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## Original Research Paper

# Estimation of Stature from Cephalo-Facial Dimensions by Regression Analysis in Gujarati Population

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## Abstract

During investigation in cases of missing body parts or unknown identity, the expert is often required to opine about the personal identification of the body. Stature of a person is a useful indicator of physical identity. Stature estimation leads to a positive identification of the living or when only cephalo-facial are brought under examination. The current study dealt with developing regression equation for stature estimation from cephalo-facial dimensions and to find out the correlation among body height with each cephalo-facial dimensions of Gujarati people. This leads to positive identification of the living or cadaver. Eight cephalo-facial dimensions of 901 Gujarati (676 male and 225 female) namely maximum head length, maximum head breadth, bizygomatic breadth, bigonial diameter, morphological facial length, physiognomic facial length, and total cephalo-facial height and biocular breadth along with body height was measured. It was marked that the mean stature and cephalo-facial measurements of males were significantly higher than that of females. The correlation coefficient (r) of all cephalo-facial dimensions were less than 0.5 which means stature estimation from cephalo-facial dimensions is not reliable. Multiple regression equations are more reliable than linear regression equations.

**Key Words:** Physical Anthropology; Cephalo-facial dimensions; Stature estimation; Gujarati population

## Introduction:

Personal identification of an individual is an important aspect of Forensic science. In the case of living individuals it is based on certain morphological characteristics unique to that individual. In case of skeletal remains it is rather more complicated and requires exhaustive examination of the skeletal remains recovered from the scene of crime.

A Forensic anthropologist would attempt to answer the following key questions relating to origin, age, sex, stature and race after examining the recovered body. In India where crimes, murders, accidents, kidnapping, missing person are at peak, the investigative measures and techniques should be tough enough to bring culprits to the book.

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Through the anthropometric dimensions, it is possible to study body proportions, size and shape of man in formulating standards which will be useful in defence forces. Stature estimation is the principal element in Forensic case studies. Formulas derived from the relevant sample provide most accurate and precise inference.

Various researchers have worked on stature estimation from different body parts of diverse ethnic groups. Bhatnagar et al [1] studied left and right hands separately on Punjabi males. Abdel-Malek et al [2] took two somatometric measurements of the hands on Egyptian subjects. Jason et al [3] estimated stature from the length of cervical, thoracic, lumbar, thoraco-lumbar and cervico-thoraco-lumbar segments of the spine.

Krishan and Sharma [4] conducted a study on the bilateral asymmetry and estimation of stature from arm length and its segments on a Punjabi population. Duyar and Pelin [5] established relationship between tibial length and stature. Ozaslan et al [6] conducted study on the estimation of stature from seven somatometric measurements of the lower.

These equations are based on measurements of different bones which are population specific and should be applied consequently. It becomes difficult to estimate stature when only cephalo-facial is brought for the examination. Regression equations for

stature estimation from cephalo-facial dimensions using non-radiological method on Gujarati population of Gujarat are not documented in any Forensic literature.

To estimate stature, measurements of maximum head length, maximum head breadth, bizygomatic breadth, bigonial diameter, morphological facial length, physiognomic facial length, and total cephalo-facial height and biocular breadth are measured of 901 Gujarati subjects whose age range between 20 to 50 years. The present research was hence undertaken to study the correlation of stature with cephalo-facial measurements and to derive formulas for determining stature.

## Material and Methods:

A randomly selected sample of 901 Gujarati subjects whose age range falls within 21 to 50 years were presented for data collection and analysis. Gujarati subjects were born, bred and live in Ahmedabad district of Gujarat state. It is the seventh largest metropolitan area of India.

The stature and eight cephalo-facial measurements viz., maximum head length, maximum head breadth, bizygomatic breadth, bigonial diameter, morphological facial length, physiognomic facial length, total cephalo-facial height and biocular breadth were measured directly using standard anthropometric instruments. Cephalo-facial dimensions are taken by spreading calliper in centimetres according to the landmarks, techniques and procedures recommended by authors Singh and Bhasin.

The anatomical landmarks were identified keeping the head in Frankfurt Horizontal plane. The measurements were taken after obtaining informed consent from the volunteers. All the subjects were healthy and free from cephalic deformity.

The landmarks selected for facial dimensions were glabella, opisthocranion, nasion, gnathion, zygomatic, gonion, euryon, trichion and ectocanthion.

i. **Height Vertex or Stature:** It measures the vertical distance from vertex to floor, where vertex is the highest point on the head when the head is held in Frankfurt Horizontal (FH) plane. The subject was asked to position with standiometer in the median sagittal plane. The subject should stand erect, feet parallel to each other with barefoot and heels to touch the wall. The horizontal length was then measured in centimetres.

