



Forensic Anthropology Population Data

New identification criteria for the Chilean population: Estimation of sex and stature

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ABSTRACT

In the analysis of human skeletal or otherwise unidentifiable remains the assessment of sex is an initial vital element when rendering a biological profile. As such other aspects of the biological profile are sex-specific (e.g. stature and age) and cannot be successfully determined without this preliminary assessment. In addition, the estimation of stature is an essential parameter of the biological profile, which is often used to confirm or exclude presumptive identifications.

The purpose of this study is to present newly developed local identification criteria for the estimation of sex from the postcrania and stature for Chileans. Linear discriminant functions were derived for the humerus and femur. Sexing accuracies of 87%, 86%, and 82% were achieved. Furthermore, new univariate predictive stature equations are presented using a Bayesian approach for the humerus, femur and tibia.

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1. Introduction

The military Dictatorship (1973–1990) led by the General Augusto Pinochet, similar to other dictatorships, which occurred during the same era in Latin America, had as a main objective to cleanse the country of socialist ideologies while raising new economic and social programs. The forced detentions and assassinations of individuals during the regime were concentrated on the government members of the Popular Union, political leaders and supporters of the left or communist party. Although most of the detentions and deaths occurred during the months subsequent to the coup, beginning in 1974–1977 the National Intelligence Directorate (Dirección de Inteligencia Nacional or DINA), subsequently renamed to the National Information Central (Central Nacional de Informaciones or CNI) was the principal entity with the authority to detain and confine persons in special centers. While there were many forms of oppression, its most tragic hallmark were the grave human rights violations that left more than 27,000 tortured persons, 1100 disappeared detainees and more than 2000 dead resulting from executions during mandatory curfew, tortures, false confrontations, excessive force and abuse of power. The bodies of the executed were buried in clandestine graves, hurled into the Pacific Ocean or some river, or buried in a cemetery as NN [1,2].

Applying the knowledge of human biological variation as it relates to developing biological profiles for unknown victims is a crucial component for the increasing number of anthropologists working globally investigating crimes against International Humanitarian Law [3]. Because of the globalization of forensic anthropology, we have seen a shift from indiscriminately and inappropriately applying standards developed from US populations on world populations to the development of local population-specific identification norms in the last decade (e.g. Trotter and Gleser).

The estimation of sex, one of the four pillars of biological profiling, is one of the first components to be assessed when rendering a biological profile from human skeletal remains. The estimation of sex is a crucial first step in a biological profile as other aspects of the biological profile are sex-specific (e.g. stature and age) and cannot be adequately determined without this initial assessment. With the recent globalization of forensic anthropology, the inappropriateness of applying U.S. standards were particularly emphasized in the identification efforts in the Former Yugoslavia [3]. In such settings, stature is one of the parameters of the biological profile used to confirm or exclude presumptive identifications [3].

The purpose of this study is to present newly developed local standards for sex determination and stature equations for the Chilean population to aid in the current identification efforts of the “disappeared” from the Pinochet Dictatorship and contemporary medico-legal cases.

2. Materials and methods

The total sample consists of 139 females and 137 males exhumed from the “Cementerio General” or General Cemetery housed at the Universidad de Chile. The

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collection consists of more than 1000 skeletonized individuals with death dates between 1950 and 1970 in the homonymous cemetery in the city of Santiago. One of the most important characteristics is that the individuals count with known demographic information including cause of death, name, age, sex, and in some cases birth and death dates. This collection was created between 1970 and 1980 by the necessity of having a large sample representative of contemporary Chileans for both research and teaching.

2.1. Sex estimation

The maximum vertical head diameter of the humerus, maximum head diameter of the femur and circumference of the femur at midshaft were used to derive linear discriminant functions (DFA) using crossvalidation or leave-one-out ($n - 1$) method. The left side was used to derive the discriminant functions, however, when missing the right was substituted. The statistical analyses were conducted using the SAS System for Windows version 9.13 [4].

2.2. Stature

Standard maximum lengths for the humerus, femur and tibia were used to estimate new stature equations [5]. A Bayesian approach using informative priors was used to calculate new stature equations using the humerus, femur and tibia [6–8]. Because actual statures were not known, these were taken from the growth literature [9]. For a more in-depth discussion of this approach please see the publication by Ross and Kongsberg [7].

