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Estimation of Adult Human Height from the Bigonial Width and Mandibular Arch

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Abstract

Introduction An individual's sex, age and height are of great importance in legal medicine, especially with regard to identifying corpses. Height estimates are based on the proportionality relationship that exists between an individual's height and his various body parts.

Objective To analyze the relationship between mandible measurements (length of the mandibular arch and bigonial width) and height.

Materials and methods This study was conducted on the population of the Mussuca quilombo settlement, which is in the municipality of Laranjeiras, state of Sergipe, Brazil. The sample was composed of 300 individuals: 150 women and 150 men aged between 18 and 85 years old. The statistical analysis was done using the Statistical Package for the Social Scienes SPSS®, version 19.0, for Windows (SPSS Inc., Chicago, EUA) and Excel 2010 (Microsoft Corp., Redmond, WA, USA).

Results The correlation coefficients were found to be low, with weak correlations between the measurements of the mandibula and height. Analysis on these values shows a very small positive correlation between height and the length of the mandibular arch among males ($r = 0.177$; $p < 0.05$) and among females ($r = 0.271$; $p = 0.001$); and between height and bigonial width among females ($r = 0.169$; $p < 0,05$).

Conclusion Height may be estimated less exactly in cases in which only cephalofacial dimensions are available for legal medical examination.

Keywords
- anatomy and anthropology
- anthropometry
- body height
- forensic anthropology
- jaw
- legal medicine

Introduction

An individual's sex, age and height are of great importance in legal medical practice for identifying corpses, and especially so when bodies are reduced to their skeletons.[1] In these situations, the absence of biological characteristics that would enable identification of individuals in scenarios of aviation accidents, automobile accidents, homicides, fires, or natural disasters still constitutes a problem, even in light of the various technical possibilities that exist within forensic anthropology. Height is one of the main criteria used in identifying human

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beings. This is based on the principle that an individual's height has a defined proportional relationship with the various parts of the body.[2,3] However, in some circumstances, it is not always possible to obtain a complete human skeleton. Thus, it becomes a challenge to estimate an individual's height and identify this person when only the cephalofacial region of the skeleton is available for an anthropological legal medical expert examination.[4] Another situation in which height estimates have been shown to be extremely important are cases of disease or deformity of the spine, which make it difficult to directly measure the individual's height.[5]

Anatomical and mathematical methods form the two main tools used in forensic anthropology for estimating height.[6] The anatomical method consists of measuring and adding together all the skeletal elements that contribute towards an individual's height, with a correction factor for soft tissues. The mathematical model consists of derivation of formulae through linear correlations that exist between given parts of the body and height.[7,8] For this calculation, some studies[2,4,9,10] have demonstrated that regression analysis is the most reliable method.

Several authors have attempted to correlate height with different parts of the body.[11–27] However, few studies on cephalofacial variables have been conducted.[2,3,28–33]

Differences in cephalofacial morphology are present between different populations worldwide. These are determined by environmental and ethnic factors and even by the customs of these populations.[34] Thus, the regression formulae through which it is sought to estimate the height of different cranial variables are specific for each sample.

Given the scarcity of studies on Brazilian populations and the need to develop such studies, the present study had the objective of analyzing the relationships that might exist between measurements of the mandible (length of the mandibular arch and bigonial width) and height.

Materials and Methods

This was an anthropometric study in which cross-sectional analytical and descriptive was analyses were conducted. Data were gathered from the subjects after they had been given explanations regarding the objectives of the study and had signed a free and informed consent statement. A direct approach was used, at the participants' homes, in the same way used in surveys conducted by the Brazilian Institute for Geography and Statistics (IBGE, in the Portuguese acronym). The instruments used in making the measurements were a pachymeter (Cerscof, Araquari, Santa catarina, Brasil) an inelastic measuring tape, and a portable stadiometer (ALTUREXATA, Belo Horizonte, Minas Gerais, Brasil).

