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Estimation of stature from cephalo-facial dimensions by regression analysis in Indo-Mauritian population

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ABSTRACT

Determination of stature from fragmented human remains is vital part of forensic investigation for the purpose of identification. The present study was aimed to modelling the stature both for male and female separately on the basis of craniofacial dimensions. The study was conducted on 150 young and healthy students (75 males and 75 females) in the age group ranging from 20 to 28 years. The stature and fourteen cephalo-facial dimensions were measured on each subject by using standard anthropometric instruments. It is remarked that the stature and craniofacial measurements of males were significantly higher than that of females, except for nasal height where no significant difference was observed ($p > 0.05$). The correlation coefficients (r) of all cephalo-facial dimensions were less than 0.5. It means the estimation of stature is not reliable with the help of cephalo-facial dimensions.

1. Introduction

During legal investigations, especially in crimes resulting in fatalities or when unknown human remains are recovered by investigating agencies, the forensic pathologist is often required to give an opinion regarding personal identification of the deceased. Stature or body height is one of the most important parameters to determine the physical identity of an individual. There is a definite biological relationship of stature with the all body parts such as extremities, head, trunk, vertebral column, etc. Many studies have been conducted on the determination of stature from percutaneous measurements of various body parts including arms, legs, feet, hands, etc.[1–17] There are few studies for stature estimation from the skull alone. Sarangi el al.[18] did not find any significant correlation between the stature and the skull but Introna el al.[19] and Chiba and Terazawa[20] reported a significant relationship between the stature and the skull. Patil and Mody[21] used radiographic lateral cephalogram of skull to estimate stature by regression analysis. However, the studies concerning stature estimation from cephalo-facial dimensions by percutaneous measurements are scanty. Jibonkumar and Lilinchandra[22] have studied the co-relation between stature and different facial measurements among the Indian population by using regression equation and multiplication factor. Krishna and Kumar[23] and Krishna[24] successfully derived equations for estimating stature from sixteen cephalo-facial measurements in north Indian population. Recently, Pelin el al.[25] have studied the relation between the body height and the head and face dimensions in Turkish population and found that the estimation of body height is not reliable with the help of head and face dimensions. These studies were conducted on male population exclusively, and thus lack to show any gender difference.

Therefore, the present study has been attempted to determine stature from cephalo-facial dimensions and formulate adequate gender-wise regression models for this purpose.

2. Materials and methods

2.1. Sample

A total 150 young and healthy students, comprising of 75 males and 75 females, within the age ranging from 20 to 28 years were selected for the present study. The study was conducted in the Department of Forensic Medicine, SSR Medical College, Mauritius in the year 2009. Mauritius is an island, geographically located in the

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Table 1
Normality test on stature by gender.

Tests of Normality (Shapiro–Wilk)			
Gender	Statistic	df	*P* value
Male	0.979	75	0.244
Female	0.957	75	0.013

Table 2
Normality test on stature by gender (outlier removed).

Tests of Normality (Shapiro–Wilk)			
Gender	Statistic	df	Sig.
Male	0.979	75	0.244
Female	0.975	74	0.143

Indian Ocean, approximately 2400 km of the south east coast of Africa.

2.2. Anthropometric methodology

The stature and fourteen cephalo-facial measurements of each subject were taken by using standard anthropometric instruments, in centimetres, to the nearest millimetres according to the technique described by Vallois.[26] The anatomical landmarks used for taking measurements were identified by keeping the head in Frankfurt horizontal plane. The instruments used for data collection were regularly checked for their accuracy. The measurements include:

2.2.1. Stature

The stature or height of the subject was measured in standing position to the vertex by using anthropometric rod.

2.2.2. Maximum head length

It is the straight distance from the glabella (the prominence on the forehead between the eyebrows, just above the nose) to the opisthocranion (the farthest occipital point) and measured by using spreading calliper.

2.2.3. Maximum head breadth

It is the maximum biparietal diameter and measured by taking a distance between the most lateral points of parietal bones (euryon) by using spreading calliper.

2.2.4. Horizontal head circumference

It is measured from glabella to glabella by using measuring tape which has passed through the opisthocranion.

2.2.5. Head vault

It is horizontal arc of the head which is measured from right tragion (the point in the notch just above the tragus of the ear) to left tragion with the help of measuring tape passing over the vertex.

2.2.6. Minimum frontal diameter

It is the minimum breadth of the forehead between two fronto-temporal points (the most medial point of temporal crest of frontal bone superior to the supraorbital ridge, identified by palpation). It is measured by sliding calliper.