The posterior probability follows a normal distribution, which is given by:

$$\hat{S} = \frac{\beta S_T V_{cl} - V_{S_T} \alpha}{\beta(V_{cl} + V_{S_T})} + \frac{V_{S_T}}{\beta(V_{cl} + C_{S_T})} \times lb$$

where $V_{cl} = V_{S_R}(r^2 - 1)$ (1)

$$s.e.(\hat{S}) = \sqrt{\frac{V_{cl} V_{S_T}}{V_{cl} + V_{S_T}}}$$

where β and α are the slope and intercept from the reference sample for the regression of a long bone on stature, while S_T is the mean stature in the target sample and V_{S_T} is the variance of stature in the target sample. Likewise, V_{S_R} is the variance for stature in the reference sample. V_{cl} is the variance for stature estimates from the reference sample under a uniform prior, which yields the classical calibration estimator [6]. Lastly, r is the correlation between the long bone and stature from the reference sample, while lb would be an actual long bone length for a forensic case. For the male reference population 545 European Americans were

Table 1
Female summary statistics for humerus head diameter, femur head diameter and femur circumference.

Variable	N	Mean	Std Dev	Minimum	Maximum
Humerus	101	39.782	2.599	33.000	48.000
Femur	139	40.576	2.374	36.000	47.000
Circumference	139	80.108	4.773	65.000	90.000

Table 2
Male summary statistics for humerus head diameter, femur head diameter and femur circumference.

Variable	N	Mean	Std Dev	Minimum	Maximum
Humerus	104	45.096	2.775	40.000	52.000
Femur	137	45.701	2.507	39.000	52.000
Circumference	134	88.993	5.820	74.000	105.000

Table 3
Linear discriminant functions for sex determination from the humerus and femur for Chileans.

	Constant	Accuracy
Humerus		
-0.735 (max. vet. diam. head)	31.181	87%
Femur		
-0.860 (max. diam. head)	37.104	86%
-0.315 (circumference at midsh)	26.617	82%

Sectioning point=0. Values greater than 0 indicate female, values less than 0 indicate male.
Equation: Bone product + constant.

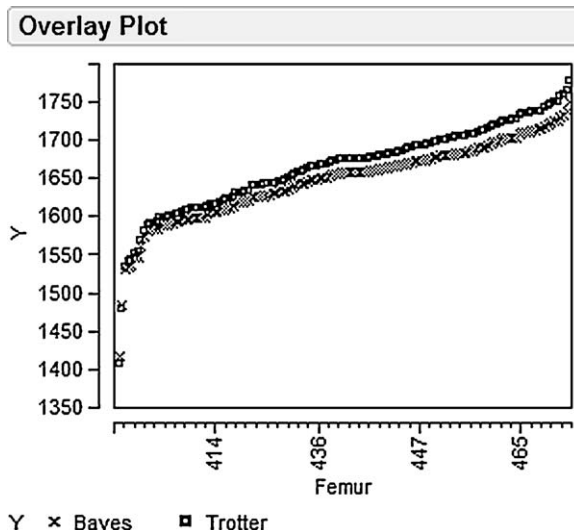


Fig. 1. Overlay of male statures using the newly derived Bayesian equations and Trotter [11] for the femur.

utilized, which were originally collected by Mildred Trotter. For the female reference population 61 European Americans from the Forensic Data Bank housed at the University of Tennessee were included. The statistics for stature estimation were calculated in Microsoft Excel and the figures were generated in SAS JMP 7.0 [10].

3. Results

Tables 1 and 2 present the summary statistics for Chilean males and females. Sexing accuracies of 87%, 86%, and 82% were achieved from the humeral head, femoral head, and femoral circumference, respectively. Table 3 presents the linear discriminant functions for sex determination using the humerus and femur.

Applying Eq. (1) using the adult Chilean stature for the target stature and 545 European males from the WWII data collected by Mildred Trotter and 61 European females from the Forensic Data Bank for the reference sample, the equations derived by Trotter [11] overestimate stature in Chilean males and females (Figs. 1–4). Comparative plots for the tibiae were not included as Trotter mismeasured the tibia by excluding the medial malleolus [12], while our equations for the tibia include the medial malleolus. In addition, the female pattern is slightly different with the lower bounds being