This study was conducted among individuals of both genders, aged 18 to 85 years, who belonged to a quilombo community, Mussuca, in the municipality of Laranjeiras, state of Sergipe, Brazil. The municipality of Laranjeiras is located in the northeast of Brazil, in the state of Sergipe, at about 18 Km from the capital, Aracaju. According to the IBGE, it had an estimated population of 29,700 people in the year of 2017, distributed in a land area of 162.273 km^2 (https://cidades.ibge.gov.br). The sample comprised 300 individuals (150 women and 150 men). The inclusion criteria were individuals in good health, of either gender, who were $\geq$ 18 years of age. Individuals who presented spinal abnormalities (kyphosis, lordosis or scoliosis), lower-limb amputations, or any macroscopic malformation in the mandibular region were excluded. The statistical analysis comprised calculation of means, standard deviation (SD), minimum and maximum values, Pearson correlation coefficient (r), and multiple linear regression analysis. It was performed using the Statistical Package for the Social Scienes SPSS®, version 19.0, for Windows (SPSS Inc., Chicago, EUA) and Excel 2010 (Microsoft Corp., Redmond, WA, USA). The present study was approved by the Research Ethics Committee of the Federal University of Sergipe, under protocol number 32813314.1.0000.5546.

Anthropometric Measurements:

- Bigonial width: this was measured as the linear distance between the two gonia, which are points at the external angle of the mandible, in posterior view. This was measured with the aid of a pachymeter (Cerscof) (►**Fig.1**).
- Length of the mandibular arch: this was measured in anterior view between the mandibular angles, following the lower edge of the mandible, using an inelastic measuring tape (►**Fig 2**).
- Height: this was measured using a portable stadiometer (ALTUREXATA) and consisted of the greatest distance between the plantar region of the feet and the top of the head (at the coronal vertex).

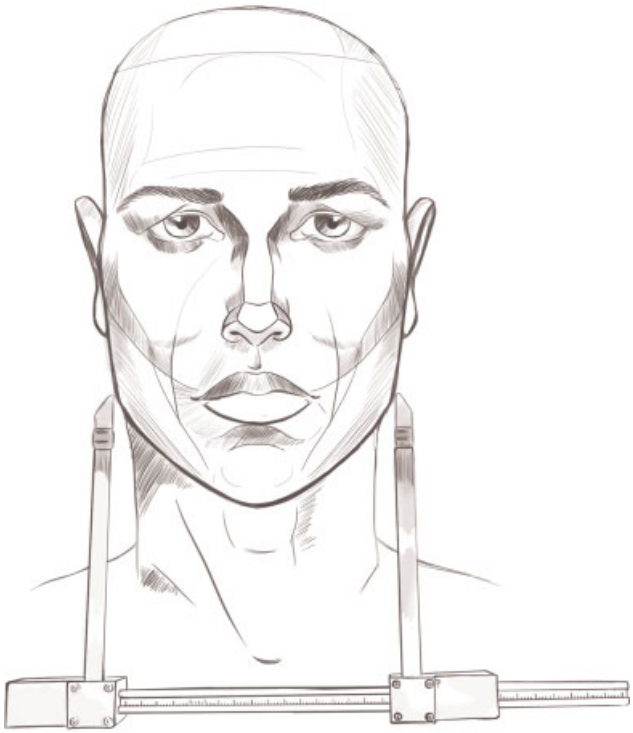

Fig. 1 Bigonial width.

