Science and Justice 56 (2016) 357–363

Contents lists available at ScienceDirect

Science and Justice

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

Sex estimation from the scapula in a contemporary Chilean population

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ARTICLE INFO

Article history:
Received 20 February 2016
Received in revised form 9 May 2016
Accepted 10 May 2016

Keywords:
Forensic anthropology population data
Adults
Scapula
Sex estimation
Discriminant functions
Chile

ABSTRACT

The scapula is valuable for sex estimation in human skeletons. Muscles provide protection to the scapula making it difficult to fracture, therefore increasing the potential for undamaged scapulae at forensic scenes. The goal of this project is to evaluate the accuracy of discriminant functions, created using an indigenous Guatemalan and contemporary Mexican population, when applied to a contemporary Chilean sample for estimation of sex from the scapula. The length of the glenoid cavity (LGC) and breadth of the glenoid cavity (BGC) were measured. The sample included 114 individuals (58 males and 56 females) with age ranges from 17 to 85 years old. When the Guatemalan discriminant functions were applied to the Chilean sample they showed higher accuracy rates for sexing male scapulae (89.6% to 94.8%) than for sexing female scapulae (53.4% to 80.3%). When the Mexican discriminant functions were applied to the Chilean sample they showed higher accuracy rates for sexing female scapulae (82.1% to 96.4%) than for sexing male scapulae (56.9% to 89.6%). Size comparisons were made to a Guatemalan, Mexican, White American, and Greek population. Overall, in males and females of the Chilean population both left and right scapulae were larger than in the Guatemalan population but smaller than in the Mexican, White American, and Greek samples. Population-specific discriminant functions were created for the Chilean population with an overall sex classification accuracy rate of 80.7% to 86.0%.

1. Introduction

On 11 of September 1973 the Chilean government experienced a military coup after the death of President Salvedor Allande. Augusto Pinochet became dictator of Chile from 1973 to 1990. The fate of those perceived as being an opponent to his government was harsh: they were interred, tortured, killed, or simply 'disappeared'. There are an estimated 40,018 individuals that were killed for political reasons during the Pinochet regime and approximately 1068 individuals 'disappeared' post-imprisonment [1]. In 1991 forensic experts began to exhume bodies of the 'disappeared' from mass graves. The task of identifying the unknown individuals is immense. The broad use of DNA testing is too expensive for the Chilean government to consider. Therefore, identification of unknown human remains has focused on utilizing a multidisciplinary approach, which includes forensic anthropological analyses [2].

Accurate sex estimation techniques for unknown human skeletal remains are important for positive identifications. The estimation of sex is important as the estimation of stature and age at death is sex dependent. However, many of the techniques utilized by forensic anthropologists were developed using non-Latin American populations. As a result, there is currently a lack of Hispanic population-specific data for sex estimation.

Discriminant function equations for sex estimation have been shown to be population-specific [3,4]. Even within small geographic areas researchers have found variation in sexual dimorphism requiring the development of population-specific discriminant function equations [4]. The Scientific Working Group in Forensic Anthropology suggests that best practice for sex estimation of skeletal remains should include methodologies that utilize population-specific and temporally-specific data [5].

Incomplete or fragmentary bones are frequently excavated at forensic sites due to postmortem damage and taphonomic changes. Therefore, developing methods for sex estimation from preservationally favored and/or fragmentary bones is essential. The infraspinous and supraspinous fossa of the scapula are more commonly eroded due to taphonomic processes but the spine and the glenoid cavity are often available for forensic analyses [6,7]. Scapular muscle attachments provide protection to the bone making it difficult to fracture or break [8]. Currently, the only scapular discriminant function equations available for the estimation of sex for Latin American populations are those developed from an indigenous Guatemalan [9] and contemporary Mexican [10,11] populations; the accuracy of these functions ranged from 83.6% to 94.8% for correct sex identification. The goals of this project are to (1) apply the indigenous Guatemalan [9] and contemporary Mexican [10] scapular (glenoid fossa) discriminant functions to a contemporary Chilean population and, (2) develop population-specific

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http://dx.doi.org/10.1016/j.scijus.2016.05.003
1355-0306/

discriminant function equations for sexing skeletons from a contemporary Chilean population.

