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Do the measurements of head, face, and sternum predict body height in forensic anthropological cases?

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Abstract

Sex, age, and body height are of fundamental importance in the identification of individuals in medicolegal investigations. Body height can be calculated more accurately from the measurements of main long bones of upper and lower limbs. In case of a lack of limb segments or the long bones of the extremities, the dimensions of the head, face, and sternum are thought to be good predictors for living stature. In the present study, the correlation between the measurements of the head, face and sternum and body height was examined and univariate and multivariate regression equations were developed. Anthropometric measurements were taken on 108 healthy male subjects with a mean age of 22.4 years (SD = 3.35 years). Equations were constructed based on the measurements taken from the study group (Group I, *n* = 54) and tested on a cross validation group (Group II, *n* = 54). The univariate analyses revealed that the measurements studied could not be used for estimating body height. With multivariate equations considered, the best predictors for stature are sternum length and total face height. Therefore, it is concluded that the only way to estimate stature reliably are the latter two variables combined when the cranium and sternum were brought for medicolegal examinations.

Introduction

To predict living height is undoubtedly important for forensic anthropologists for reliable identification. Though long bones of the limbs or limb segments, if the body was not completely decayed, are the most frequently used variables for stature estimation, they are not always available. For example, during mass disasters in which many individuals had been killed, such as plane crashes or terrorist attacks, sometimes only the isolated head and/or torso of a mutilated body exists. Mutilated bodies could also be found in ordinary forensic cases such as murders. In such cases measurements from body parts other than limbs could be used for estimating stature.

Head, face and sternum dimensions were thought to be good predictors for body height. However, only a few studies have been reported in the literature on stature estimation based on head and face dimensions (e.g., Saxena et al., 1981; Sarangi et al., 1981; Introna et al., 1993; Chiba and Terezawa, 1998; Jadav and Shah, 2004; Krishan, 2008; Pelin et al., 2010; Ilayperuma, 2010; Sahni et al. 2010; Agnihotri et al., 2011; Giurazza et al., 2012; Shrestha et al., 2015; Kamal and Yadav, 2016; Torimitsu et al., 2016). On the other hand, the sternum is commonly used for sex and age determination (Ashley, 1956; Jit and Bakshi, 1986; Gautam et al., 2003). However, there were only a few studies for estimating stature from sternal measurements when we referred to the literature (Dwight, 1881, 1890). The main aim of the present study was to examine the correlation between living stature and head, face, and sternum dimensions and to construct regression equations.

Subjects and methods

The study was conducted on 108 healthy male subjects, with no morphological disorders, aged 18 to 36 years old with a mean of 22.4 years (SD = 3.35 years). The following anthropometric measurements were taken from each subject:

Body height: Body height was measured with the subject standing bare-foot with his back to the anthropometer, and with the head adjusted such that the Frankfurt plane was horizontal (Cameron et al., 1981).

Morphological face height (MFH): The distance between nasion and gnathion when the mouth is completely closed (Olivier, 1969).

Total face height (TFH): The distance on mid-sagittal plane between gnathion and the most distant point to it on the dome of the skull.

Bizygomatic breadth (BZB): The distance between the most distant points on the zygomatic arcs on horizontal plane (Olivier, 1969).

Maximum head length (MHL): The distance between glabella and the most posterior point on occipital bone (Olivier, 1969).

Head circumference (HC): The head circumference was measured by taking glabella and the most posterior point on occipital bone as landmarks (Olivier, 1969).

Sternum length (SL): When the subject was lying naked in supine position, the distance between the deepest point of jugular notch and the most distal point of xiphoid process.

Each subject was randomly assigned to either the study group (Group I, *n* = 54) or the cross-validation group (Group II, *n* = 54). Linear regression equations were devised using the measurement data from the study group subjects and the cross-validation group data were then used to test these formulae.

The actual height of the individuals in the cross-validation group and their predicted heights by using the different equations constructed in the study were evaluated primarily by root mean squared error (RMSE).

$$\text{RMSE} = \sqrt{\frac{\sum(\text{observed} - \text{predicted})^2}{(n - p - 1)}}$$

where n is the number of observation and p is the number of the predictor variables. Since RMSE reflects only the uncertainty of the estimate, the mean bias values were also given.

