. The whole thickness of the scalp was incised between the mastoid processes over the vertex in the coronal plane using a Bard-Parkers knife. The anterior and posterior halves of the scalp were separated from the skull and then reflected forward and backward. The anterior flap was reflected to a level of 2 cm above the supraorbital ridge. The posterior flap was reflected down to a level just above the occipital protuberance. The temporalis muscle was incised along the superior temporal line on both sides. The soft tissues adherent to the periosteum along the coronal and sagittal sutures were scraped manually until the suture line over the vertex, the pterion on both sides, bregma, and lambda were clearly visible. The length of coronal and sagittal sutures was measured using a non-extensible thread (polypropylene twine, manufactured by Oswal Poly Tech, Bangalore, South India) and a metal scale graduated in millimeters. The following measurements were selected because of the ease with which they could be reproduced and included:

1. Length of the coronal suture: One end of the inelastic thread was placed over the right pterion at the junction of the sphenoparietal [24] with the sphenofrontal sutures [24] and passed along the coronal plane, over the coronal suture to the pterion at the junction of the sphenoparietal with the sphenofrontal sutures on the right side.
2. Length of the sagittal suture: One end of the inelastic thread was placed over the bregma (junction of coronal suture with sagittal suture) and passed along the sagittal plane over the sagittal suture to the lambda (junction of sagittal suture with the lambdoid sutures).

All the measurements were recorded by one author to minimize measurement error. The data were analyzed using Statistical Package for Social Sciences (version 10.0), to derive a linear regression equation for stature estimation. To assess the correlation between stature and the length of coronal and sagittal suture Pearson's correlation coefficient was calculated and its significance was tested by Students *t* test. *P* value of less than 0.05 was considered as significant.

Results

Mean (± standard deviation (SD)) age of the study sample was 39.72 (±13.33). Stature ranged from 150 to 181 cm with a mean of 166.83 (±6.74). The length of the coronal suture ranged from 22 to 27 cm with a mean (±SD) of 23.97 (±1.20). The linear regression equation Stature (cm)= 117.98+(2.04×Coronal suture length) was derived to estimate the stature from the length of the coronal suture. The correlation coefficient was 0.363. The standard error of the estimation was 5.67 cm. The 95% confidence interval for a stature prediction using the linear regression equation ranged from 0.75 to 1.47 cm. The results derived from the present study were statistically significant (*P*=0.001; Fig. 1).

The length of the sagittal suture ranged from 10 to 15 cm with a mean (±SD) of 12.92 (±0.77). The correlation coefficient was 0.090. The standard error of the estimate was 9.42 cm. The results derived from the present study were statistically not significant (*P*=0.408; Fig. 2). Hence, a linear regression equation to estimate the stature from the length of the sagittal suture could not be derived.

Discussion

Identification of human remains is a major challenge in every country. There are numerous techniques of identification, some of them being reconstructive and others comparative techniques [25–27]. The ultimate goal is positive identification by antemortem and postmortem comparison and craniofacial reconstruction techniques may only be a lead towards a proposal for identification [28]. Quatrehomme et al. [28] estimated the accuracy of craniofacial reconstruction from a series of 25 controlled cases and showed that a thorough anthropological, odontological, and X-ray analysis is indispensible before performing craniofacial reconstruction. Morphological trait analyses for sexing skeletons are well established, but they may be difficult due to breakage or postmortem damage of the skeletal remains. Ramsthaler et al. [29] verified the applicability of software-based sex estimations outside the reference population group for which discriminant equations were developed. Braga and Treil [30] developed a method for estimating the skeletal age of children based on the centroid size of their face and their basicranium, derived from the three-dimensional coordinates of anatomical landmarks and showed that the centroid size of the facial skeleton can be used an age-related variable without any loss of accuracy with increased age, contrary to most of the methods of pediatric age estimation.