2.2.7. Bizygomatic breadth

It is measured between the two most lateral points on the zygomatic arches i.e. zygion to zygion by using spreading calliper.

2.2.8. Bigonial diameter

It is the maximum breadth of lower jaw between two gonion points present on the external angles of the mandible. It is measured by sliding calliper.

2.2.9. Nasal height

It is measured from the nasal root (nasion) to the nasal base (subnasale) by using sliding calliper.

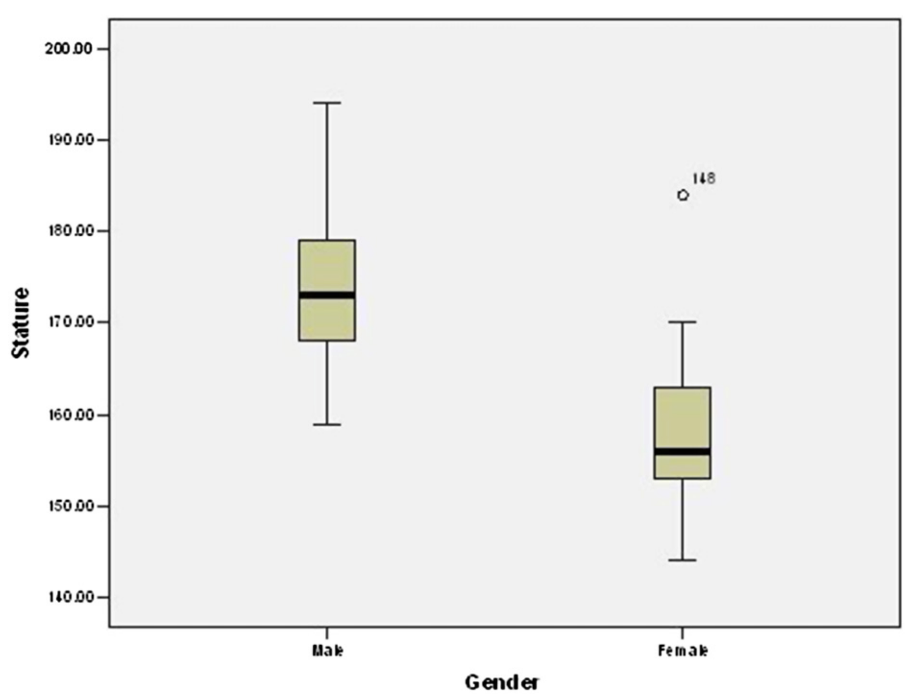

Fig. 1. Box-and-whisker plot for male and female stature.

Table 3
Normality tests (Shapiro–Wilk) on stature and cephalo-facial measurements by gender.

Measurement	Gender	Statistic	df	*p*
Stature	Male	0.979	75	0.244
	Female	0.975	74	0.143
Maximum Head Length	Male	0.946	75	0.003[a]
	Female	0.975	74	0.148
Maximum Head Breadth	Male	0.965	75	0.034[a]
	Female	0.972	74	0.093
Horizontal Head Circumference	Male	0.968	75	0.054
	Female	0.968	74	0.060
Head Vault	Male	0.977	75	0.181
	Female	0.983	74	0.404
Minimum Frontal Diameter	Male	0.969	75	0.060
	Female	0.988	74	0.729
Bizygomatic Breadth	Male	0.983	75	0.431
	Female	0.977	74	0.185
Bigonial Diameter	Male	0.986	75	0.579
	Female	0.986	74	0.602
Nasal Height	Male	0.948	75	0.004[a]
	Female	0.969	74	0.069
Nasal Breadth	Male	0.926	75	0.000[a]
	Female	0.952	74	0.007[a]
Nasal Depth	Male	0.952	75	0.007[a]
	Female	0.947	74	0.004[a]
Morphological Facial Length	Male	0.979	75	0.246
	Female	0.981	74	0.339
Physiognomic Facial Length	Male	0.982	75	0.359
	Female	0.980	74	0.289
Physiognomic Ear Length	Male	0.974	75	0.126
	Female	0.941	74	0.002[a]
Physiognomic Ear Breadth	Male	0.902	75	0.000[a]
	Female	0.895	74	0.000[a]

[a] Data for that measurement was not normal.

2.2.10. *Nasal breadth*

It is the distance between two most prominent points on the lateral aspect of the ala nasi and measured by using sliding calliper.

2.2.11. *Nasal depth*

It is measured from the tip of the nose to the deepest concavity at the base of the nose with the help of sliding calliper.

2.2.12. *Morphological facial length*

It is measured from the nasion to the gnathion (the lowest point on the lower border of mandible in the mid sagittal plane) by using sliding calliper.