Results

The mean age and the anthropometric values of the study and the cross-validation groups are presented in Table 1. Since there was no statistically significant difference between the groups for each variable by one-way ANOVA, it could be concluded that both of the groups represent the same population.

Table 2 presents the Pearson's correlation coefficients between the body height and the variables studied for the total sample (n = 108). The most highly correlated variables with body height were total face height and the sternum length respectively. These were followed by morphological face height. All the above-mentioned correlations were statistically significant (P < 0.001). On the other hand head circumference, maximum head length and bizygomatic breadth gave lower correlation coefficients (P = 0.051 – 0.082)

Table 1. Anthropometrical characteristics of the study (Group I, n = 54) and the cross-validation (Group II, n = 54) groups

	Group I		Group II			
	Mean	SD	Mean	SD	F	Sig.
Age (years)	22.76	3.34	22.07	3.35	1.133	0.289
Body height (mm)	1740.43	51.64	1736.43	56.19	0.148	0.701
Morphological face height (mm)	120.78	5.70	122.00	5.30	1.333	0.251
Total face height (mm)	253.24	8.14	252.72	8.85	0.100	0.752
Bizygomatic breadth (mm)	142.43	5.55	141.78	5.22	0.390	0.533
Maximum head length (mm)	190.43	7.85	191.00	7.14	0.158	0.692
Head circumference (mm)	560.72	16.96	560.54	16.56	0.003	0.954
Sternum length (mm)	206.31	13.89	203.31	14.55	1.201	0.276

Table 2. Pearson correlation coefficients (r) between body height and the dimensions of head, face, and sternum for the total sample (n = 108)

Variables	r	Sig. (2-tailed)
Morphological face height (MFH)	0.209	0.030
Total face height (TFH)	0.361	0.000
Bizygomatic breadth (BZB)	0.168	0.082
Maximum head length (MHL)	0.186	0.054
Head circumference (HC)	0.188	0.051
Sternum length (SL)	0.338	0.000

Table 3. Regression equations for body height estimation based on the anthropometric dimensions from the study group (Group I, n = 54) (mm)

Variables	Regression equations	R^2	SEE
Morphological face height (MFH)	H = 1506.84 + 1.934 * MFH	0.046	50.93
Total face height (TFH)	H = 1234.18 + 1.999 * TFH	0.099	49.48
Bizygomatic breadth (BZB)	H = 1778.91– 0.270 * BZB	0.001	52.11
Maximum head length (MHL)	H =1534.04 + 1.084 * MHL	0.027	51.42
Head circumference (HC)	H = 1639.34 + 0.180 * HC	0.004	52.04
Sternum length (SL)	H = 1442.41 + 1.444 * SL	0.151	48.03
SL + TFH	H = 1111.23 + 1.482 TFH + 1.231 SL	0.202	47.02
SL + MFH	H = 1274.52 + 1.367 SL + 1.522 MFH	0.179	47.70

Table 4. The differences between estimated and actual height (mean = 173.43 mm; SD = 56.19 mm) of the subjects in cross-validation group (Group II, n = 54) (mm)

Variable(s)	Mean bias	Minimum	Maximum	$\sqrt{MSE}$
Morphological face height (MFH)	-6.36	-124.5	127.2	55.5
Total face height (TFH)	-2.95	-97.9	134.1	48.8
Bizygomatic breadth (BZB)	-4.20	-114.2	130.0	58.8
Maximum head length (MHL)	-4.66	-109.6	135.4	55.5
Head circumference (HC)	-3.81	-106.4	133.5	55.9
Sternum length (SL)	0.43	-119.1	115.7	53.0
SL + TFH	0.38	-107.5	120.9	47.5
SL + MFH	-1.71	-128.3	114.5	52.3

Table 5. Comparison of the estimated and actual heights of the subjects in cross-validation group (Group II, n = 54) (mm)