Precautions were taken not to exert pressure as that may affect the contact measurement. The height is highly sensitive to fatigue and even up to 3 cms of diurnal differences have been recorded in it in the same subjects (Tanner, 1964).

ii. **Maximum Head Length (g-op):** It measures the straight distance between glabella (g) and opisthocranion (op) i.e., the most protruding point on the dorsal surface of the head in the mid-sagittal plane.

iii. **Maximum Head Breadth (eu-eu):** It measures the straight distance between the two eurya (eu).

iv. **Breadth of Bizygomatic Arch (zy-zy):** Direct distance between the two most lateral points on the zygomatic arches (zy-zy)

v. **Bigonial Breadth (go-go):** It measures the straight distance between the two gonia (go), rounded postero-inferior corner of the mandible between ramus and the body.

vi. **External Biocular Breadth (ec-ec):** It measures the straight distance between the two external canthi (ectocanthion) i.e., outer corners of the eye.

vii. **Total Head Height (v-gn):** It measures the projective distance between vertex (v) and gnathion (gn).

viii. **Physiognomic Facial Height (tr-gn):** It measures the straight distance between trichion (tr) and gnathion (gn).

ix. **Morphological Facial Height (n-gn):** It measures the straight distance between nasion (n) and gnathion (gn).

The data collected were recorded and subjected to statistical analysis by SPSS Version 20.0. Thereafter, a hypothetical regression equation was formulated using the regression coefficients as follows:

**S = a + bx**

where, s = stature i.e. the dependent variable.

x = any cephalo-facial measurement i.e. the independent variable.

a = the regression coefficient of dependent variable.

b = the regression coefficient of independent variable.

The regression formulae were calculated separately by using computerized regression analysis of the parameters with stature to derive the regression coefficients ‘a’ and ‘b’. The appropriate values of constants ‘a’ and ‘b’ were then substituted in the standard equation of regression. Standard Error of Estimate (SEE) was calculated for each and every regression equation.

## Results:

Statistical analysis was presented in tabular form as means, standard deviations, minimum and maximum value of stature and

cephalo-facial anthropometric measurements namely maximum head length, maximum head breadth, bizygomatic breadth, bigonial diameter, morphological facial length, physiognomic facial length, total cephalo-facial height and biocular breadth of adult Gujarati. (Table 1)

In the sample of 901 Gujarati, the mean values were found to be greater in males than the females. Table 2 displays Karl Pearson's correlation coefficients between stature and various cephalo-facial anthropometic measurements in adult Gujarati.

## Discussion:

Facial assessment by metrical methods is currently performed in different fields such as plastic and orthodontic surgery and diagnosis for cephalo-facial anomalies, medico-legal aspects and in Forensic science. However, very few studies have proposed facial analysis for forensic purpose. In cases where only fragmentary body parts are recovered, it becomes difficult to establish identity. In such cases, identification of stature and ethnic group becomes important to establish identity. In this study attempt has been made to determine stature of Gujarati people from eight cephalo-facial measurements.

The study revealed the mean value of all facial measurements in Gujarati people to be comparatively lower in females than males. The mean stature of Gujarati male was 164.3 cm and female was 150.56 cm. Our study showed that when sex is unidentified all the facial measurements except morphological facial length was found to show positive significance (p-value<0.05) with stature. (Table 2)

The result indicated that using either of the cephalo-facial dimensions and putting the values in linear regression equation, stature can be known when sex is unidentified. Bigonial diameter gives significant model for stature determination in male and female.

Other cephalo-facial measurements namely, maximum head length, maximum head breadth, bizygomatic breadth, morphological facial length, physiognomic facial length, total cephalo-facial height and biocular breadth shows weak and statistically insignificant relation with stature as p-value>0.05.

The correlation coefficients (r) of cephalo-facial measurements are less than 0.5 in all the cases. As the correlation coefficients (r) are considered to be significant only above 0.5, the cephalo-facial dimensions are not very good predictors for estimating stature in Gujarati population. However it must be kept in mind that precise prediction of stature from cephalo-facial dimensions may be unattainable and there would always be an SEE. Multivariate regression for stature estimation can be used when all the facial measurements are available. When sex is unknown, stature can be identified precisely using multivariate regression equations.

Many authors have derived formulas for stature estimation from cephalo-facial measurements on various ethnic groups. Mahesh Kumar et al. [7] worked on Haryanvi adults and reported that the most reliable cephalo-facial measurements to estimate stature using regression analysis among males is morphological facial length (r=1.39) and in female is maximum head length (r=1.037). Kewal Krishnan et al [8] noted that horizontal head circumference (r=0.781) show good reliability and applicability for estimation of stature in male Gujjars of North India.

A. K. Agnihotri et al [9] studied stature estimation in Indo-Mauritian by using facial measurements where horizontal head circumference (r=0.494), nasal breadth (r=0.380) and morphological facial length (r=0.328) predicts stature among males and among females physiognomic facial length (r=0.382), bizygomatic breadth (r=0.276) and horizontal head circumference (r=0.375). Patil and Mody [10] showed somewhat higher standard errors for most of the variables except head length which showed high degree of reliability (SEE= 3.71) in estimating stature.