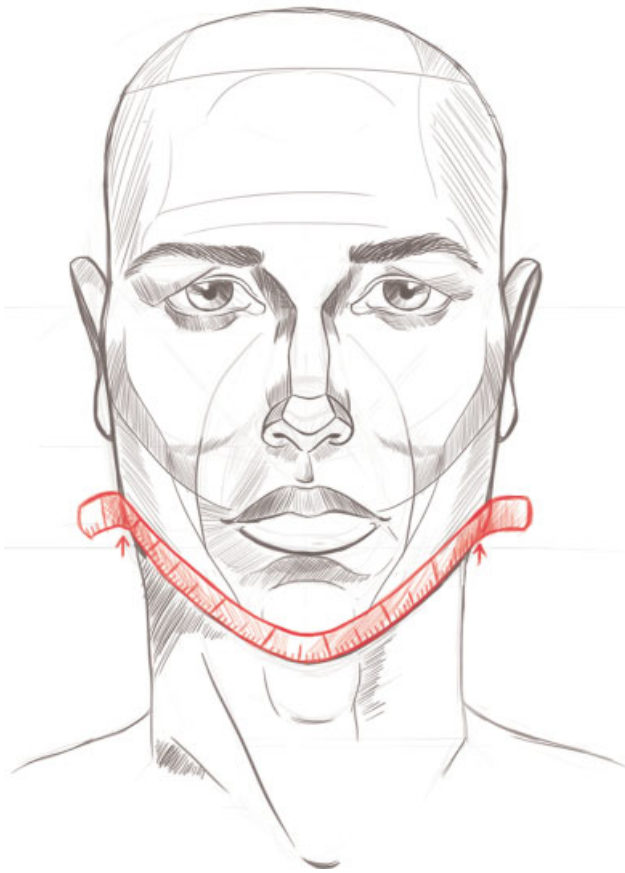

Fig. 2 Length of the mandibular arch.

Results

The ages among the sample ranged from 18 to 85 years, with a general mean of 38.8 years and a SD of 15.6 years. The mean for males was 39.1 years and for females, 38.4 years, without any statistically significant difference ($p = 0.688$). The mean height of the men (170.4 cm) was significantly greater ($p < 0.001$) that that of the women (158.6 cm). The heights of the men ranged from 150.4 to 190.7 cm, while the heights of the women ranged from 142.6 to 170.6 cm. The mean difference in height was 11.8 ± 0.7, with a 95% confidence interval (CI) of 10.4 to 13.2. The mean values for both anthropometric facial variables were significantly larger ($p < 0.001$) among the men. The length of the mandibular arch showed a mean difference of 1.3 ± 0.12 with 95% CI of 1.04-1.52. The bigonial width of the mandible showed a mean difference of 0.56 ± 0.07 with 95% CI of 0.42-0.7 (►**Table 1**).

In the present study, the anthropometric measurements on the mandible showed weak correlations with height, such that the Pearson correlation coefficients (r) were low. Analysis on these values showed very low positive correlations between height and the length of the mandibular arch, both among men ($r = 0.177$; $p < 0.05$) and among women ($r = 0.271$; $p = 0.01$); and between height and the bigonial width of the mandible among women ($r = 0.169$; $p < 0.05$) (►**Table 2**).

Multiple regression models were calculated for males and females, with height as the dependent variable in both cases. For males, age, length of the mandibular arch and bigonial width of the mandible were used as independent variables. Among these measurements, the one that presented greatest explanatory power regarding variation of height was the bigonial width of the mandible (standardized beta = 0.200) (►**Table 3**).

Among females, age and the length of the mandibular arch were represented as independent variables. In this multiple linear regression model, the bigonial width of the mandible was shown not to be statistically significant ($p = 0.756$). Thus, the length of the mandibular arch emerged as the variable that best explained variations of height (standardized beta = 0.259) (►**Table 4**).

The regression formulas were calculated separately for each gender, from their independent variables (►**Table 5**). Among the men, age, length of the mandibular arch and bigonial width of the mandible explained around 27% of the variation of height. Among the women, age and length of the mandibular arch emerged as the main predictors for height, explaining around 25.4% of its variation. The standard error of the estimate (SEE) for the regression model derived was greater for men than for women.

Discussion

So far, anthropometric studies of the Brazilian population with the aim of correlating the length of the mandibular arch and its bigonial width have been scarce or nonexistent. Starting from this observation, we sought, with the present study of a population in a quilombo settlement, to construct a specific equation for each gender that would be useful for making height estimates from each individual's age and facial variables.

Table 1 Characterization of age and anthropometric variables according to gender in a "quilombo" community

	Male (n = 150)				Female (n = 150)				*p*
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Age	39.1	16.2	18	85	38.4	15.1	18	83	0.688
Height	170.4	6.7	150.4	190.7	158.6	5.9	142.6	170.6	< 0.001
Length of mandibular arch	22.5	1.1	19.9	25.5	21.2	1.0	17.7	23.8	< 0.001
Bigonial width of mandible	10.5	0.7	9.0	12.2	9.9	0.5	8.6	11.3	< 0.001

Abbreviations: Min, minimum; Max, maximum; SD, standard deviation; *p*, significance level.

