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Determination of Stature from the length of Cranial Sutures- A Study from Central India

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Abstract
Background:*Skulls frequently represent the only skeletal remains of an unidentified corpse brought for forensic examination. This study aims to determine the correlation between the cadaveric supine length and the length of three cranial sutures viz. coronal, sagittal, and lambdoid.*
Material and Methods: *A cross-sectional study was conducted in the department of forensic medicine, Gandhi Medical College, Bhopal between the period of January 2016-June 2017. A total of 500 dead bodies were examined for this study. We utilized the correlation coefficient and the linear regression methods to predict a relationship between the stature and the length of cranial sutures.*
Results:*The age range of dead bodies brought for examination was 20 to 89 years, mean age 38.07(standard deviation 13.61) and the median age was 35. There were total of 307 males and 193 females. On statistical analysis, both the coronal and the sagittal sutures showed a positive correlation with the supine length which was statistically significant. The lambdoid suture did not show any significant correlation with supine cadaveric stature.*
Conclusion: *With some assumptions, the supine length can be estimated from the length of cranial sutures with a fair degree of accuracy.*

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I. Introduction

In medicolegal investigations, identification of a dead body is important because it helps in connecting the crime to the criminal [1]. For medicolegal purposes, forensic experts rely on two types of methods:the quick but less precise “field-based” methods and costly, precise, and time-consuming “laboratory” methods. In medico-legal cases where bodies have decomposed to a greater degree, the examination of the skeletal remains may help in the identification of the dead [2]. Traits of identity viz. age, sex, stature,and race are some of the biological entities that can be estimated from the skeletonremains long after the flesh has been decomposed. Estimation of the stature of an individual from various body parts is considered as an important tool in personal identification. This is possible because of a definite biological relationship between stature with body parts like extremities, head, trunk, vertebral column[3]. Studies have shown that stature can be estimated with reasonable accuracy from a variety of skeletal remains like the length of long bones,foot, spine, metacarpal, metatarsal, and scapula. [4-8]. In the last few decades, forensic scientists along with anthropologists have even used foot dimensions and shoe size to estimate body sizeand stature [9,10]. Since the length of various body parts and the stature are both continuous variables, a linear regression equation can be derived to determine the stature from skeletal remains. Researchers have also tried with varying degrees of success to determine the stature while relying on fragments of long bones as intact bones were not always available for analysis[11, 12].

Skull is a unique skeletal structure in several ways; be its origin as embryonic cellular form (neural crest), ossification (intramembranous and endochondrial) and flexibility (fibrous sutures) [13]. The cranial vault bones are formed by intramembranous ossification, while the bones of the base of the skull are formed by endochondrial ossification [13]. Contrary to long bones, the skull is a combination of numerous bones [13]. The large flexible fibrous joints between cranial bones are termed as cranial sutures, which allows the head to pass through the birth canal and postnatal brain growth [13, 14]. The three important sutures are coronal, sagittal and lambdoid [14]. The timing of fusion of a suture is a helpful aid for age determination whereas the length of suture helps in sex and stature estimation [14, 15]. Researchers have also attempted to estimate the stature of the dead using various parameters of the human skull [16, 17]. Some researchers in past have attempted to determine stature from cephalon-facial and craniofacial material e.g. Introna et al. [17], and Patil and Mody [18]. 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. Therefore, the present study aims to determine the usefulness of the length of skull sutures in determining the stature for dead bodied brought for medico-legal postmortem.

II. Material and Methods

Study Design: This was a cross-sectional study. **Study Setting:** The present study was conducted in the Department of Forensic Medicine and Toxicology, Gandhi Medical College, Bhopal, Madhya Pradesh. **Study Duration:** The total duration of the study was eighteen months (January' 2016- June' 2017). **Study Subject:** The study was undertaken on dead bodies coming for medico- legal examination to the Department of Forensic medicine, Gandhi Medical College, Bhopal.

Inclusion Criteria

1. The cases whose correct gender was known before the medicolegal postmortem examination.
2. The age of the person at the time of death was ≥ 20 years.

Exclusion Criteria

1. Unidentified bodies, where exact gender cannot be confirmed.
2. Cases with a severe head injury (based on history and external examination), which may hamper the examination of suture closure.
3. Cases with any congenital or hereditary bony deformity based on history or external examination.

Sample Size: We collected data from 500 dead bodies.

