Legal Medicine 31 (2018) 24–29

Contents lists available at ScienceDirect

Legal Medicine

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

Sex and age at death estimation from the sternal end of the fourth rib. Does Íşcan's method really work?

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ARTICLE INFO

Keywords:
Fourth rib
Age-at-death estimation
Sex estimation
Bayes
Forensic anthropology

ABSTRACT

The fourth rib has been used commonly in order to estimate age at death and even sex in skeletal remains but many often, Iscan's estimates do not adjust to the real age of the individual. Population specific references for sex and age-at-death estimation from the sternal end of the fourth rib are presented for a contemporary Mexican sample. A total of 504 ribs with known sex and age from a morgue sample were studied (444 males, 60 females, 17 to 92 years old). The height and breadth of the sternal end of the rib were sexually dimorphic ($p = .000$), and allowed a correct sex assignment in 73.3% to 84% of the cases from univariate and multivariate discriminant functions. With regard to age-at-death estimation, the morphological changes summarized by the phases of the sternal end of the fourth rib are correlated with known age in this sample (Spearman's Rho, $p = .000$). However, the original age intervals tend to underestimate age at death and inaccuracy increases with phase scored in males. Descriptive statistics for rib phase are provided for males and females, and new age-at-death estimates based on transition analysis and Bayesian statistics are provided for the male sample. The test of universally applied methods and the development of population specific references is an important task for forensic anthropology around the world.

1. Introduction

Estimation of sex is one of the first steps in the identification process of human remains. In well preserved and completely skeletonized remains, sex estimation is mainly based on the visual assessment of morphological features of pelvis and cranium [1]. In cases of decomposition, fragmentation, commingling or poor state of preservation, sex estimation is generally based on metric assessment of various bones or bone fragments [2,3]. Since the original research of Íşcan [4], the dimensions of the sternal end of the fourth rib have been studied for estimation of sex in dry-bone cases and in medical imaging in several populations [5–11]. In those studies, authors obtained its own discriminant function or linear regression formulae according to each population. The sternal end of the fourth rib is also one of the skeletal locations useful for age-at-death estimation in adult remains. In the original method developed by Íşcan and Loth [12,13] nine phases are described, which summarize the aging process of the sternal end of the rib. The shape, texture and quality of the bone are assessed in order to assign a phase, which is in turn associated to an age range and descriptive statistics [12,13]. Since the initial work on a North American sample, the method of Íşcan has been tested in different populations [14–18], including a sample of contemporary Mexican males [19].

National [20] and international organisms [21,22] indicate a high number of disappeared persons in the global context and the local context of Mexico, a situation that requires that every effort must be made to assist the identification process of unidentified corpses. Amongst these efforts, the development of references specific for methods of sex and age-at-death estimation is a crucial one. It should be remarked the importance of improving identification methods, including age-at-death estimation methods in adults due to the Mexican context of violence, especially against women. The present study tested for the first time Íşcan's method in females, which implies a progress in the study of feminicide [23,24], and it also enlarged the male sample in comparison with the previous research [19].

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https://doi.org/10.1016/j.legalmed.2017.12.002
Received 3 August 2017; Received in revised form 7 November 2017; Accepted 2 December 2017
Available online 05 December 2017
1344-6223/

The goal of the present work is twofold. The first objective is the study of sex estimation by metric measurements of the fourth rib. The second objective is to develop age-at-death new estimates based on the method of the fourth rib. To accomplish the latter goal, we apply transition analysis (TA) in the context of Bayesian statistics for adult age-at-death estimation [25]. This approach has been increasingly applied by several authors in forensic contexts due to its methodological improvement in age estimation [26–36].

2. Materials and methods

The sample was obtained from the Instituto de Ciencias Forenses (INCIFO) in México City following the bioethical committee recommendations of the institution. At the INCIFO only corpses (with remaining soft tissue) who will underwent an autopsy procedure are received. The age-at-death estimation of the unidentified corpses is undertaken by the Forensic Anthropologist by application of several methods, including the examination of the sternal end of the fourth rib if available. A section of the rib including the sternal end is kept in water for two days, then boiled so the cartilage can be gently removed, and subsequently it is left to dry for at least 24 h. Once the individual has been identified through fingerprints, odontologic and anthropological examinations, the relatives provide official documentation about the deceased, and thus age and sex of all the individuals is known. In the years 2014 and 2015, 1043 and 1148 corpses respectively arrived to the INCIFO. The left fourth ribs from identified individuals constituted the sample analysed for the present study. Left side was chosen according to the protocol for collecting biological samples from the INCIFO and following Buikstra and Ubelaker Standards [37]. Furthermore, other authors proved there are no significant differences in age at death estimation phase between right and left ribs from the fourth to the ninth [15]. Ribs with gross, observable pathological conditions were excluded. The target sample consisted on 504 fourth left ribs of 444 males and 60 females, with an age interval from 17 to 92 years old (Table 1, Fig. 1). In the Fig. 1 the number of individuals and the age split by decade were shown.