Variable(s)	Mean estimated height (mm)	SD	t	Sig.
Morphological face height (MFH)	1742.79	10.24	0.852	0.398
Total face height (TFH)	1739.37	17.69	0.418	0.677
Bizygomatic breadth (BZB)	1740.63	1.41	0.545	0.588
Maximum head length (MHL)	1741.08	7.74	0.622	0.537
Head circumference (HC)	1740.24	2.98	0.506	0.615
Sternum length (SL)	1736.00	21.00	-0.058	0.954
SL + TFH	1736.04	25.03	-0.055	0.957
SL + MFH	1738.14	23.64	0.234	0.816

In Table 3, regression equations based on single and multiple variables are presented. When the equations based on single variables were evaluated depending on R^2 values, the most accurate equation was the one based on sternum length. This was followed by total face height. Standard error of the estimates (SEE) also supports these findings. In addition, multiple regression equations were developed by stepwise regression analysis. The two most successful were reported in the Table 3. As is seen in the table, multiple equations based on SL + TFH; and SL + MFH yielded relatively more accurate results.

In Table 4, the differences between the actual and estimated heights of the subjects in the cross-validation group (Group II) were examined. According to the RMSE the most predictive single variables for body height were TFH and SL, as was expected. When bias column was considered it was seen that the TFH based equation underestimates the body height while the one based on SL overestimates. In addition, the latter two variables have the lowest bias. On the other hand, a multiple regression equation based on SL + TFH gave the most accurate results among all other equations. The latter equation also gave the lowest bias.

Figures 1 and 2 show the characteristics of the residuals of the estimated height based on SL and SL + TFH, respectively. It is obvious that equations constructed in this study overestimate short individuals, but also underestimate tall ones. This pattern was also observed when the equations were compared with the ones based on long bones (Duyar and Pelin, 2003; Pelin and Duyar, 2003).

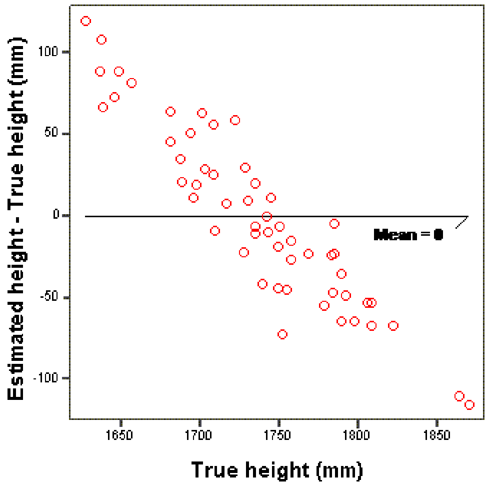

Figure 1. The scatter-plot of the residuals of estimated height based on sternum length

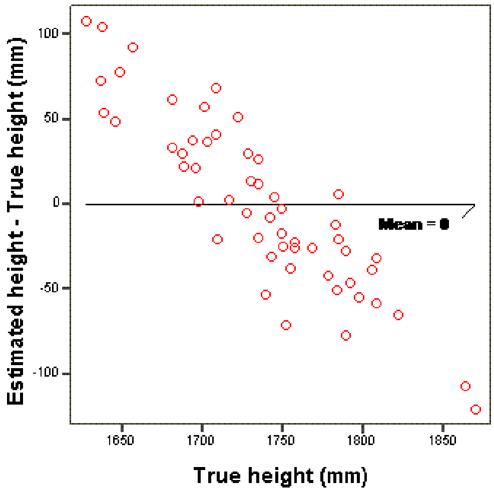

Figure 2. The scatter-plot of the residuals of estimated height based on sternum length + total face height

Discussion

In the present study, the most predictive variables were SL and TFH for estimating living stature. The above-mentioned two variables have the highest correlation with body height among the variables evaluated in the study. The RMSE and SEE values also support the finding that these variables are the most precise ones for estimating body height. A stepwise regression analysis indicates that the regression equations based on SL + TFH and SL + MFH yield more reliable estimates.

It is expected that the length of the sternum will have a relatively high relationship with body height. Similarly, it is not surprising that facial height, especially total facial height, is relatively highly correlated with stature. As a matter of fact, studies on adolescents revealed that the growth of facial height is more correlated with general body growth (e.g., with the body height) than those of cranial measurements (Baume et al., 1983; Duyar, 1998).