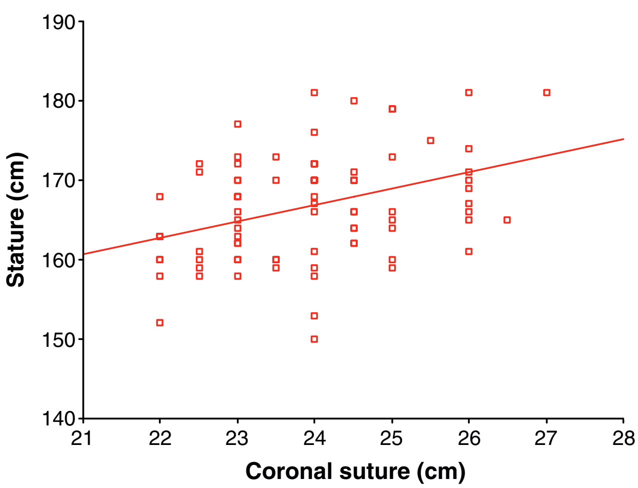

Fig. 1 Relationship between coronal suture length and stature

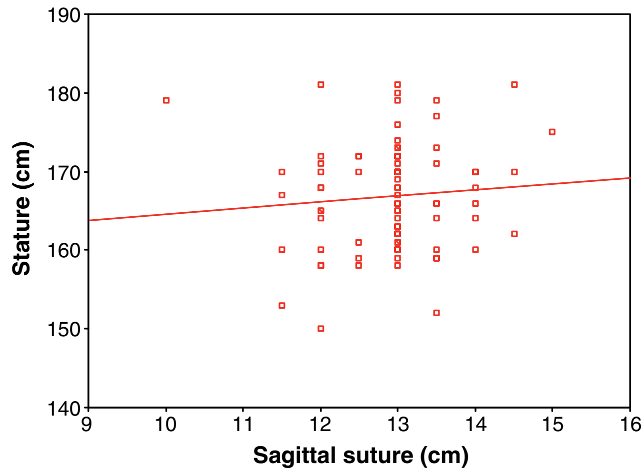

Fig. 2 Relationship between sagittal suture length and stature

Various methods are used to establish the identity of unknown human remains [31]. Estimation of stature and body size is of great interest to forensic and physical anthropologists. A detailed account of the different methods of stature estimation and body size from bones using various techniques is well documented in previous studies by Olze et al. [32]. Among the forensically relevant skeletal remains, the skull is greatly overrepresented, simply because the laymen who normally report the skeletal findings can easily see the human nature of the skull, but not of other bones. In cases where the identification has to be performed based on skeletal remains, stature is usually estimated by applying the regression equation to the length of intact long bones of the upper and lower extremities [10, 14, 33]. A drawback to the techniques used is the limited applicability to fragmentary remains [34]. This has necessitated the need to assess the usefulness of measurements of fragments of long bones in the estimation of stature. Bidmos [33] derived regression equations for estimation of the maximum length of the femur and stature from fragments of the femur in indigenous South African population. The difficulty in developing a stature estimation formula is the availability of skeletal series with known body height data [14]. When the body has been mutilated, it is common to have the extremities or head amputated from the trunk. An estimate must then be made based on the known relationship of the remains to stature [35]. The estimation of living stature from long bones is based on the principle that the long bones correlate positively with stature. Since this is true, parts of each bone should also be related to stature even though they may not correlate as highly [36]. In South India, linear regression equations have been derived for stature estimation from measurements of different segments of the vertebral column [4], hand dimensions [2], and by using odontometry and skull anthropometry [37].

