Journal of Forensic and Legal Medicine 54 (2018) 87–90

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/yjflm

Stature estimation formulae for Mexican contemporary population: A sample based study of long bones

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ARTICLE INFO

Keywords:
Forensic anthropology
Stature estimation
Forensic osteology
Regression equations
Mexican population

ABSTRACT

Stature estimation is an important step to create a biological profile for human identification of unknown individuals in forensic anthropological practice, and it is well known that the long bone length is highly correlated with this feature. The purpose of the present study is to develop formulae for height estimation, based on simple linear regression model for humerus, femur and tibia in Mexican contemporary population.

Stature was taken in 56 males and 30 female corpses as well as maximum length of three long bones of the limbs after autopsy following the Menéndez et al. (2014) criteria, at the Facultad de Medicina (School of Medicine) of the Universidad Nacional Autónoma de México.

Based on this data, equations for each sex and for the three long bones were developed, obtaining a highly significant ($p < .001$) linear regression models with correlation coefficients of $r = 0.820$ for female femur and $r = 0.855$ for male tibia. In this manner, the new formulae provide better and reliable results of stature estimation for the contemporary population of Mexico.

1. Introduction

From the perspective and practice of forensic anthropology, to achieve a proper identification of individuals with unknown identity from skeletal remains it is necessary to count on with appropriate standards (population-specific) to estimate sex, age, stature and biological affinity or ancestry.

Population specific approach is important in stature estimation because secular change and environmental factors affect non-uniformly the adulthood height. In this context, the aim of the studies is to establish the correlation and proportionality of long bones and stature across different human groups; thus achieving, an increase in the accuracy of the estimations. Hence, we must bear in mind the need of stature estimation equations for each population.[1–3]

There are few attempts on the reconstruction of stature for Mexican population,[4–6] but these are not reliable for contemporary population.[7]

This lack of reliability in the existing formulae is due to different reasons: the equations of Trotter and Glesser[4] were developed with population assumed as Mexican from the Korea war, and only for men; Genovés research[5] was performed for Mesoamerican populations, and the equations of Del Ángel and Cisneros[6] are a modification of Genovés proposal[5]; and they were elaborated using the predicted and not with the cadaveric statures, resulting in a deterministic (non probabilistic) model.[7] Finally, these formulae do not reflect the stature of the Mexican contemporary population.

According to the previously mentioned, plus the current situation of violence that we live in Mexico, it is essential to create new regression equations to help identifying the Mexican contemporary population.

However, the task of making this standards it is not easy, mainly due to the lack of documented contemporary osteological collections and the absence of laws that permit the researchers make another kind of investigations (like with corpses).

For these reasons the purpose of this paper is to generate new stature formulae for contemporary Mexican population with the humerus, femur and tibia, combining a sample of corpses and skeletons of known height.

2. Materials and methods

Measurements of height and humerus, femur and tibia maximum lengths were taken from 86 corpses (56 males and 30 females) used by students for dissection and training at the Facultad de Medicina (School

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https://doi.org/10.1016/j.jflm.2017.12.019
Received 24 January 2017; Received in revised form 12 October 2017; Accepted 31 December 2017
Available online 03 January 2018
1752-928X/

of Medicine) of the Universidad Nacional Autónoma de México (UNAM), from the Instituto de Ciencias Forenses (INCIFO), public hospitals and shelter institutions in Mexico City. All corpses belong to unclaimed individuals. The age at death for this sample range from 19 to 91 years old. Most individuals have recorded antemortem data, at least one of these features: sex, age, name, death cause and provenance. Lamentably, none of the individuals have a recorded living stature.

Cadavers with amputations, fractures, atrophies, skeletal deformities or any other pathology were excluded.

To measure cadaveric height and humerus, femur and tibia (in situ) we followed Menéndez et al., proposal[8] with the cadaver in supine position. All measurements were taken after the autopsy. The osteological measurements were made with calipers, after incisions ensuring the integrity of the subject, on the left side according to the standards established by Buikstra and Ubelaker.[9]

This study was carried out following the established norms of items 4° y 5° from the third chapter of the "Regulations for Safety and Coordination of Health Research" belonging to the Legislación Universitaria of the Universidad Nacional Autónoma de México.[10]These regulations specify the legal procedures for scientific research of human cadavers including their procurement, conservation, usage, and final destination of organs and tissues. Due to actual Legislations, our primary concern for the execution of the incisions, which allow us to observe the reference points for measuring the long bones, was the preservation of the joints of each corporal segment and the reduction of the alteration of the soft body tissues.