In forensic and medico-legal contexts, the correlation between the somatometry of cephalo-facial dimensions and body height was studied by various authors, but most studies were focused on head dimensions (e.g., Sarangi et al., 1981; Introna et al., 1993; Chiba and Terazawa, 1998; Jadav and Shah, 2004; Patil and Mody, 2005; Krishan, 2008; Ilayperuma, 2010; Giurazza et al., 2012; Shrestha et al., 2015; Torimitsu et al., 2016). There are only a few studies on stature estimation from face and sternum dimensions (Dwight, 1881, 1890). According to our analyses, it is clear that face dimensions and sternum length give more accurate estimates than head dimensions. Therefore, in forensic examination, if the face and the sternum are present together, the body height of the deceased can be estimated relatively accurately.

Our findings indicate that the correlation between head dimensions and stature was not significant (Table 2). The RMSE and SEE values also support these findings. In other words, head measurements are not applicable for stature estimation. There are some controversial studies on whether or not head measurements could be used in body height estimation. Some authors (e.g., Sarangi et al., 1981; Pelin et al., 2010; Agnihotri et al., 2011; Shrestha et al., 2015) conclude that the head dimensions are not successful for reconstructing the stature of deceased brought in for medico-legal examination, while some others have reported that skull dimensions could be used to predict living stature (e.g., Introna et al., 1993; Chiba and Terezawa, 1998; Jadav and Shah, 2004; Krishan, 2008; Ilayperuma, 2010; Sahni et al. 2010; Giurazza et al., 2012; Kamal and Yadav, 2016; Torimitsu et al., 2016).

In most studies on stature estimation the accuracy of the formulae was generally evaluated by SEE values. It is well known that the most reliable equations were derived from long bones of the limbs approximately 3 to 5 cm (Trotter and Gleser, 1958). Similarly, in their anthropometric study on measurements from lower limbs Özaslan et al. (2003) finds that SEE values for male individuals varies between 4.3 and 5.9 cm. On the other hand, estimations based on other somatometric dimensions' SEE values were relatively higher. For head and face dimensions the values of SEE are generally 6 cm or higher (see Chiba and Terezawa, 1998; Torimitsu et al., 2016). SEE of the equations in this study based on sternum length (SL) and total face height (TFH) were 4.80 and 4.95 cm, respectively.

Although SEE is widely used to test the reliability of the regression equations, the more effective method is to apply the equations generated on another group and compare the calculated body height values with the actual ones. In our study, we tested all univariate and multivariate regression equations on the control group. The difference between the calculated body height and the measured body height is taken into account, and the most accurate equations contain sternum length (SL) and total face height (TFH), with an average error of 4.75 cm. In all other equations, the error exceeded 5.0 cm. This analysis also suggests that no single variable can be used to predict body height.

Conclusion

This study demonstrates that no single measurement taken on head, face, and sternum could be used for the estimation of body height in forensic and anthropological cases. The best way to estimate body height from the measurements of head, face, and sternum is to apply multivariate regression equations in which sternum length (SH) and total face height (TFH) are combined, when the limbs' elements are not available.

References

Agnihotri AK, Kachhwaha S, Googoolye K, Allock A. (2011) Estimation of stature from cephalo-facial dimensions by regression analysis in Indo-Mauritian population. J Forensic Leg Med 18:167-172.

Ahmed AA, Taha S. (2016) Cephalo-facial analysis to estimate stature in a Sudanese population. Leg Med 20:80-86.

Ashley GT. (1956) The human sternum – The influence of sex and age on its measurements. J Forensic Med 3:27-43.

Baume RM, Buschang PH, Weinstein S. (1983) Stature, head height, and growth of the vertical face. Am J Orthod 83:477-484.

Cameron N, Hiernaux J, Jarman S, Marshall WA, Tanner JM, Whitehouse RH. (1981) Anthropometry. In: Weiner JS, Lourie JA, eds. Practical human biology. London: Academic Press, p. 25-52.

Chiba M, Terezawa K. (1998) Estimation of somatometry of skull. Forensic Sci Int 97(2-3):87-92.