Table 2 Correlation of height with age and anthropometric variables of the mandible according to gender

	Male (n = 150)		Female (n = 150)	
	r	*p*	r	*p*
Age	-0.414	< 0.001	-0.433	< 0.001
Length of mandibular arch	0.177	0.030	0.271	0.001
Bigonial width of mandible	0.144	0.079	0.169	0.038

Abbreviations: *p*, significance level; r, Pearson correlation coefficient.

Table 3 Multiple linear regression model for males

	B	Beta	*p*
Constant	132.771	–	< 0.001
Age	-0.209	-0.504	< 0.001
Length of mandibular arch	1.109	0.179	0.028
Bigonial width of mandible	1.993	0.200	0.016

Abbreviations: B, non-standardized partial regression coefficient; Beta, standardized partial regression coefficient; *p*, significance level.

Table 4 Multiple linear regression model for females

	B	Beta	*p*
Constant	133.1	–	< 0.001
Age	-0.165	-0.425	< 0.001
Length of mandibular arch	1.456	0.259	< 0.001
Bigonial width of mandible	0.281	0.025	0.756

Abbreviations: B, non-standardized partial regression coefficient; Beta, standardized partial regression coefficient; *p*, significance level.

Table 5 Regression equations for height estimates according to gender

Sex	Equation	R^2	SEE (cm)
Male	Height (cm) = 132.771 - 0.209 x age (years) + 1.109 x LMA (cm) + 1.993 x BWM (cm)	0.269	5.8
Female	Height (cm) = 133.1 -0.165 x age (years) + 1.456 x LMA (cm)	0.254	5.1

Abbreviations: BWM, bigonial width of the mandible; LMA, length of the mandibular arch; R^2, coefficient of determination; SEE, standard error of the estimate.

The word "quilombo" in the Yoruba language, means "dwelling", and Bantu, "gathering camps," "union".[35] For the National Institute of Colonization and Agrarian Reform (INCRA, in the Portuguese acronym),[36] quilombo communities represent ethnic groups predominantly made up of black population, self-defined from the relationship with the land, ancestry, territory and own cultural practices (http://www.incra.gov.br/quilombola).

According to Moura,[37] quilombo is defined as a sociopolitical organization that originated from the fight and resistance against the slavery system. The quilombos were regarded as a cultural space of resistance and preservation of the African culture, in which blacks were able to speak their language and worship their religion; in that sense, the quilombo represented rebellion against standards imposed by the official society and restoration of the old values.[38]

The results from this study demonstrated that the length of the mandibular arch presented the best correlation coefficient with height, both for men (r = 0.177) and for women (r = 0.271). Previous studies did not mention this facial variable among their results.[3,4,29–34,39–42] The correlation between the bigonial width of the mandible and height among men was not shown to be statistically significant ($p > 0.05$), and this was also observed by Agnihotri et al,[3] and Sahni et al.[4] Among women, the bigonial width presented a weak statistically significant correlation with height, similar to the values found by Ahmed and Taha,[29] and by Shah et al.[30] A comparison of the different correlation coefficients between bigonial width of the mandible and height, according to gender, as described by some authors, is presented in ►**Table 6**.

Only a few studies have attempted to correlate height with cephalofacial anthropometric variables in different populations around the world. A study conducted by Krishan and Kumar[31] on an endogamous group of castes in northern India demonstrated that the 16 cephalofacial measurements used presented significant correlations with height. The highest correlation coefficient among these was with the horizontal circumference of the head (r = 0.773), and the lowest was with the nose size (r = 0.265). A subsequent study conducted by Krishan[40] on a sample of 996 adults Gujjars in northern India indicate that all the variables used presented positive correlations with height, with correlation coefficients ranging from 0.455 to 0.781. In a study on Sudanese Arab students, Ahmed and Taha[29] reported that the highest correlation coefficients between cephalofacial measurements and height related to the width of the base of the cranium (r = 0.370) and the bizygomatic width (r = 0.350) among men; and to the bizygomatic width (r = 0.369) and bigonial width (r = 0.368) among women. Sahni et al[4] found low correlation coefficients between facial variables and height. From measurements on 124 Japanese cadavers, Chiba and Terazawa[41] found correlation coefficients for various craniofacial parameters ranging from 0.32 to 0.53, but when individuals aged 70 years or over were excluded from the sample, the correlation coefficients ranged from 0.38 to 0.6. These authors also stated that height estimates from these variables could be used in forensic practice. In the present

