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Estimation of stature in a quilombola community in northeastern Brazil using anthropometric measurements of the hands

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Abstract

Background Estimating or predicting stature, using fragments of the body or components of the human skeleton, for this purpose, originates from the idea of proportionality between the different parts of the body. The aim of this study is to estimate stature from anthropometric measurements of the hands (length and width). The sample consisted of 300 individuals from a quilombola community in northeastern Brazil, 150 males and 150 females. All people from the quilombola community, enjoying good general health, were included, and those people who presented deformities of the hand, spine, and lower limbs were excluded.

Result The correlation coefficients between stature and hand length values were positive and moderate. As for females, the correlation between stature and lengths of the right and left hands were respectively 0.574 ($p < 0.0001$) and 0.612 ($p < 0.0001$).

Conclusion The measure that best correlated with stature in the quilombola community in northeastern Brazil was hand length for both sexes, with the highest correlation for females.

Keywords Forensic medicine, Forensic anthropology, Height estimation, Anthropometry, Hands

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Background

Anthropometry is a very useful tool in forensic medicine for identifying an individual, measuring human body parts remaining at crime scenes, major natural disasters, terrorist attacks, or accidents (Jee and Yun 2015). The stature of an individual is an essential part of its identification. Its assessment using traditional methods can be difficult in cases of non-existence of intact bodies. Thus, it becomes important to research alternative methods that can be used to estimate the stature of individuals (Agnihotri et al. 2008; Akhlaghi et al. 2012; Uhrová et al. 2015; Ibeabuchi et al. 2021).

Associated with body weight, the stature is highlighted as a parameter for nutritional assessment and prediction of energy expenditure, in addition to being important in pharmacokinetics. This is how patients with pathologies or deformities such as kyphosis, lordosis, scoliosis, and contractures or absence of legs, are prevented from having their stature directly evaluated through the stadiometer, corroborating this fact for the search for indirect measurements (Rabito et al. 2006; Ilayperuma 2010; Melo et al. 2014).

Estimating or predicting stature, using fragments of the body or components of the human skeleton, originates from the idea of proportionality between the different parts of the body. This means that stature has a precise and linear relationship with the various elements and bones of an individual (Krishan et al. 2012). Some studies have sought to establish a relationship between stature and the most diverse body structures, such as clavicle, feet, tibia, femur, and upper limb (Kamal and Yadav 2016; Torimitsu et al. 2017; Gwani et al. 2017; Brits et al. 2017; Ibeabuchi et al. 2021). In this sense, the hand, for Jee and Yun (2015), presents itself as a rich structure, due to its large number of components (27 bones and 15 joints) and is commonly found in crime and disaster sites. Some studies have established a positive correlation between stature and hand dimensions (Jasuja and Singh 2004; Ahemad and Purkait 2011; Ishak et al. 2012; Sen et al. 2014; Mahakizadeh et al. 2016). However, these studies have a very specific character, in view of the isolated observation of certain populations, such as Indian groupings and specific regions of Australia and Egypt. Thus, the applicability of such anthropometric relationships becomes questionable, when considering the existence of variation in stature among the numerous ethnic groups, in addition to the fact that in Brazil there is no precise delineation between the various mixed ancestry groups, due to their strong crossing. This alerts us to the need for studies to be carried out in our country (Borborema et al. 2010).

In the present study, our objective was to estimate the stature of individuals who compose a quilombola community in northeastern Brazil, based on anthropometric measurements of the hands (length, width). Quilombolas are remnants of African slaves who inhabited Brazil. These communities recognized and legitimized by the Brazilian Constitution live in their own territorial areas delimited by law. It is estimated that there are, in the state of Sergipe, 45 quilombola groups defined in census tracts. Of these, only 16 are delimited, defined, and certified. In the 2022 census, currently underway, information will be collected by the Brazilian Institute of Geography and Statistics (IBGE) on the quilombo population of the state (IBGE 2019).

Methods

This is a cross-sectional, descriptive, and analytical study, consisting of a sample of 300 individuals from a quilombola community, 150 males and 150 females, aged between 18 and 85 years. All individuals over 18 years of age, in good general health, were included, and those who on visual inspection showed deformities of the hand, spine, lower limbs, or other factors that could make the study unfeasible were excluded. The current study comprises the population in general, without taking into account the individual evolution of stature and the possible secular trends in stature of this population. The approach to the participants was carried out directly in their respective homes, following a similar organization used by the Brazilian Institute of Geography and Statistics (IBGE), located in the village of Mussuca, belonging to the municipality of Laranjeiras, in the State of Sergipe, and after clarification of the objectives of the research and signing the Free and Informed Consent Term (FICT), data were collected using an inelastic and inextensible measuring tape (Cerscof®) to measure the stature and width of both hands (Fig. 1) and a portable stadiometer (ALTUREXATA) for stature measurement. The present study was approved by the Research Ethics Committee of the Federal University of Sergipe, under protocol number 716.525.