A few studies worldwide have been conducted on stature estimation from the skull. Chiba and Terazawa regressed cadaver length on to three skull variables (skull diameter, skull circumference, and the sum of the diameter and circumference) to estimate stature for a Japanese sample [10]. Krogman and Iscan reviewed the use of radiography in anthropology such as calculation of the cranial capacity, identification by means of sinus pattern and sphenoid sella turcica shape, and of victims of mass disasters [38]. Patil and Mody [22] used measurements of the skull from lateral cephalometric radiographs for sex determination and stature estimation and derived a regression equation from the length of the skull which they concluded is very reliable in the estimation of stature. Kalia et al. [37] used measurements of the skull from lateral cephalometric radiographs and mesiodistal crown width of the six maxillary anterior teeth to derive regression equation in estimating stature. Introna et al. [21] performed somatometry on maximum anterior–posterior and lateral diameter of skull and reported the feasibility of obtaining an estimation of stature from the skull through calculating correlation coefficients by multiple linear regression, from young age male samples ranging in age between 17 and 27 years old. To our limited knowledge, no studies have derived linear regression equations to estimate stature using cranial sutures. The present study was an attempt to estimate the stature of male individuals from the coronal and sagittal suture length in a South Indian population group and to compare the reliability of this study with other somatometric measurements of the skull.

In the present study, the correlation coefficient for the linear equation using coronal suture length was 0.363. The length of the coronal suture length showed less correlation coefficient to estimate stature when compared to somatometry of the skull variables (skull diameter, skull circumference, and the sum of the diameter and circumference), as described by Chiba and Terazawa in Japanese male cadavers [10]. The authors [10] reported a correlation coefficient of 0.43 for estimating stature using skull variables. Ryan and Bidmos [16] reported correlation coefficients to estimate stature using combination of various parameters of skull variables in South African population, varying from 0.49 to 0.54, which are greater compared to our present study. Kalia et al. [37] reported correlation coefficients to estimate stature using combination of skull variables and mesiodistal width of maxillary anterior teeth of Mysorean population (South India), varying from 0.38 to 0.56, which are slightly greater than our study.

In our study, the standard error of estimate was 5.67 cm using coronal suture length and 9.42 cm using sagittal suture length. Chiba and Terazawa [10] reported standard error of estimate ranging from 6.59 to 8.59 cm from skull variables, which are greater than the standard error in estimating stature using coronal suture length but lower than in the sagittal suture. Ryan and Bidmos [16] reported the standard error of estimate for the combinations of various parameters of skull variables, ranging from 4.37 to 4.50 cm, which are less than the standard error in estimating stature using coronal suture length. Kalia et al. [37] reported the standard error of estimate for the combinations of skull variables and odontometry, ranging from 0.18 to 3.23 cm, which are less than the standard error in our study.

The authors [10, 16, 37] in the above studies used for comparison adopted combinations of various parameters of skull variables, rather than depending on a single parameter. Correspondingly, the correlation coefficient was greater in the above studies [10, 16, 37], when compared to coronal suture length. Probably, combinations of various parameters of skull variables along with coronal suture length could provide better estimates of stature.

The correlation coefficient between stature and sagittal suture length was 0.090. No correlation was observed between stature and sagittal suture length in the South Indian male population for the linear regression equation (P=0.408).

Sarangi et al. [39] performed somatometry on the maximum anterior–posterior length, maximum transverse length, and circumference of skull in 220 autopsy cases and reported that the correlation coefficient of stature for those parameters was insignificant for estimation of stature (P> 0.5). In our study, the correlation coefficient of stature from coronal suture was significant for estimation of stature (P= 0.001). It was concluded that there was a significant relationship between stature and the coronal suture length of a South Indian male population, used through the derived linear regression equation.

Conclusion

Stature reconstruction is important as it provides a forensic anthropological estimate of the height of a person in the living state and plays a vital role in the identification of individuals from their skeletal height. Our study indicates that stature can be predicted from the length of coronal suture by linear regression analysis. The equation presented in this study should be used with caution in forensic cases when only the skull is available for human identification, since regression equation is known to be population and sex specific [33, 38]. Hence, an attempt was made to derive equation based on measurement of coronal suture for the indigenous South Indian male population.

Since due to paucity of information in the literature regarding such study, a hypothesis was put forward to relate the skull sutural lengths to the stature. This would serve as a useful tool of identification for forensic surgeons to estimate stature from cranial suture length, when only the skull bone was recovered. Studies on a larger male sample in this region are needed to further confirm the findings of our study. Similar studies applicable to the South Indian female population are proposed. Additional research needs to be conducted to establish the relationships between stature and cranial suture length.

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