Table 6 Correlation coefficients (r) between the bigonial width of the mandible and height in various studies

Authors	Population	Age (years)	Bigonial width of the mandible					
			Men			Women		
			n	r	*p*	n	R	*p*
Present study	Brazilian	18–85	150	0.144	0.079	150	0.169	< 0.05
Ahmed and Taha[29]	Sudanese	18–25	120	0.247	< 0.01	120	0.368	< 0.001
Shah et al[30]	Indian	21–50	676	0.096	< 0.05	225	0.193	< 0.05
Agnihotri et al[3]	Indian-Mauritian	20–28	75	0.022	0.853	75	0.159	0.175
Pelin et al[34]	Turkish	18–45	286	0.164	< 0.001	–	–	–
Sahni et al[4]	Indian	18–70	173	0.064	0.201	127	0.047	0.299
Krishan[40]	Indian	18–30	996	0.462	< 0.001	–	–	–
Krishan and Kumar[31]	Indian	12–18	252	0.449	< 0.001	–	–	–

Abbreviations: n, number of individuals in the sample; *p*, significance level; R, Pearson correlation coefficient.

study, the means for all the variables used were shown to be greater among males than among females. Similar results were obtained by Shah et al[30] and by Patil and Mody[42] in a lateral cephalometric study on adults in central India. Agnihotri et al[3] studied height estimates from cephalofacial variables among 150 young adults aged 20 to 28 years and observed that among the men, the horizontal circumference of the head ($r = 0.494$), nose width ($r = 0.380$) and morphological length of the face ($r = 0.328$) stood out as the main factors responsible for height estimates. On the other hand, among the women, the main predictors were the physiognomic length of the face ($r = 0.382$), horizontal circumference of the head ($r = 0.375$) and bizygomatic width ($r = 0.276$). In a Turkish population, Pelin et al[34] sought to evaluate the correlation coefficients between cephalofacial anthropometric variables and height, according to different types of head (dolichocephalic, mesencephalic, brachycephalic and hyperbrachycephalic) and different types of face (hypereuryprosopic, euryprosopic, mesoprosopic, leptoprosopic and hyperleptoprosopic). They concluded that these variables were not good predictors for estimating height. In a study on 200 cadavers (148 male and 52 female) from a population in Nepal, Shrestha et al[33] found statistically significant correlation coefficients between all the anthropometric variables and height, for their entire sample. Height in young individuals grows progressively, reaching the highest values between 21 and 25 years of age. After this age, the values decrease by an average of 2.5 cm every 25 years. This has been attributed to the wear of the intervertebral discs, plus a greater postural complacency, to lean, resulting from the reduction of muscle tone inherent in advancing age.[43] Therefore, it can be observed that the coefficient of Pearson found in our study, as occurred in most descriptions of the studied literature, is negative when correlated with age stature, demonstrating objectively that, in fact, there was a decrease in stature with advancing age of the individual.

This large variability in the results presented, between different studies, in attempts to find positive and statistically significant correlation coefficients between cephalofacial anthropometric variables and height may be related to the samples that different researchers have used (castes versus ethnically mixed populations; and living individuals versus cadavers) and the methodologies used (facial and/or cranial anthropometry; or imaging examinations). However, we emphasize that the formulae derived in the present study are specific for the quilombo population of the Mussuca settlement, in the state of Sergipe, given that the morphometric diversity of crania seems to be influenced by environmental, racial and nutritional factors.

Conclusion

All the anthropometric variables of the mandible in the quilombo population studied presented very low correlation coefficients with height. Therefore, it can be concluded that height estimates may be less accurate in cases in which only the cephalofacial dimensions are available for forensic medical anthropological examination.

Conflicts of Interest

The paper has not been submitted for publication elsewhere, and all authors were fully involved in the study and preparation of the manuscript. The authors also declare that there are no conflicts of interest.

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