2. Materials and methods

This research utilized 114 individuals (58 males and 56 females) from the Subactual Skeletal Collection (Subactual Colección de Santiago) housed at the Laboratorio de Antropología Física, Departamento de Antropología (Physical Anthropology Laboratory, Department of Anthropology) at the Universidad de Chile in Santiago. The collection consists of over 1000 documented skeletons, i.e. sex, age at death, occupation, and cause of death. The individuals ranged in age from 17 to 85 years old. This skeletal collection was donated, under the National Monument Law N 17228, to the Universidad de Chile from the Cemetario Generale de Santiago. These individuals are unclaimed by relatives and would have otherwise been cremated. This collection represents a contemporary Chilean population as all of the individuals lived the majority of their life during the twentieth century; all individuals used in this study were born between 1920 and 1969 and died between 1950 and 1970.

Following the protocol of Frutos (2002) and Hudson et al. (2016), the length of the left and right glenoid cavity (LGC) and breadth of the left and right glenoid cavity (BGC) were recorded using a standard Vernier caliper to the nearest 1/100 of a millimeter (Table 1, Figs. 1 and 2). A comparison of the measurements taken from 12 paired male scapulae and 12 paired female scapulae showed statistically significant side differences with all $p < 0.05$. Therefore both the left and right scapulae were measured. In cases where either the left or right scapula showed evidence of trauma, damage, pathological changes, or was absent the individual was not included in the study. Intra- and inter-observer rates were calculated by re-measuring 20 randomly selected scapulae (10 males and 10 females) for each measurement variable. These sample sizes are appropriate as previous studies have shown that a subsample of 10% to 20% of the total population should be used to test for intra-observer and inter-observer error [12]. There were two observers. The intra- and inter-observer measurements were collected one week apart.

All statistical analyses were performed with the SPSS (version 22.0) software program with a level of significance $\alpha = 0.05$. Parametric (normally distributed) data were analyzed using a paired t-test and non-parametric (not normally distributed) data were analyzed using a paired Wilcoxon test. Descriptive statistics were obtained for each measurement. Males and females were analyzed separately. Using a two sample t-test for the parametric data and a Mann–Whitney U test for the non-parametric data the mean values of the two measurements were compared between the sexes to estimate if statistically significant differences existed. The contemporary Chilean scapulae measurements were compared with other populations using two sample t-tests: indigenous Guatemalans [9], contemporary Mexican [10], contemporary White Americans [13], and contemporary Greeks [13]. The indigenous Guatemalan [9] and contemporary Mexican [10] discriminant functions were applied to the contemporary Chilean sample to estimate their accuracy for sex classification. Population-specific discriminant functions were created for the contemporary Chilean population.

All data were tested for normality. The LGC and BGC measurements were separated into groups (i.e. male and female) to ensure that each sex was accurately represented. The Kolmogorov–Smirnov (KS) test was used to evaluate normality of the data with a significance level of $\alpha = 0.05$. For males and females, both the left and right LGC and BGC measurements were normally distributed.

Table 1
Measurement descriptions.

Measurement	Description
Length of glenoid cavity of the scapula[a] (LGC)	Greatest length across glenoid cavity perpendicular to anterior–posterior axis
Breadth of the glenoid cavity of the scapula[a] (BGC)	Greatest width across glenoid cavity measured at a right angle to axis of length of glenoid cavity

[a] (Modified from Frutos 2002).

Fig. 1. Length of the glenoid cavity measurement as described in Table 1.

Fig. 2. Breadth of the glenoid cavity measurement as described in Table 1.