Data Collection:

The body was placed in a supine position on the autopsy table, with the neck and feet in a neutral position. The whole thickness of the scalp was incised with the help of a scalpel between the mastoid process over the vertex in the coronal plane [19,20]. The anterior and posterior halves of the scalp were separated from the skull and then reflected forward and backwards. An incision was made and then the soft tissues adherent to the periosteum along the coronal, sagittal, lambdoid sutures were scraped manually until the suture line over the vertex, the pterion on side, bregma, lambda and asterion on both sides were visible [19, 20]. The length of coronal, sagittal, lambdoid sutures was measured using a non-extensible thread and Vernier caliper graduated in millimeters [19, 20].

The following measurements were taken:

1. **Length of coronal suture:** One end of the inelastic thread was placed over the right pterion then along the coronal suture thread extended up to left pterion. Then these two points were marked, a thread was then fixed on wooden cardboard with the help of pins and distance between the two pins was calculated with the help of Vernier caliper.
2. **Length of sagittal suture:** One end of the inelastic thread was placed over the bregma and passed along the sagittal plane to the lambda and two points were marked, further process same as above.
3. **Length of lambdoid suture:** Distance from one asterion to another along the lambdoid suture.

Data Analysis:

Descriptive analyses were conducted to study the distribution of dependent variables among study participants. A *P*-value < 0.05 was considered statistically significant. Sex was determined from the length of Sagittal, Coronal and Lambdoid sutures by using correlation coefficient and linear regression. We utilized correlation coefficient and linear regression to determine the relationship between dependent variable stature and the independent variables were the length of coronal, sagittal and lambdoid sutures. The data was analyzed using SPSS version 20.0. Appropriate statistical tests were applied for comparative data analysis.

Ethical Clearance: The present study was approved in the year 2016 by the ethical board on human research of the Gandhi Medical College, Bhopal.

III. Results

The length of coronal sutures rangedfrom a minimum of 206.02 mm to a maximum of 263.22 mm (Mean 288.70 SD±8.159 mm). Gender wise, the length of coronal suture in males varied from 214.39 to 263.22 mm with a mean value of 230.21 mm (SD±7.668 mm). The length of coronal suture in females varied from 206.02 to 245.51 mm with a mean value of 226.31 mm(±SD 8.362 mm).Similarly, the length of sagittal sutures ranged from 117.31 to 144.32mm with mean of 128.46mm (SD ±4.968 mm). The length of sagittal suture in males ranged from 117.31 to 144.32 mm with a mean of 129.30 mm (SD ±5.499 mm). The length of sagittal suture in females ranged from 118.57 mm to 139.42 mm with a mean value of 127.10 mm (SD ±3.600 mm).

The length of the lambdoid suture ranged from 159.07 to 209.70 mm (mean 182.49, SD ±8.403mm). The length of lambdoid suture in males ranged from 169.28 to 209.70 (Mean 183.51, SD± 6.369 mm). The length of lambdoid suture in females varied from 159.07 mm to 207.39 mm with a mean value of 180.87 mm (SD± 10.702 mm).

Table 1: Gender wise analysis of the length of three cranial sutures (male= 307, female= 193)

Gender	Mean (in mm)	SD	Max	Min
Coronal sutures				
Male	230.21	7.668	263.22	214.39
Female	226.31	8.362	245.51	206.02
Sagittal Sutures				
Male	129.30	5.499	144.32	117.31
Female	127.10	3.600	139.42	118.57
Lambdoid Sutures				
Male	183.51	6.369	209.70	169.28
Female	180.87	10.702	207.39	159.07

Table 2 gives details of the correlation and linear regression equations. The value of ‘r’ for the total population suggest a moderate degree of correlation (r= 0.416) between supine length and length of the coronal suture. The linear regression equation Stature (mm) = 1578.14 + (0.015 × lengths of coronal suture) was derived to estimate the stature from the length of coronal suture in the total population. The value of ‘r’ for males was 0.379 and the standard error of estimate for males was ± 43.832. The linear regression equation Stature (mm) = 1605.37 + (0.061 × lengths of coronal suture) was derived to estimate the stature from the length of coronal suture in males. The value of ‘r’ in females was 0.362 and the standard error of estimate for females was ± 37.750. The linear regression equation Stature (mm) = 1504.57 + (0.074 X length of coronal suture) was derived to estimate the stature from the length of coronal suture in females.