Anthropometric measurements used were as follows:

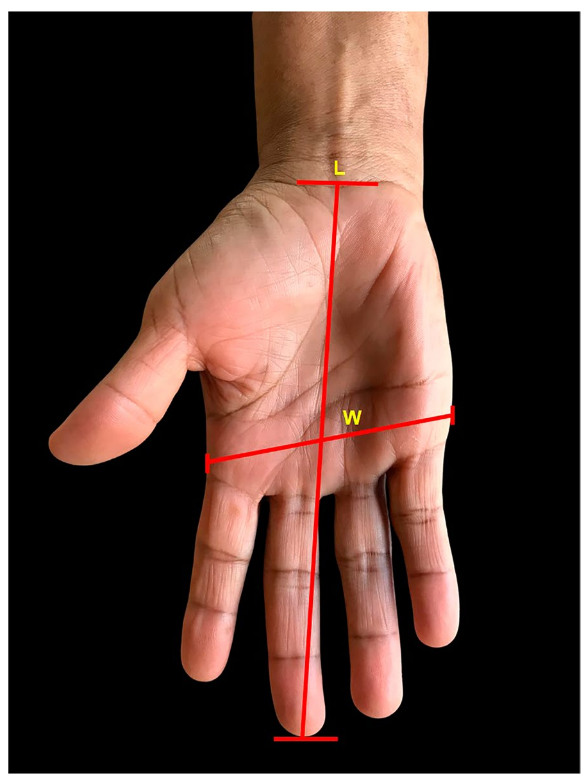

Fig. 1 Length and width of hands. L – Length. W – Width

- Body stature: is the maximum distance between the plantar region (feet) and the coronal vertex (top of the head).
- Hand length: corresponds to the distance between the midpoint located between the styloid processes (of the radius and ulna) on the anterior surface of the wrist, and the most distal point of the middle finger.
- Hand width: distance from the most prominent point outside the lower epiphysis of the second metacarpal to the most prominent point within the lower epiphyses of the fifth metacarpal.

Data analysis was conducted in R Core Team 2022 software (Version 4.2.1). We used mean and standard deviation to describe anthropometric measurements. The Shapiro-Wilks test was used to evaluate normality adherence assumptions. The Student *t* test for independent samples was used to evaluate mean equality hypothesis when normality assumption was met; otherwise, the Mann–Whitney test for independent samples was used. Pearson correlation was used to evaluate correlation between anthropometric measurements. Multiple linear regression was applied to estimate linear equations for stature by sex, and backward variable selection method was also applied. F-test was used and establishes the existence of significant regression coefficients and *T*-test to identify them. We also estimate standardized coefficients to evaluate variable effect size and importance. We used correlation coefficient (R), adjusted determination coefficient (R^2_{adj}), mean absolute error (MAE), and root mean squared error (RMSE) to evaluate goodness of fit. We also use *k*-fold cross-validation to evaluate outsample validity with $k=5$. We tested if linear regression model assumptions of homoscedasticity, multicollinearity, residual normality and no autocorrelation were met by the White test, variance inflation factor under 10, the Shapiro–Wilk test, and the Durbin-Watson test respectively. We adopted 5% level of significance.

Results

The mean age of the research participants was 38.7 years and ranged between 18 and 85 years. The lower limit of stature was 150.4 cm and the upper limit was 190.7 cm for males and ranged from 142.6 to 170.6 cm for females. Males had a significantly higher mean stature than females (T = −16.2430, df = 239.2900, $p<0.0001$). The mean difference was 11.8 ± 0.7 with a 95% confidence interval (CI) from 10.4 to 13.2 (Table 1).

