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Forensic anthropology population data

Sex assessment from carpals bones: Discriminant function analysis in a contemporary Mexican sample

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ABSTRACT

Sex assessment is one of the first essential steps in human identification, in both medico-legal cases and bio-archaeological contexts. Fragmentary human remains compromised by different types of burial or physical insults may frustrate the use of the traditional sex estimation methods, such as the analysis of the skull and pelvis. Currently, the application of discriminant functions to sex unidentified skeletal remains is steadily increasing. However, several studies have demonstrated that, due to variation in size and patterns of sexual dimorphism, discriminant functions are population-specific [1–5]. In this study, in order to improve sex assessment from skeletal remains and to establish population-specific discriminant functions, the diagnostic values of the carpal bones were considered. A sample of 136 individuals (78 males, 58 females) of known sex and age was analyzed. They belong to a contemporary identified collection from the Laboratory of Physical Anthropology, Faculty of Medicine, UNAM (Universidad Nacional Autónoma de México, Mexico City). The age of the individuals ranged between 25 and 85 years. Between four and nine measurements of each carpal bone were taken [6,7]. Independent *t*-tests confirm that all carpals are sexually dimorphic. Univariate measurements produce accuracy levels that range from 61.8% to 90.8%. Classification accuracies ranged between 81.3% and 92.3% in the multivariate stepwise discriminant analysis. In addition, intra- and inter-observer error tests were performed. These indicated that replication of measurements was satisfactory for the same observer over time and between observers. These results suggest that carpal bones can be used for assessing sex in both forensic and bio-archaeological identification procedures and that bone dimensions are population specific.

1. Introduction

Correct sex identification of the human skeleton is an important factor in both forensic practice and bio-archaeological and palaeodemographic research [8]. In forensic context, the assessment of sex can substantially narrow the biological profile for unidentified remains. Indeed, in most cases, clarification of the events and later juridical decisions will depend on the precision and the reliability of identification procedures [4,8]. In bio-archaeological studies, sex assessment considerably influences our interpretation of most biological and cultural factors in past populations, burial practices, palaeobiology and palaeodemography [9,10].

The success of assessing sex in skeletal remains depends on the completeness and expression of sexual dimorphism in the recovered structures [6,33]. Although only two biological sexes exist in humans, it is a very complex task to diagnose the sex of a human skeleton from morphological features [6,11,12]. This is due, firstly, to the fact that sex-related differences between skeletons are only tertiary, and secondly to the fact that there is a large overlap between the sexes in the distribution of most features; so that in the middle of the overall range no sexual distinction can be made [9]. In addition, both general robusticity/gracility and the sexual dimorphism depend on the particular regional population [1,2,13–17].

Most researchers agree that sex diagnosis of adult skeletons can be performed easily and with high accuracy [10,17]. However, the overall reliability depends on the method and on the skeletal data taken into account. If almost all the bones composing the skeleton are present, sex assessment is not difficult. In the presence of complete skeleton, sex can be assessed with nearly 100% accuracy. This estimation rate is 98% for pelvis and cranium, 95% with only pelvis or pelvis and long bones, and 80–90% with only long bones [4,18,19]. Nevertheless, fragmentary human remains compromised by different types of burial, or physical insults such as explosions, fires, and mutilations may hamper the use of traditional morphognostic sex assessment methods, such as the analysis of the skull and pelvis [20–22]. It is therefore important to develop methods for fragmented and incomplete material.

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New techniques based on discriminant function analysis and mathematical models of sexually dimorphic bone traits have recently been proposed to obviate this limitation [2,12,14,22–25]. Walker [26], in his study about sex estimation by visual assessment of cranial traits, noted that not only is collecting osteometric data time consuming, but also it often requires expensive, specialized anthropometric equipment. However, these metrical methods and statistical procedures using quantitative analysis are more objective and repeatable than the morphologic methods and can be performed even on fragmentary skeletal remains [1,2,27–29]. Although the great value of sexually dimorphic features of the skull, os coxae, mandible, etc., is unquestionable, the main advantage of discriminant function analysis is that it reduces subjective judgment as well as the level of expertise and experience needed for the assessment of sex [3,30–32]. Unfortunately, technical application would be limited to the specific population from which the bone remains were obtained. This methodical limitation of the mathematical functions is related to the variability of a population with respect to body size. Traits that are sexually dimorphic in one population may be much less so in another [17,33]. This spatial variation within and between populations makes it necessary to reevaluate the diagnostic value of sexually dimorphic traits each time a new population is studied [1,2,5,34,35].

In the past few years, numerous studies have addressed sex estimation from the hands and feet with varying results [36–41]. These studies have varied primarily in terms of the specific bones and populations used to generate either regression equations or discriminant functions. In the hands, most studies have focused on the metacarpals [3,36,37,42–46]. In the feet, studies have been published on the metatarsals [17,25], tarsals [31,39,47–49], proximal phalanges, distal first phalanx [37], and the talus plus calcaneus [29]. Owing to the high incidence of recovery of these compact bones in both forensic and archaeological contexts, Sulzmann et al. [7] investigated and identified the potential of using carpals bones for sex assessment. They were the first researchers to devise a metrical method of assessing sex from the complete carpal bones. Mastrangelo et al. [50], in order to determine the applicability of this technique to other populations, tested its accuracy in a 20th century Spanish sample from Granada (Spain), with known sex and age.

