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Estimating age at death using the sternal end of the fourth ribs from Mexican males

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ABSTRACT

The indicators proposed by İşcan et al. (1984) are said to reflect age changes that occur in the sternal end of the fourth rib. These indicators have been used to estimate age-at-death in adult skeletal samples. However, Isçan et al. developed their methods using a forensic sample from Florida (U.S.A.). In order to test the reproducibility of those methods we evaluate its accuracy for the fourth ribs by applying it to a sample of known age and sex but of different biological affinity: modern males from Mexico City. We found that the method developed by İşcan et al. underestimates age-at-death in the Mexican sample.
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1. Introduction

Estimation of biological age-at-death is one of the more important parts of the analysis of modern and ancient human skeletal remains. For adults, age-at-death estimates frequently utilize multiple indicators that reflect standard processes of bone deposition, remodeling, and reabsorption that occur throughout the life of an individual. However, these processes are affected and influenced by numerous genetic, environmental, and cultural factors. Taking these into consideration, the selection of appropriate methods for estimating age needs to be informed by method-specific data on the margins of error for each target sample.

Skeletal maturation processes provide a basis for estimating the age of a skeleton. In younger subadults, the estimation of age usually relies on bone and tooth maturation. However, there are substantial variations in the timing of these developmental changes among different individuals, even those who do not suffer from any major growth disruptions and/or stress episodes [1,2]. With mature adults, estimations of age-at-death are mainly derived from evaluating degenerative processes usually caused by normal wear and tear on the body over time. Researchers have observed and analyzed these changes in specific skeletal samples, and they have developed classification methods to estimate group-specific age-at-death (for a summary and discussion of these methods and techniques see references [2–6]). These degenerative processes also reflect an individual's life history of growth, development and genetic predisposition. Considering this, it is likely that degenerative changes will differ in timing and manner among different populations. Taking into consideration an individual's life history of growth, development, lifestyle, and genetic predisposition, researchers argued for critically evaluating existing methods that estimate the age-at-death among different populations [7–10]. Several studies have concluded that it is essential to assess the accuracy of and, if necessary, modify existing methods to more effectively estimate the age-at-death of individuals from different populations around the globe [e.g., 7–10]. These types of studies are very useful as they facilitate the process of adjusting existing methods to specific populations and of acquiring a deeper and wider understanding of human variation.

Most standards used to estimate age-at-death were developed with samples from North America, such as the Terry collection at the Smithsonian Institution in Washington, D.C., the Hamann–Todd collection in Cleveland, Ohio, and individuals from the Korean War, among others [11]. These collections are primarily composed of Americans with Northern European and African ancestry. Individuals in these collections had very different life styles and genetic heritages than Latin American populations. This research evaluates the applicability of methods developed to

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estimate age-at-death in adults using the sternal end of ribs by İşcan et al. [12,13] using a sample from Florida and İşcan and Loth [14] with a modern Mexican population from Mexico City. We evaluate the accuracy of the method, including consideration of the individual components of the rib.

The chest plate, including the sternal end of the rib, is an area where age changes have been documented through time by many researchers using radiography and multislice computed tomography [e.g., 15–19], histological analysis [e.g., 20–24], and osteological studies [e.g., 12–14, 25, 26]. For example, McCornick and Stewart [18], using roentgenograms to analyze age changes in the entire chest plate, suggested the alterations that occurred in this area included progressive ossification in the costal cartilages at the sternal rib end, both centrichondrally and peristernally, and often with age and sex distinctive patterns. In addition, they mentioned that other changes included maturation of the newly formed bone with trabeculation formation, loss of the smooth contour of the costo-manubrial junction, cupping of rib ends, osteoporotic changes, and arthritic changes in the sternal head of the clavicles. At a gross anatomy level, the sternal end of the rib is probably one of the areas of the chest plate that has received most of the attention in physical anthropological studies to estimate age based on techniques proposed by İşcan et al. [12,13] and İşcan and Loth [14].

The technique proposed by İşcan et al. [12,13] and İşcan and Loth [14], which estimates the age-at-death based on degenerative processes, evaluates changes that occur with age in the sternal end of the fourth rib. The authors proposed nine phases of degenerative progression graded from zero to eight [12,13]. They tested the precision of this technique and found that morphological changes occurring in the osseous rib segment have significant statistical relationships with the age-at-death. In these tests, there was minimal interobserver error and estimated phase associations departed from the expected by no more than one phase [14]. İşcan et al. [12,13] also mentioned that factors such as physical activity and heavy labor, endocrine disorders, chronic lung disease, drug use, sex differences, diet, and intercostal variations [e.g., 16, 27–28] can affect the normal aging patterns characteristic of the rib ends. They also cautioned that the intercostal variation, positive identification of the fourth rib and differences between sex were the most important factors to consider when using this method.