In males, the average length for the left hand were 19.40 ± 0.95 cm and were not statistically different than the average length of the right hand, 19.31 ± 0.93 cm, with a mean difference of 0.091 ± 0.039 ($U=10{,}529$, $p=0.4025$). In females, there was no significant difference when the length of the hands ($T=-0.3953$, df = 300.7100, $p=0.6929$) was compared bilaterally. In addition, males presented means of 19.3 cm in length for the right hand and 19.4 cm for the left hand, significantly higher (left hand length: $U=2631$, $p<0.0001$; right hand length: $T=-14.2300$, df = 295.6400, $p<0.0001$) than the means for females, 17.8 cm for the left hand right and 17.9 to the left (Table 1).

Table 1 Characterization of age and anthropometric variables according to sex in a quilombola community

	Male ($n=150$)		**Female ($n=150$)**		***p***
	Mean	**SD**	**Mean**	**SD**	
Age	39.12	16.20	38.39	15.11	0.8099 M
Stature	170.43	6.70	158.61	5.85	< 0.0001 T
Right hand length	19.31	0.93	17.87	0.80	< 0.0001 M
Left hand length	19.40	0.95	17.91	0.85	< 0.0001 ^{T}
Right hand width	8.72	0.40	7.89	0.40	< 0.0001 ^{T}
Left hand width	8.60	0.52	7.78	0.43	< 0.0001 ^{T}

Values expressed as mean and *SD* Standard deviation

T Student's *t* test for independent sample, *W* Mann–Whitney test for independent sample, *p* significance level

Similarly, when we took the width of the hands for descriptive analysis in males, significantly higher mean values were obtained (left hand width: $T=-14.7500$, $p<0.0001$; right hand width: $T=-16.971$, $p<0.0001$) in relation to females, with a mean difference of 0.83 ± 0.05 and a 95% confidence interval (CI) from 0.7 to 0.9. When bilaterally compared in the same sex, mean values of the right hand, 8.73 ± 0.45 cm, were shown for males, higher than the values obtained for the left hand, 8.60 ± 0.52 cm, with a mean difference of 0.121 ± 0.022 ($T=2.1500$, df = 291.9300, $p=0.0324$). This same pattern was observed for females, in which the hands presented mean width of the right hand of 7.89 ± 0.40 cm, higher than those of the left hand, 7.78 ± 0.44 cm, with a mean difference of 0.104 ± 0.019 ($T=2.1158$, df = 300.1700, $p=0.0352$) (Table 1).

The correlation coefficients between stature and hand length values obtained in our study were positive and moderate. With regard to males, these values were 0.557 ($p<0.0001$) and 0.571 ($p<0.0001$) for the length of the right and left hands, respectively. As for females, the correlation between stature and lengths of the right and left hands were respectively 0.574 ($p<0.0001$) and 0.612 ($p<0.0001$). However, when hand widths were correlated with stature, a weak positive relationship was obtained, with a value of 0.313 ($p<0.0001$) for the right hand in males, and values of 0.402 ($p<0.0001$) and 0.305 ($p<0.0001$) for left and right hands, respectively, in females. As an exception, the width of the left hand

Table 2 Correlation of stature with age and anthropometric variables of the hands according to sex in a quilombola community

	Sex			
	Male ($n = 150$)		Female ($n = 150$)	
	r	*p*	*r*	*p*
Age	−0.414	< 0.0001	−0.433	< 0.0001
Right hand length	0.557	< 0.0001	0.574	< 0.0001
Left hand length	0.571	< 0.0001	0.612	< 0.0001
Right hand width	0.313	< 0.0001	0.402	< 0.0001
Left hand width	0.262	0.001	0.305	< 0.0001

r Pearson correlation, *p* significance level

Table 3 Correlation of stature with age and anthropometric variables of the hands for both sexes in a quilombola community

Variables	*r*	*p*
Age	−0.291	< 0.0001
Left hand length	0.763	< 0.0001
Right hand length	0.751	< 0.0001
Right hand length	0.668	< 0.0001
Left hand width	0.610	< 0.0001

r Pearson correlation, *p* significance level

in males showed a very weak correlation with height ($r = 0.262$, $p = 0.001$) (Table 2).

When both sexes were analyzed, the correlation coefficients between stature and hand length were positive and high, with a value of 0.763 ($p < 0.0001$) for the left hand and 0.751 ($p < 0.0001$) for the right hand; when the width was analyzed, a positive and moderate correlation was obtained, 0.668 ($p < 0.0001$) in the right hand and 0.610 ($p < 0.0001$) in the left hand (Table 3).