Studies on metric assessment of sexual dimorphism in Mexican skeletons are few [19,51–53], while there has been an escalation in crime, an increasing number of unidentified cadavers and human remains and a need for forensic anthropological standards. Some of the most important investigations are based on populations of Central America, such as the contemporary indigenous Guatemalan in which measurements of the clavicle [14], scapula [15] and humerus [54] have been used. These recent studies suggest that not only the skeletal biology of Mexicans is different from others but many divergences exist among several human groups from Mexico. In addition, much of the research has been conducted in Europe and North America where many skeletal collections and archaeological populations reside. While standards from these studies have been applied to other populations, they may not provide the most reliable results.

The main aim of this study is therefore to develop new discriminant functions for assessing sex from measurements of carpal bones in a Mexican sample. For this purpose, a modern Mexican skeletal collection, with known sex and age, was analyzed in order to establish population-specific discriminant functions.

2. Materials and methods

2.1. Sample

The skeletal remains of this study were selected from the identified osteological collection housed in the Laboratory of Physical Anthropology, Faculty of Medicine, UNAM (Universidad Nacional Autónoma de México, Mexico City). Following an agreement between the School of Medicine (UNAM), the Health Ministry and the Mexico City Government, the authors received permission to study the skeletons from the Director of the Anatomy Department who is officially responsible for the collection and has authorization from the Health Ministry.

In 1966–1968, Dr. Santiago Genovés began to collect human skeletons from cadavers used in the Medical School's Anatomy classes. These bodies were obtained from the institutional morgues. The cadavers predominantly consisted of those individuals whose bodies became property of the State when they were not claimed, or whose relatives signed over the remains to the State. The bodies were subsequently turned over to the Faculty of Medicine for cadaver research. When Dr. Genovés retired, another skeletal biologists, Dr. Reyes-Tellez and Dr. Alba, diligently continued collecting skeletons until their retirement in 1993. During the decade of 1993–2003, Dr. Martha Pimienta and her staff established a uniform protocol for collecting, cataloging, maceration and storage of the skeletons. At present, Dr. Gabriela Sánchez-Mejorada and Dr. Patricia Herrera Saint-Leu, Professors at the Department of Anatomy, curate this collection.

The documentation of these subjects consists of morgue's records with the name of the individual, the sex, age and ethnic identity, date and cause of death. The skeletal catalog also indicated damaged or absent bones for each subject. Based on

Table 1
Variables used in this study.

Carpal bone	Number	Variable	Denomination
Lunate	1	ML	Maximum length
	2	MW	Maximum width
	3	MWDH	Maximum width of the dorsal horn
	4	MWTF	Maximum width of the triquetral facet
	5	HTF	Height of the triquetral facet
Scaphoid	1	ML	Maximum length
	2	MW	Maximum width
	3	MLRF	Maximum length of the radius facet
	4	MLST	Maximum length of the scaphoid tubercle
	5	MLCF	Maximum length of the capitate facet
	6	MWCF	Maximum width of the capitate facet
Triquetral	1	ML	Maximum length
	2	MH	Maximum height
	3	MW	Maximum width
	4	MLLF	Maximum length of the lunate facet
	5	MWLF	Maximum width of the lunate facet
	6	MLPF	Maximum length of the pisiform facet
	7	MWPF	Maximum width of the pisiform facet
	8	MHHF	Maximum height of the hamate facet
	9	MWHF	Maximum width of the hamate facet
Capitate	1	MH	Maximum height
	2	MIWH	Minimum width of the head
	3	MAWH	Maximum width of the head
	4	MLDB	Maximum length of the distal base
	5	MWDB	Maximum width of the distal base
	6	LT	Length of tuberosity
Hamate	1	MH	Maximum height
	2	MW	Maximum width
	3	HB	Height of the body
	4	MWH	Maximum width of the hamulus
	5	MWDF	Maximum width of the distal facets
	6	HM(V)F	Height of metacarpal V facet
	7	HM(IV)F	Height of metacarpal IV facet
Pisiform	1	MH	Maximum height
	2	MW	Maximum width
	3	HTF	Height of the triquetral facet
	4	WTF	Width of the triquetral facet
Trapezium	1	ML	Maximum length
	2	MH	Maximum Height
	3	MLM(I)F	Maximum length of metacarpal I facet
	4	MWM(I)F	Maximum width of metacarpal I facet
	5	MLTF	Maximum length of the trapezoid facet
	6	MLTSF	Maximum length of trapezoid and scaphoid facets
	7	WSF	Width of the scaphoid facet
Trapezoid	1	MH	Maximum height
	2	LDF	Length of the dorsal surface
	3	LPS	Length of the palmar surface
	4	WDF	Width of the dorsal surface
	5	MW	Mid width
	6	MLTF	Maximum length of the trapezium facet
	7	MWTF	Maximum width of the trapezium facet