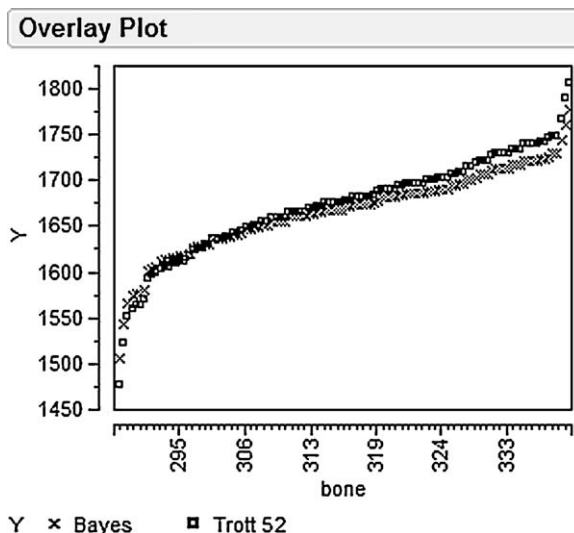


Fig. 2. Overlay of male statures using the newly derived Bayesian equations and Trotter [11] for the humerus.

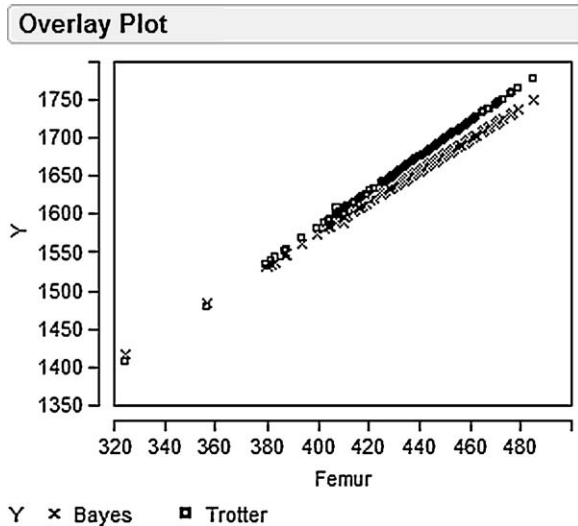


Fig. 3. Overlay of female statures using the newly derived Bayesian equations and Trotter [11] for the femur.

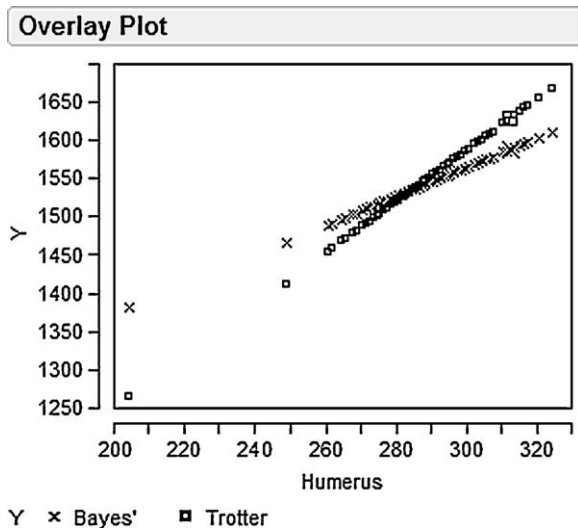


Fig. 4. Overlay of female statures using the newly derived Bayesian equations and Trotter [11] for the humerus.

underestimated suggesting greater variation in bone lengths for females. Using a Bayesian approach, new univariate predictive stature equations are presented for Chileans to aid in present-day medico-legal cases and the identification of the disappeared from the Pinochet Regime (Tables 4 and 5).

4. Conclusions

With the global involvement of forensic anthropologists in humanitarian missions, it has become imperative to test old standards developed from primarily European populations and

Table 4

Stature prediction equations for Chilean males and standard errors (in mm).

Equations	Se
Stature = $820.36 + 2.53 \times \text{humerus}$	± 36.7
Stature = $510.32 + 2.07 \times \text{femur}$	± 31.7
Stature = $356.48 + 2.26 \times \text{tibia}$	± 31.0

Table 5

Stature prediction equations for Chilean females and standard errors (in mm).

Equations	Se
Stature = $989.28 + 1.91 \times \text{humerus}$	± 41.5
Stature = $813.85 + 1.76 \times \text{femur}$	± 37.8
Stature = $1026.97 + 1.41 \times \text{tibia}$	± 41.1

anatomical samples and develop new population-specific criteria tailored to the region's biological variability. The results of this research show that the classic equations developed by Trotter [11] generally overestimate stature in Chileans. Since Chileans are shorter than European Americans it is appropriate to use this knowledge as an "informative prior" that can be applied to forensic cases. This "informative prior" can then be utilized in the predictive equations as it is assumed to be similar to the sample from which Chilean forensic cases were derived from.

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