To estimate stature, two multiple linear regression models were built, one for each sex and for both sexes, and all models presented statistically relevant regression coefficients ($p < 0.05$) (Table 4). Thus, for males, the length of the left hand, age, and length of the right hand were obtained as independent significant variables. For females, age, left hand length, right hand width, and left hand width were used as independent significant variables. For both sexes, age, left hand length, right hand width, and left hand width were used as independent significant variables.

The female model presented better stature in-sample prediction (adjusted $R^2 = 0.543$, MAE = 3.169, RMSE = 3.878) and out-sample prediction (*K*-fold cross-validation: $R^2 = 0.545$, MAE = 3.233, RMSE = 3.952) in relation to the male regression model (In sample: adjusted $R^2 = 0.454$, MAE = 3.743, RMSE = 4.890; Out-sample: *K*-fold cross-validation: R^2: 0.472, MAE: 3.850, RMSE: 4.897) but inferior to the both sexes model (In sample: adjusted $R^2 = 0.683$, MAE = 3.776, RMSE = 4.805; Out-sample: *K*-fold cross-validation: R^2: 0.669, MAE: 3.913, RMSE: 4.951). Among the anthropometric measurements used, the one that presented the greatest accuracy in the male model was the length of the right hand (standardized $\beta = 0.292$), while for the female model, the length of the left hand emerged as the variable that best explained the variation in stature (standardized $\beta = 0.517$) and for the both sexes model the length of the left hand emerged as the variable that best explained the variation in height (standardized $\beta = 0.558$) (Tables 5, 6, and 7).

Discussion

Knowing that Brazil has large mix in the ancestry of its population and with the aim of predicting stature, in our study we correlated some anthropometric measurements of the hands with the height of adult individuals from a quilombola community in northeastern Brazil, observing whether it was possible to construct an equation that could play a predictive role in such an ethnically diverse society.

Such considerations originated from the idea that the applicability of these formulas depends on the population from which the data were extracted, since environmental and biological variations can result in changes in the dimensions of the hands, not being possible to transplant them to other populations (Agnihotri et al. 2008; Ibeabuchi et al. 2021).

Thus, in our analysis, we obtained a positive and statistically significant correlation between stature and

Table 4 Regression equations to estimate stature according to sex

Sex	Equation
Male	$\text{Stature(cm)} = 98.658 - 0.147 \times \text{age(yearsold)} + 1.910 \times \text{LHL(cm)} + 2.097 \times \text{RHL(cm)}$
Female	$\text{Stature(cm)} = 86.262 - 0.155 \times \text{age(yearsold)} + 3.537 \times \text{LHL(cm)} + 4.736 \times \text{RHW} - 2.875 \times \text{LHW(cm)}$
Both	$\text{Stature(cm)} = 61.918 - 0.151 \times \text{age(yearsold)} + 4.111 \times \text{LHL(cm)} + 6.412 \times \text{RHW} - 2.625 \times \text{LHW(cm)}$

LHL Left hand length

RHL Right hand length

RHW Right hand width

LHW Left hand width

Table 5 Multiple linear regression model for males

	β	β standardized	T	p	VIF
Constant	98.658	-	11.169	< 0.0001	-
Age	−0.147	−0.356	−5.827	< 0.0001	1.020
Left hand length	1.910	0.292	2.364	0.0310	4.211
Right hand length	2.097	0.271	2.182	0.0190	4.171
Shapiro–Wilk test				0.2068	
Durbin-Watson test				0.8270	
White test				0.9670	

$R = 0.682$, R^2 adjusted = 0.454, MAE = 3.743, RMSE = 4.890, *F*-test: $p < 0.0001$, *K*-fold cross-validated results: R^2 0.472, MAE 3.850, RMSE 4.897

β beta coefficient

β standardized standardized beta coefficient

T *T*-test for regression coefficient

VIF variance inflation factor

Table 6 Multiple linear regression model for females

	β	β standardized	T	p	VIF
Constant	86.261	-	11.429	< 0.0001	
Age	−0.155	−0.399	−7.190	< 0.0001	1.018
Left hand length	3.537	0.517	7.861	< 0.0001	1.431
Right hand width	4.736	0.327	3.125	0.0020	3.628
Left hand width	−2.875	−0.215	−2.088	0.0380	3.501
Shapiro–Wilk test				0.6964	
Durbin-Watson test				0.2647	
White test				0.3500	

$R = 0.745$, R^2 adjusted = 0.543, MAE = 3.169, RMSE = 3.878, *F*-test: $p < 0.0001$, *K*-fold cross-validation results: $R^2 = 0.545$, MAE = 3.233, RMSE = 3.952