Other investigations, such as those from Dudar [29] and Saunders et al. [8], tested the validity of the techniques of İşcan et al. [12,13] and İşcan and Loth [14] and corroborated the usefulness of this technique to estimate age-at-death. However, Saunders et al. [8] found that the ages were usually underestimated and as age increased, the biases and inaccuracies also increased. Recent studies by Fanton et al. [10] suggested that analyses using the sternal end of the rib showed poor reproducibility and repeatability due to difficulties in measurement, imprecision in describing pit depth, and failure to take into account the pit shape, rim, and wall configuration. Hartnett [30] also tested the accuracy of age-at-death estimation using the sternal end of the fourth rib. She suggested that there are significant differences in the observed versus actual ages and significant interobserver variation. She also concluded in her study that the most important departures from the original study by İşcan et al. [12,13] are the incorporation of bone quality and density as they play bigger roles in phase assignment and revisions.

Application of these age indicators also identified differences between sexes and populations [e.g., 14, 31–33]. Other researchers have modified the technique for use with "white" females [14,31–33]. İşcan et al. [13] and Loth [34] later applied their methods to "white" and "black" population samples from the United States, and found statistically significant sample differences. Loth [34] attributed those findings to differences in osseous density between the two groups with each having different biological histories. Loth [34] also noted that processes of deterioration occurred later in life on the sternal end of the rib in a 16th–18th century cemetery population from Spitalfields, UK. Subsequently, İşcan [35] did another study on "white" and "black" males and females to evaluate discrepancies with the technique. He found that the morphological characteristics defining the phases were age-related. Also, he found significant differences in the rate and pattern of the metamorphosis by both sex and race.

In 1998, Yavuz et al. [36] studied a sample of males and females from Istanbul in order to evaluate the İşcan et al. [12,33] method. They found that the phases proposed by İşcan et al. [12] present similar morphological characteristics to their sample. They concluded that this technique can be accurately applied to Turkish populations. In 2000, Oettlé and Steyn [37] replicated the study done by İşcan et al. [12] using a sample of "South African blacks" from the Gauteng Province. This study concluded that the estimated ages were acceptable, but that the indicators were not precise. They subsequently adjusted the criteria by modifying the existing phases and proposing new phases. Meena et al. [38] also tested the accuracy and bilateral variation of the method developed by İşcan et al. [12] on a sample of Indian males and female from Lady Hardinge Medical College, New Delhi, India. They found that the average of an individual's phase score was not significantly different in either the right or left rib and concluded that the method can be used in Indian populations with little variation.

Most aging standards only estimate age-at-death up to 50 years of age. However, using the sternal end of ribs, age can be estimated in individuals who are older than 50 [12]. The method also has been applied to historic, prehistoric, and hominid specimens [12,34,39]. Unfortunately, due to its fragile nature, this portion of the rib is infrequently preserved in archeological samples. It also has been suggested that the ribs most suitable for estimating age-at-death are the first four and the last rib [12,35,40,41]. However, Yoder and Ubelaker [42] tested this technique on the left and right second through ninth ribs. They found that the fourth through ninth left ribs did not vary significantly from the other ribs analyzed. Only the second right rib was found to vary significantly from the other four ribs. They recommended the use of a composite score to assign ages in a more accurate manner. Nikita [43] also examined intercostal and age differences in the sternal rib end morphology of documented female skeletons from Spitalfields and St. Bride Church, London. The morphology of this area was captured using three-dimensional morphometric analysis, and statistical manipulation was employed. She found statistically significant differences between the fourth and the other ribs, with exception of the third rib. In addition, she found that all the characteristics of the ribs varied with age. However, Nikita [43] did not find any statistically significant differences among the various age groups and was unable to use any discriminant or multilinear regression analyses based on digitized coordinates, bringing into question the rigorousness of the method for estimating the age using the sternal end of the ribs.

2. Materials and methods

In the current study, the analysis sample consists of 71 males who were more than 16 years old at the time of death. All individuals in the sample lived in Mexico City and were Mexican. The sample comprises a total of 55 individuals from the Servicio Médico Forense (SEMEFO) and 16 individuals from the civil cemetery San Nicolás Tolentino, located in the *delegacíon* Iztapalapa (Table 1). However, not all individuals available from these two sample sets were selected for this study. Selection criteria focused on Mexican males of known age-at-death who did not present bone-altering pathological conditions.