Daisy Sahni [11] found low correlation coefficients and suggested the correlations of facial measurements with stature to be very poor. S. Nath et al [12] revealed that Jatavs males shows greater multiplication factor for nasal height, head breadth, and ear length while female exhibit greater multiplication factor for nasal breadth and head length.

The results of the present study can be compared with the similar available studies on different population group of the world. The comparison and differences obtained establish the fact that different Indian population shows variation in the morphology of different population group of India. It is emphasized that all the measurements exhibit correlation when sex is unknown and hence any of the cephalo-facial can estimate stature of Gujarati people. Moreover, stature can be satisfactorily estimated for medico-legal and forensic purpose using multiple regression equations.

## Conclusion:

From the present study, it can be concluded that like other parts of body, cephalo-facial dimensions can also be used for

estimating stature when sex is unknown. The facial measurement does not give good reliability and applicability to estimate stature in the sample of Gujarati origin, though the models are significant. Estimation of stature from cephalo-facial measurements is an additional approach when practical samples like extremities and other body parts are not available for examination.

Therefore, it can be concluded that, like other parts of the human body, the cephalo-facial dimensions can also be used for estimation of stature with less accuracy rate when cephalo-facial remains are brought for forensic examination. While applying linear regression formulae, one should keep in mind that these are population specific; these cannot be used on other populations of the world.

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**Table 1**
**Descriptive Statistics for Stature and Cephalo-Facial Measurements in Gujarati (n=901)**

| Variables | Sex | N | Mini | Maxi | Mean | S.D | S.E Mean | t | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| g-op | Both | 901 | 13.6 | 21.4 | 17.34 | 1.72 | 0.05 | 14.967 | 0.00 |
| | Male | 676 | 14.0 | 21.4 | 17.79 | 1.52 | 0.05 | | |
| | Female | 225 | 13.6 | 18.8 | 16.01 | 1.6 | 0.1 | | |
| eu-eu | Both | 901 | 9.6 | 19.0 | 13.39 | 1.63 | 0.05 | 11.404 | 0.00 |
| | Male | 676 | 10.1 | 19.6 | 13.72 | 1.52 | 0.05 | | |
| | Female | 225 | 9.6 | 18.6 | 12.38 | 1.54 | 0.1 | | |
| zy-zy | Both | 901 | 9.0 | 16.8 | 12.65 | 1.68 | 0.05 | 14.258 | 0.00 |
| | Male | 676 | 9.8 | 16.8 | 13.07 | 1.54 | 0.05 | | |
| | Female | 225 | 9.0 | 14.5 | 11.4 | 1.46 | 0.09 | | |
| go-go | Both | 901 | 5.9 | 14.6 | 9.99 | 1.66 | 0.05 | 13.689 | 0.00 |
| | Male | 676 | 6.2 | 14.6 | 10.38 | 1.54 | 0.05 | | |
| | Female | 225 | 5.9 | 11.5 | 8.79 | 1.42 | 0.09 | | |
| tr-gn | Both | 901 | 12.0 | 21.5 | 15.99 | 1.72 | 0.05 | 13.464 | 0.00 |
| | Male | 676 | 12.0 | 20.1 | 16.4 | 1.55 | 0.05 | | |
| | Female | 225 | 12.2 | 21.5 | 14.76 | 1.62 | 0.1 | | |
| v-gn | Both | 901 | 10.2 | 25.3 | 21.39 | 1.77 | 0.05 | 15.027 | 0.00 |
| | Male | 676 | 12.5 | 25.3 | 21.85 | 1.48 | 0.05 | | |
| | Female | 225 | 10.2 | 23.5 | 20.01 | 1.88 | 0.12 | | |
| n-gn | Both | 901 | 6.1 | 12.6 | 9.52 | 1.5 | 0.05 | 12.219 | 0.00 |
| | Male | 676 | 6.3 | 12.6 | 9.85 | 1.36 | 0.05 | | |
| | Female | 225 | 6.1 | 12.0 | 8.54 | 1.46 | 0.09 | | |
| ec1-ec2 | Both | 901 | 6.4 | 12.7 | 9.36 | 1.59 | 0.05 | 9.850 | 0.00 |
| | Male | 676 | 6.7 | 12.7 | 9.65 | 1.5 | 0.05 | | |
| | Female | 225 | 6.4 | 11.3 | 8.5 | 1.54 | 0.1 | | |
| height | Both | 901 | 135.0 | 186.5 | 160.92 | 9.54 | 0.31 | 24.094 | 0.00 |
| | Male | 676 | 137 | 186.5 | 164.3 | 7.55 | 0.29 | | |
| | Female | 225 | 135 | 170 | 150.56 | 7.11 | 0.47 | | |