β beta coefficient, *β standardized* standardized beta coefficient, *T* *T*-test for regression coefficient, *VIF* variance inflation factor

anthropometric measurements of the hands (width and length) with the highest Pearson coefficient found when we correlated stature with hand length. Similar findings have also been described in previous studies (Ishak et al. 2012; Akhlaghi et al. 2012; Pal et al. 2016). In addition, higher correlation values were found for hand length in females, thus differing from the results found by other authors (Habib and Kamal 2010; Paulis 2015). When we took the width of the hand to study, we saw that lower correlation values were found, in both sexes, demonstrating a weak or very weak positive correlation when it came to the width of the left hand in males. Uhrová et al. (2015), when analyzing the width and length of

Table 7 Multiple linear regression model in both sexes

	β	β standardized	T	p	VIF
Constant	61.918	-	13.353	< 0.0001	-
Age	−0.151	−0.274	−8.297	< 0.0001	1.032
Left hand length	4.111	0.558	11.401	< 0.0001	2.274
Right hand width	6.412	0.446	5.235	< 0.0001	6.898
Left hand width	−2.625	−0.193	−2.355	0.0192	6.349
Shapiro–Wilk test				0.0620	
Durbin-Watson test				0.2379	
White test				0.1130	

$R = 0.829$, R^2 adjusted = 0.683, MAE = 3.776, RMSE = 4.805, *F*-test: $p < 0.0001$, *K*-fold cross-validation results: $R^2 = 0.669$, MAE = 3.913, RMSE = 4.951

β beta coefficient, *β standardized* standardized beta coefficient, *T* *T*-test for regression coefficient, *VIF* variance inflation factor

hands and feet of 250 students from different regions of Slovakia, reached similar results, showing lower correlations for hand width in both sexes, when compared to the other variables studied. We also found that when stature was correlated with the dimensions of the hands (width and height), without taking into account the difference between sexes, the Pearson coefficient values increased, including for the width of the hand that passed to the quality of moderate positive correlation.

Through multiple linear regression, we were able to observe that the female model presented the highest value of the coefficient of determination (R^2), which allows us to admit that this same model presents a better prediction of stature when compared to the male model. The same could be observed by Krishan and Sharma (2007) when studying 246 individuals in Rajpts population in northern India, where better accuracy in stature prediction was attributed to the analysis of the dimensions of hands and feet among female individuals. Among the variables studied, the one that best explained the variation in stature was the length of the hand for both sexes, differing only in laterality (right hand in males and left hand in females). For Ishak et al. (2012), analyzing the dimensions of the handprints of 201 individuals from Western Australia, they similarly observed that hand length is among the variables that most strongly explained the variation in stature in the multiple linear regression model.

Conclusions

The measure that best correlated with stature in the quilombola community studied in northeastern Brazil was hand length for both sexes, with the highest correlation for females. Furthermore, in the regression models, the variable that showed the greatest accuracy in predicting height was hand length, with a greater accuracy in the prediction of body stature being found in the female regression model. Thus, it is concluded that it is possible to predict stature through measurements of the hands (width and length) in the quilombola community in northeastern Brazil, with greater accuracy when using the length of the hands.

Abbreviations

L	Length
W	Width
SD	Standard deviation
p	Significance level
r	Pearson correlation
LHL	Left hand length
RHL	Right hand length
RHW	Right hand width
LHW	Left hand width
R	Coefficient of determination
R^2	Coefficient of determination adjusted
CI	Confidence interval
β	Beta coefficient
β standardized	Standardized beta coefficient
T	Student's *t* test for independent sample
W	Mann-Whitney test for independent sample
T	*T*-Test for regression coefficient
VIF	Variance inflation factor
R^2_{adj}	Adjusted determination coefficient
MAE	Mean absolute error
RMSE	Root mean squared error

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Authors' contributions
JAA: Conception, design and Overall responsibility. EMS: Data collected and statistical analysis. ISM: Data collected and statistical analysis. ICSA: Methodology and writing the article. FMSA: Methodology and writing the article. FPR: Critical revision of the article. All authors read and approved the manuscript.

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Availability of data and materials
Data and materials would be made available upon request.

Declarations

Ethics approval and consent to participate
The study adhered to the Helsinki Declaration and the material was used in accordance with Law 8501 of November 30, 1992, which provides for the use of unclaimed corpses for study or scientific research purposes and was approved by the Ethics and Research Committee of the Federal University of Sergipe, with approval number: 716.525.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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