The value of ‘r’ for the total population was 0.251 and so the relationship between supine length and length of sagittal suture was weakly correlative. The linear regression equation Stature (mm) = 1579.10 + (0.019 × lengths of sagittal suture) was derived to estimate the stature from the length of sagittal suture in the total population. The linear regression equation Stature (mm) = 1618.25 + (0.009 × lengths of sagittal suture) was derived to estimate the stature from the length of sagittal suture in males. The linear regression equation Stature (mm) = 1519.66 + (0.013 X length of sagittal suture) was derived to estimate the stature from the length of sagittal suture in females.

The correlation coefficient was 0.082 for lambdoid suture and supine length. The standard error of the estimate was ± 65.305 mm. The results derived from the present study were statistically not significant (p = 0.065). Hence, a linear regression equation to estimate stature from the length of the lambdoid suture could not be derived.

Table 2: **Results of the linear regression between the length of cranial sutures and stature**

Gender	Regression equations	SE	Correlation coefficient	P-value
Coronal sutures				
Male	1605.37 + (L×0.061)	0.44	0.379	0.000
Female	1504.57 + (L×0.074)	0.60	0.362	0.000
Both	1578.14 + (L×0.015)	0.37	0.416	0.000
Sagittal Sutures				
Male	1618.25 + (0.009 x L)	46.940	0.135	0.018
Female	1519.66 + (0.013 x L)	40.016	0.153	0.033
Both	1579.10 + (0.019 × L)	63.439	0.251	0.000
L- length of suture				

IV. Discussion:

Estimation of stature and body size is of great interest to forensic and physical anthropologists. The body is said to increase in stature after death by about 2 cm due to loss of muscle tone, relaxation of joints and tensions of interventricular discs [21]. To calculate stature of an individual, to the total length of the entire skeleton 2½ - 4 cm is added for the thickness of soft parts [21].In cases where identification has to be performed based on skeletal remains, stature is usually estimated by applying regression equation to the length of intact long bones of the upper and lower extremities. A drawback to the techniques used is the limited applicability to fragmentary remains. This necessitated the need to assess the usefulness of measurements of fragments of long bones in the estimation of stature. When the body has been mutilated, it is common to have extremities or head amputated from the trunk. Stature estimation formula should be derived based on the known relationship of the remains to stature.

A few studies worldwide have been conducted on stature estimation from the skull. Chiba and Terazawaregressed 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 [16]. Patil and Modyused 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 isvery reliable in the estimation of stature [18]. Kalia et al62 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 [22]. Introna et al. 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 [17].

As there are very few studies that have derived linear regression equations to estimate stature using the length of Coronal, Sagittal and Lambdoid sutures. The present study was an attempt to estimate the stature of male and female individuals from the length of Coronal, Sagittal and Lambdoid suture and to compare the reliability of this study with other somatometric measurements of the skull. In present study means of stature in the total population was 158.15 cm, in the male population was 161.94 cm and in female population was 152.15 cm. The correlation coefficient of the length of the coronal suture of the present study was greater than the correlation coefficient of Rao et al. [23]. The length of the coronal suture showed less correlation to estimate stature as 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 [16]. They reported a correlation coefficient of 0.43 for estimating stature using skull variables. Ryan and Bidmos reported correlation coefficients varying from 0.49 to 0.54 for estimating stature using a combination of various parameters of skull variables in the South African population, which are greater compared to our present study [12].

According to Rao et al., the correlation coefficient between stature and sagittal suture length was 0.09 and no correlation was found between stature and sagittal suture length[23]. But in present study correlation coefficient between stature and the sagittal suture was 0.251 and it was statistically significant ($p < 0.001$). In the present study, the correlation between stature and the lambdoid suture was 0.082 and it was statistically not significant ($p = 0.065$).

Table 3: Comparison of findings with similar studies.

Author	Parameters studied	Correlation coefficient
Present Study	Length of coronal, sagittal and lambdoid sutures	Coronal= 0.416, Sagittal= 0.251 Lambdoid=0.082
Rao et al[23]	Length of the coronal, sagittal suture	0.363
Chiba and Terazawa[16]	Skull diameter and circumference	0.43
Kalia et al[22]	Skull variables and mesiodistal width of maxillary anterior teeth	0.38 to 0.56

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