**Table 2**
**Regression Equations for Estimation of Stature (In Cm) From Cephalo Facial Dimensions in Gujarati (N=901)**

| | | r | $r^2$ | Adjusted r | SEE | Equation: Stature= |
|---|---|---|---|---|---|---|
| Both | g-op | 0.275* | 0.076 | 0.074 | 9.182 | 134.541+1.520(g-op)*±SEE |
| | eu-eu | 0.223* | 0.05 | 0.049 | 9.308 | 143.437+1.305(eu-eu)*±SEE |
| | zy-zy | 0.260* | 0.067 | 0.066 | 9.222 | 142.317+1.470(zy-zy)*±SEE |
| | go-go | 0.177* | 0.031 | 0.03 | 9.4 | 150.804+1.013(go-go)*±SEE |
| | v-gn | 0.277* | 0.077 | 0.076 | 9.176 | 129.145+1.485(v-gn)*±SEE |
| | tr-gn | 0.290* | 0.084 | 0.083 | 9.139 | 135.263+1.604(tr-gn)*±SEE |
| | n-gn | 0.223 | 0.05 | 0.049 | 9.308 | 147.413+1.418(n-gn)±SEE |
| | ec1-ec2 | 0.190* | 0.036 | 0.035 | 9.376 | 150.257+1.138(ec1-ec2)*±SEE |
| Male | g-op | 0.021 | 0.00 | -0.001 | 7.55 | 166.224-0.104(g-op)±SEE |
| | eu-eu | 0.014 | 0.00 | -0.001 | 7.556 | 165.312-0.069(eu-eu)±SEE |
| | zy-zy | 0.032 | 0.001 | 0.00 | 7.553 | 166.390-0.155(zy-zy)±SEE |
| | go-go | 0.096* | 0.009 | 0.008 | 7.522 | 169.253-0.470(go-go)*±SEE |
| | v-gn | 0.008 | 0.00 | -0.001 | 7.557 | 165.241-0.040(v-gn)±SEE |
| | tr-gn | 0.007 | 0.00 | -0.001 | 7.557 | 164.937-0.035(tr-gn)±SEE |
| | n-gn | 0.044 | 0.002 | 0.00 | 7.55 | 166.787-0.245(n-gn)±SEE |
| | ec1-ec2 | 0.021 | 0.00 | -0.001 | 7.555 | 165.381-0.105(ec1-ec2)±SEE |
| Female | g-op | 0.035 | 0.001 | -0.003 | 7.122 | 148.097+0.154(g-op)±SEE |
| | eu-eu | 0.048 | 0.002 | -0.002 | 7.118 | 147.854+0.219(u-eu)±SEE |
| | zy-zy | 0.048 | 0.002 | -0.002 | 7.118 | 147.925+0.231(zy-zy)±SEE |
| | go-go | 0.193* | 0.037 | 0.033 | 6.993 | 159.024-0.962(go-go)*±SEE |
| | v-gn | 0.001 | 0.00 | -0.004 | 7.126 | 150.51+0.003(v-gn)±SEE |
| | tr-gn | 0.213 | 0.046 | 0.041 | 6.962 | 136.807+0.932(tr-gn)±SEE |
| | n-gn | 0.061 | 0.004 | -0.001 | 7.113 | 148.032+0.297(n-gn)±SEE |
| | ec1-ec2 | 0.034 | 0.001 | -0.003 | 7.122 | 149.238+0.156(ec1-ec2)±SEE |

*p-value<0.05

**Table 3**
**Multiple Regression Equations for Estimation of Stature (In Cm) From Cephalo-Facial Dimensions in Gujarati (N=901)**

| Sex | r | $r^2$ | Adjusted r | SEE | Equation: Stature= |
|---|---|---|---|---|---|
| Both | 0.408* | 0.167 | 0.159 | 8.751 | 102.688+1.420(g-op)*-0.234(eu-eu)*+3.697(zy-zy)*-1.620(go-go)*+1.644(tr-gn)*+1.351(v-gn)*-1.447(n-gn)*-3.766(ec1-ec2) |
| Male | 0.174* | 0.030 | 0.019 | 7.481 | 153.653-0.83(g-op)+0.345(eu-eu)+0.190(zy-zy)-1.336(go-go)*+0.206(tr-gn)+1.013(v-gn)*-1.267(n-gn)*+0.604(ec1-ec2) |
| Female | 0.584 | 0.342 | 0.317 | 5.87 | 109.263-0.713(g-op)+0.093(eu-eu)+5.077(zy-zy)*-4.739(go-go)*+2.912(tr-gn)*+1.384(v-gn)*-0.338(n-gn)-4.496(ec1-ec2)* |

*p-value<0.05