Duyar İ. (1998) Ergenlik çağı çocuklarında yüz büyümesinin vücudun diğer bölümlerinin büyümesiyle ilişkisi. Turk J Orthod 11(1):6-12.

Duyar İ, Pelin C. (2003) Body height estimation based on tibia length in different stature groups. Am J Phys Anthropol 122:23-27.

Dwight T. (1881) The sternum as an index of sex, age and height. J Anatomy 15:327-330 (cited in Gautam et al., 2003).

Dwight T. (1890) The sternum as an index of sex, age and height. J Anatomy 24:527-535 (cited in Gautam et al., 2003).

Gautam RS, Shah GV, Jadav HR, Gohil BJ. (2003) The human sternum – as an index of age and sex. J Anat Soc Ind 52:20-23.

Giurazza F, Del Vescovo R, Schena E, Battisti S, Cazzato RL, Grasso FR, Silvestri S, Denaro V, Zobel BB. (2012) Determination of stature from skeletal and skull measurements by CT scan evaluation. Forensic Sci Int 222:398.e1-398.e9.

Gordon CC, Buikstra JE. (1992) Linear models for the prediction of stature from foot and boot dimensions. J Forensic Sci 37(3):771-782.

Ilayperuma I. (2010) On the prediction of personal stature from cranial dimensions. Int J Morphol 28:1135-1140.

Introna F Jr, Di Vella G, Petrachi S. (1993) Determination of height in life using multiple regression of skull parameters. Boll Soc Ital Biol Sper 69(3):153-60.

Jadav HR, Shah GV. (2004) Determination of personal height from the length of head in Gujarat region. J Anat Soc India 53(1):20-21.

Jit I, Bakshi V. (1986) Time of fusion of the human mesosternum with manubrium and xiphoid process. Ind J Med Res 83:322-331.

Kamal R, Yadav PK. (2016) Estimation of stature from different anthropometric measurements in Kori population of North India. Egypt J Forensic Sci 6:468-477.

Krishan K. (2008) Estimation of stature from cephalo-facial anthropometry in north Indian population. Forensic Sci Int 181:52.e1-52.e6.

Olivier G. (1969) Practical Anthropology. Springfield: Charles C Thomas, p. 287.

Özaslan A, İşcan MY, Özaslan İ, Tuğcu H, Koç S. (2003) Estimation of stature from body parts. Forensic Sci Int 132:40-45.

Patil KR, Mody RN. (2005) Determination of sex by discriminant function analysis and stature by regression analysis: a lateral cephalometric study. Forensic Sci Int 147:175-180.

Pelin C, Duyar İ. (2003) Estimating stature from tibia length: a comparison of methods. J Forensic Sci 48:708-712.

Pelin C, Zağyapan R, Yazıcı C, Kürkçüoğlu A. (2010) Body height estimation from head and face dimensions: a different method. J Forensic Sci 55:1326-1330.

Sahni D, Sanjeev, Sharma P, Harjet, Kaur G, Aggarwal A. (2010) Estimation of stature from facial measurements in northwest Indians. Leg Med 12:23-27.

Sarangi AK, Dadhi B, Mishra KK. (1981) Estimating stature from adult skull bone. J. Acad Forensic Med 24 – 26. 182

Saxena SK, Jayasingh P, Gupta AK, Gupta CD. (1981) The estimation of stature from head-length. J Anat Soc India 30:78-79.

Shrestha R, Shrestha PK, Wasti H, Kadel T, Kanchan T, Krishan K. (2015) Craniometric analysis for estimation of stature in Nepalese population-a study on an autopsy sample. Forensic Sci Int 248:187.e1-187.6

Torimitsu S, Makino Y, Saitoh H, Sakuma A, Ishii N, Yajima D, Inokuchi G, Motomura A, Chiba F, Yamaguchi R, Hashimoto M, Hoshioka Y, Iwase H. (2016) Stature estimation from skull measurements using multidetector computed tomographic images: a Japanese forensic sample. Leg Med 18:75-80.

Trotter M, Gleser G. (1958) A re-evaluation of estimation of stature based on measurements of stature taken during life and long bones after death. Am J Phys Anthropol 16:79-123.