2.2.13. *Physiognomic facial length*

It is the straight distance, measured from trichion (the midpoint of anterior line) to the gnathion by using sliding calliper.

2.2.14. *Physiognomic ear length*

It is measured from the superior aspect (supra-aurale) to inferior aspect (sub-aurale) of the external ear by using sliding calliper.

2.2.15. *Physiognomic ear breadth*

It is the maximum breadth, measured from the anterior aspect (pre-aurale) to the postrior aspect (post-aurale) of the external ear by using sliding calliper.

2.3. *Statistical analysis*

Excel 2007 and SPSS 13.0 were used for the statistical analysis of data. Descriptive statistics, namely, mean, standard deviation, minimum, maximum values as well as graphical displays like box-and-whisker plots and bar charts were obtained for stature and the 14 cephalo-facial measurements. All the analyses were carried out gender-wise. Test of normality was carried on each measurement before opting for a particular parametric or non-parametric test. Statistical tests used were independent *t*-test and its non-parametric alternative: Mann–Whitney *U* test; Pearson correlation coefficient and its non-parametric alternative: Spearman Rank correlation coefficient; and multiple linear regression analyses.

3. Results

Normality test was carried on stature as well as the 14 cephalo-facial measurements. While data for male stature was normal ($P = 0.244$) that of female stature was not normal ($p = 0.013$) Table 1. A box-and-whisker plot for female stature revealed the presence of an outlier, as depicted in Fig. 1, and removal of that outlier resulted in the data for female stature becoming normal Table 2. That outlier was in fact a female subject with stature 180 cm, much higher than the average of 157.4 cm. Hence, that outlier was removed from the dataset before further analyses were carried out, that is, the rest of the analyses were based on a sample of 75 males and 74 females.

From the normality test performed on the stature and the cephalo-facial measurements (Table 3), it was obvious that data for Maximum Head Length (male), Maximum Head Breadth (male), Nasal Height (male), Nasal Breadth (both male and female), Nasal Depth (both male and female), Physiognomic Ear Length (female) and Physiognomic Ear Breadth (both male and female) were not normally distributed. Hence, non-parametric tests were used for those measurements.

Table 4 and Fig. 2 shows descriptive statistics for stature and cephalo-facial measurements by gender.

Table 4
Descriptive statistics for stature and cephalo-facial measurements by gender (Male, N = 75; Female, N = 74).

Measurement	Mean		Std. Deviation		Minimum		Maximum	
	Male	Female	Male	Female	Male	Female	Male	Female
Stature	173.40	157.36	7.70	6.17	159.0	144.0	194.0	170.0
Maximum Head Length	18.66	18.13	0.79	0.91	17.2	15.8	20.0	19.8
Maximum Head Breadth	15.45	14.48	0.76	0.81	14.0	12.3	17.0	16.5
Horizontal Head Circumference	56.79	54.78	1.70	1.64	53.4	50.5	61.0	57.5
Head Vault	37.62	36.13	1.84	1.53	34.0	32.0	43.5	39.5
Minimum Frontal Diameter	11.57	11.15	0.51	0.63	10.3	9.5	13.3	12.7
Bizygomatic Breadth	14.39	14.01	0.95	1.00	12.1	10.6	17.0	16.0
Bigonial Diameter	10.55	9.90	0.76	0.84	8.8	8.0	12.8	12.5
Nasal Height	5.27	5.20	0.33	0.35	4.5	4.5	6.5	6.2
Nasal Breadth	3.28	2.95	0.49	0.37	2.1	2.4	4.1	3.8
Nasal Depth	1.59	1.37	0.29	0.34	1.0	0.8	2.2	2.1
Morphological Facial Length	11.58	11.00	0.71	0.58	9.8	9.8	12.8	12.4
Physiognomic Facial Length	17.85	16.46	0.85	0.92	15.8	14.4	20.0	18.6
Physiognomic Ear Length	6.17	5.69	0.40	0.37	5.2	4.1	7.0	6.4
Physiognomic Ear Breadth	3.36	3.06	0.32	0.41	2.9	1.9	4.6	4.7