2.1. Statistical methods

In order to minimize any accumulative error the osteometric technique was made following the Buikstra and Ubelaker standards[9] and by only one observer (AMG) and non significant intra-observer errors was obtained, as can be seen in Menéndez et al.,.[8]

Firstly, the descriptive statistical analysis and Shapiro-Wilk's Goodness-Fit test was carried out; which allowed us to determine whether or not it was possible to affirm a normal distribution. Besides, the minimum, maximum, mean, standard deviation, skewness, and kurtosis of each measurement were calculated.

Pearson's correlation tests (product moment correlation) were conducted to evaluate the degree to which the variables are related. Then, comparing the data of bones we created a correlation-coefficient matrix between all possible pairs of bones and stature.

Subsequently, the regression model was performed in order to obtain formulae for the humerus, femur and tibia bones. Ordinary Least Squares regression (OLS) or simple linear regression model, corresponds to a method that minimizes the sum of square differences between the observed (dependent) and predicted variables.

To test the proportion of variability in a dependent variable that is accounted for the predictor variable, the coefficient of determination R^2 was used; whereas the F statistics prove the likelihood ratio of the explained variance by the model in front of the residual sum of squares, and t-statistics can help to determine the relative importance of each variable in the model, beside this prove the linearity.

With the purpose to strengthen the linear regression models based on least squares approach, we required verify certain assumptions over the residual values. Residuals are estimates of the true errors in the model, in significant and robust models the residuals follow a normal distribution. To verify the density of the residuals we used the normal probability plot from the raw residuals and empirically we evaluated the trends by assume goodness of fit (Supplementary Figure 1), in the same manner, the descriptive statistics of the residuals can help to evaluate their distribution, in a robust model the residuals should follow a normal distribution and the standardized predicted and observed values take mean zero and standard deviation one (Supplementary Table 1).

In our work, an empirical approach was taken to verify the homoskedasticity of the residuals, plotted the dependent variable over the standardized residuals and we consider an tendency lies more or less three standard deviations suggest a constant variance from the residuals (Supplementary Figure 2).

Durbin-Watson values show the independence of the residuals from the OLS. This statistic values lies between 0 and 4, and d = 2 there is no statistical significance that errors are autoregressive, which mean that observations are not positive autocorrelated. Durbin-Watson test permit us enhance the standard errors for the regression coefficient and give reliability to the t-test.[11] In cases when small samples are used, the Durbin-Watson test is dramatically substantial.

Whenever the model has been built, again, the product moment Pearson's correlation tests served to known the relation of the observed stature and the stature derived from the formulae estimated.

All the analyses were made separated according by sex. In all cases the significance was placed at $\alpha = 0.05$. The statistical analysis was carried out using the STATISTICA (v. 8.0) software.

3. Results

The height of cadavers, in the female sample values between 140 cm and 169.8 cm, with a mean stature of 151.23 cm. For the male sample the mean was 162.62 with a range between 144.2 cm and 178 cm (Table 1).

A summary of descriptive statistics are provided in Table 1. Our results show that all variables have normal distribution in each bone tested with the Shapiro Wilks' test (Table 1).

As expected, the matrix correlation shows that all combinations of bone are correlated with stature. As can be seen, results show that correlations are higher in tibia for male sample (0.855) and femur for females (0.820). Nevertheless, the tibia in females have moderate correlation (0.708), despite this, all pairwise comparisons were statistically significant ($p \leq .001$) (Fig. 1 and Table 2).

Residuals represent unexplained variation after OLS regression

Table 1
Descriptive statistics means, minimum, maximum, standard deviation values and density parameters for the stature and long bones used in this study.

	N	Mean	Median	Minimum	Maximum	S.D.	Skewness	Kurtosis	Shapiro-Wilk	*p*
Male										
Stature	56	162.62	163.30	144.2	178.0	7.26	−0.247	−0.122	0.989	.902
Humerus	56	31.04	31.15	27.5	35.3	1.68	0.067	−0.360	0.987	.799
Femur	56	42.99	42.85	38.1	47.4	2.36	−0.132	−0.789	0.975	.304
Tibia	56	36.23	36.40	31.9	40.5	2.24	0.004	−0.932	0.975	.294
Female										
Stature	30	151.23	150.00	140.0	169.8	8.20	0.714	−0.008	0.930	.050
Humerus	30	28.85	28.68	25.3	32.0	1.47	0.027	0.536	0.985	.933
Femur	30	39.99	39.70	35.9	45.2	2.14	0.766	0.995	0.945	.120
Tibia	30	33.14	33.18	29.3	38.2	1.93	0.234	0.568	0.981	.844

Stature is in centimeters and long bones measurements are in millimeters. Shapiro-Wilk test prove normal distribution in all cases.