For the study of sex estimation, the discriminant analysis functions were tested on a sample consisted on 160 fourth left ribs (Males, Iscan's Phase 1–4: N = 40, Iscan's Phase 5–8: N = 40; Females Iscan's Phase 1–4: N = 40, Iscan's Phase 5–8:N = 40) from the INCIFO that were collected during the years 2014 and 2015 and that were not used to calculate the discriminant functions.

For the study of age-at-death estimation, a second archival sample was gathered from the INCIFO records, comprising the age and sex of all the identified corpses from the year 2013 (N = 358 males, 17 to 91 years; 52 females, 17 to 96 years).

2.1. Sex estimation

Two measurements of the sternal end were recorded: Superior-Inferior Height (SIH), or maximum distance from the most superior point to the most inferior point of the sternal end, and Anterior-Posterior Breadth (APB), or the maximum distance between the most anterior and posterior points of the sternal end. Measurements were taken using a Vernier caliper, with a precision to the nearest tenth of a millimetre (0.1 mm), and with the observer (A.M.) blinded to the sex of the ribs. The intraobserver and interobserver errors were evaluated by the re-measurement of 69 ribs. For the former error, there was a period of two weeks between both assessments, while for the interobserver error, two authors (A.M., N.M.) independently re-measured the error sample. The Intraclass Correlation Coefficient (ICC) and Alpha of Cronbach (AC) were calculated in order to evaluate both errors. Descriptive statistics were calculated for each measurement. All statistic test were carried out with a 95% of significance. The data was tested for normality and homogeneity of variances by using a Kolmogorov-Smirnov and a Levene's test respectively ($p > .05$) and it result in a normal and homoscedastic sample. A Student test and discriminant analyses were performed in order to assess sexual dimorphism and obtain a univariate discriminant function (leave-one-out-method using its cross-validated percentage) and multivariate discriminant function (stepwise and leave-one-out for sex estimation using its cross-validated percentage). Furthermore, these discriminant functions were tested on a sample of 160 ribs. These analyses were carried out with the total sample and dividing the sample by phase scored. Two groups were formed, phases 1–4 and 5–8. All analyses were carried out with SPSS 22.0.

Table 1
Target sample size and age by sex.

	Males	Females
N	444	60
Mean	45.49	43.08
Median	43	37.5
SD	17.55	18.75
Min	17	17
Max	92	91

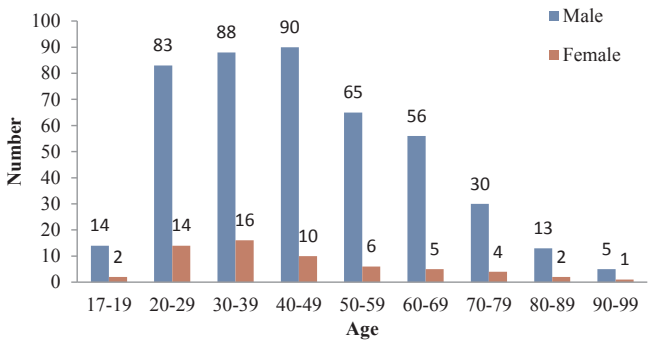

Fig. 1. Sex and age distribution of the target sample.

2.2. Age-at-death estimation

A phase of the Íşcan's method was assigned to each rib by comparison with the written descriptions and images from the original works [12,13]. The observer (A.M.) was blinded to the sex and age-at-death of the ribs. The ICC, AC and the Kappa test (only for interobserver error) were calculated. Descriptive statistics of age by phase were obtained. The Spearman's Rho correlation was applied to test the association between phase and age-at-death in this sample. The frequency of correct assessment, bias and inaccuracy of the original age intervals were tested [12,13,38]. An assessment was considered correct when the actual age fell within the age interval associated to the phase scored. As explained elsewhere [39], bias was defined as the mean over (if the sign is positive) or under prediction (if the sign is negative), and inaccuracy was defined as the average of absolute error of age estimation:

$$\text{Bias} = \frac{\Sigma(\textit{estimated age} - \textit{known age})}{n}$$

$$\text{Inaccuracy} = \frac{\Sigma(|\textit{estimated age} - \textit{known age}|)}{n}$$

In both cases, the estimated age was the mean age of the scored phase provided in the original works [12,13]. All analyses were carried out with SPSS 15.0.

In order to obtain age-at-death new estimates, TA (transition analysis) in the context of Bayesian statistics was applied just for males due to the limited sample for females. As explained elsewhere [34], this methodology includes two approaches: The "Rostock" approach, originally developed for bioarchaeological samples, and the "Forensic