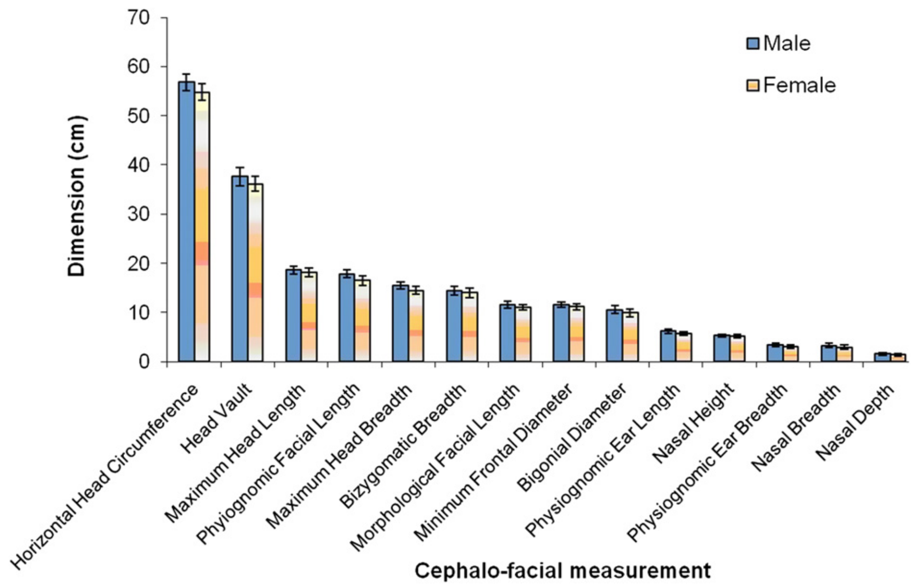

Fig. 2. Mean and standard deviation of cephalo-facial measurements of males and females.

On comparing the equality of means of male and female measurements (Table 5), it is evident that comparisons of the different measurements gender-wise were quite distinct and that male stature and cephalo-facial measurements were significantly higher than for females, except for Nasal height where no significant difference was observed ($P > 0.05$). Based on that evidence, data for males and females were treated separately. That is, one cannot come up with a model explaining for stature, based on cephalo-facial measurements, which is common for both sexes. Hence, correlation coefficients and regression analyses were carried out for each gender separately.

From Table 6, it can be deduced that stature was significantly positively correlated with Horizontal Head Circumference, Head Vault, Minimum Frontal Diameter, Bizygomatic Breadth, Physiognomic Facial Length and Physiognomic Ear Length among females. Among males (Table 7), stature was strongly positively correlated with Maximum Head Length, Horizontal Head Circumference, Nasal Breadth, Nasal Depth, Morphological Facial Length and Physiognomic Ear Length. It can also be noted that nasal depth tended to decrease with increasing stature among females while among males, Physiognomic Ear Breadth tended to decrease with increasing stature. However, both correlation coefficients were very small and, hence, not statistically significant.

3.1. Models explaining for variation in stature

Regression analysis was carried to determine which cephalo-facial measurement(s) best explained for variability in stature among males and females.

3.1.1. Male stature model

3 cephalo-facial measurements, namely, Horizontal head circumference, Nasal breadth and Morphological facial length best explained for stature among males. Horizontal head circumference alone explained for 24% variation in stature while nasal breadth explained for 9% variation and morphological facial length explained for a further 5% variation in stature. In all, the three variables explained for around 39% variation in stature among males. Hence,

Table 5
Test for equality of means by gender for stature and other cephalo-facial measurements.

Independent *t*-test		
	t	*P* (2-tailed)
Stature	14.02	0.000***
Horizontal Head Circumference	7.35	0.000***
Head Vault	5.38	0.000***
Minimum Frontal Diameter	4.39	0.000***
Bizygomatic Breadth	2.33	0.021*
Bigonial Diameter	4.99	0.000***
Morphological Facial Length	5.55	0.000***
Physiognomic Facial Length	9.61	0.000***
Mann–Whitney *U* test		
	Mann–Whitney U	*P* (2-tailed)
Maximum Head Breadth	1094.5	0.000***
Nasal Height	2386.5	0.137^{ns}
Nasal Breadth	1517.0	0.000***
Nasal Depth	1756.0	0.000***
Physiognomic Ear Length	1016.0	0.000***
Physiognomic Ear Breadth	1287.0	0.000***

ns: *t*-test is not significant.
**t*-test is significant at the 5% level (2-tailed).
****t*-test is significant at the 0.1% level (2-tailed).

Table 6
Correlation coefficients between stature and various cephalo-facial measurements among females (N = 74).

	Correlation Coefficient (r)	*P* value (2-tailed)
Maximum Head Length	0.159	0.176
Maximum Head Breadth	0.193	0.100
Horizontal Head Circumference	0.375	0.001**
Head Vault	0.318	0.006**
Minimum Frontal Diameter	0.255	0.028*
Bizygomatic Breadth	0.276	0.017*
Bigonial Diameter	0.159	0.175
Nasal Height	0.154	0.189
Nasal Breadth	0.054	0.645
Nasal Depth	−0.012	0.921
Morphological Facial Length	0.164	0.164
Physiognomic Facial Length	0.382	0.001**
Physiognomic Ear Length	0.242	0.037*
Physiognomic Ear Breadth	0.222	0.058

*Correlation is significant at the 5% level (2-tailed).
**Correlation is significant at the 1% level (2-tailed).

Table 7
Correlation coefficients between stature and various cephalo-facial measurements among males (N = 75).

Measurement	Correlation Coefficient (r)	*P* (2-tailed)
Maximum Head Length	0.331	0.004**
Maximum Head Breadth	0.015	0.896
Horizontal Head Circumference	0.494	0.000***
Head Vault	0.178	0.127
Minimum Frontal Diameter	0.103	0.380
Bizygomatic Breadth	0.177	0.129
Bigonial Diameter	0.022	0.853
Nasal Height	0.190	0.103
Nasal Breadth	0.380	0.001**
Nasal Depth	0.342	0.003**
Morphological Facial Length	0.328	0.004**
Physiognomic Facial Length	0.192	0.099
Physiognomic Ear Length	0.245	0.034*
Physiognomic Ear Breadth	−0.079	0.503

*Correlation is significant at the 5% level (2-tailed).
**Correlation is significant at the 1% level (2-tailed).
***Correlation is significant at the 0.1% level (2-tailed).

a model that would explain for variation in stature in males would result as follows:

$$\text{Stature (male)} = 32.277 + 1.637\,\text{Horizontal head circumference} + 5.474\,\text{Nasal Breadth} + 2.603\,\text{Morphological Facial Length}\ \left(R^2 = 0.389\right)$$

3.1.2. Female stature model

Among females too 3 cephalo-facial variables emerged as major predictors for stature. These variables were Physiognomic Facial Length, explaining for 15% variation, followed by Bizygomatic Breadth, explaining for an additional 12% variation and Horizontal Head Circumference for an additional 4% variation in stature. These three predictors explained for nearly 32% variation in stature among females which is less than that of males. It is to be noted that, apart from Horizontal Head Circumference, different caphalo-facial measurements explained for stature among males and females. Nevertheless, all three predictors in the model for female stature were significant and could be written as follows:

$$\text{Stature (female)} = 42.036 + 2.577\,\text{Physiognomic facial length} + 1.849\,\text{Bizygomatic breadth} + 0.858\,\text{Horizontal Head Circumference}\ \left(R^2 = 0.315\right)$$

4. Discussion and conclusion

Accurate estimation of stature from fragmented body remains is of great importance in forensic investigation. For such estimation, the regression analysis is considered as the best and most reliable method.[27]

The results of present study indicate that the cephalo-facial measurements were significantly higher in males as compared to females, except for the nasal height where no significant difference was observed. Patil and Mody[21] in their lateral cephalometric study on 150 healthy adults (75 males and 75 females) found that all linear measurements were significantly greater in males as compared to females. The formulae of stature estimation showed high degree reliability which may be due to the fact that the growth of skull (cephalo-facial) is mainly genetically determined through local epigenetic factors such as growth of brain.[28] As the stature of an individual is genetically determined, therefore, there must be some co-relation between the stature and cephalo-facial measurements.

Comparative statistical analysis among both gender clearly revealed that out of 14 variables, only three cephalo-facial variables such as horizontal head circumference, nasal breadth and morphological facial length emerged as major predictors for stature estimation among males, while among females, the stature is best explained by physiognomic facial length, bizygomatic breadth and horizontal head circumference in descending order. Jibonkumar and Lilinchandra[22] studied stature estimation on 199 male (18–45 years) by using facial measurements and found the highest correlation of stature with bigonial breadth. Krishna and Kumar[23] conducted a study on 252 male adolescents for the determination of stature from cephalo-facial measurements and observed that the cephalic measurements such as horizontal head circumference, maximum head length and maximum head breadth give better prediction of stature.

As per the Tables 6 and 7, 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 good predictors for estimating stature in Indo-Mauritian population. These findings are supported by Pelin el al.[25]

It is concluded that accurate stature estimation is not possible from percutaneous cephalo-facial dimensions in Indo-Mauritian population.

4.1. Limitation of study

This study has been conducted on medical students of India and Mauritius (Asian type population) that is in same ethnic group. Therefore the studies in other parts of the world and different ethnic group are required to confirm whether the cephalo-facial dimensions can be used for estimation of stature elsewhere.

Ethical approval

None declared.

Conflict of interest

None.

Funding

None declared.

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