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Sex estimation from the navicular bone in Spanish contemporary skeletal collections

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A B S T R A C T

Sexual estimation is fundamental to reconstruct the biological profile of individuals, but postdepositional factors can alter the resistance of the bones, thereby preventing accurate diagnosis especially when the skull and the pelvis are absent. Navicular bones are usually well preserved in archeological and forensic contexts and can a good alternative to discriminate sex. On the basis of these aspects, the present investigation analyzed the sexual dimorphism in 231 pairs of navicular bones from documented contemporary collections from Spain. Receiver operating characteristic (ROC) curve analysis and binary logistic regressions were carried out in eight replicable linear measurements of the navicular bone. Each of the eight variables showed a significant sexual dimorphism in our sample.

The ROC curve results indicate that at least five out of the eight variables used have high ability for sex diagnosis, among which the maximum length of the cuneiform surface (LMAXCUN) showed a better performance (area under the curve value = 0.86). Moreover, we introduced regression equations with combination of measurements that correctly allocated the skeletons with 80% or greater accuracy. The equation with high allocation accuracy rate (83.4%) included a combination of the maximum height of the navicular (HMAX), maximum length of the cuneiform surface (LMAXCUN), and maximum length of the talar facet (LMAXTAL). The regression equations presented here are useful for the Western Mediterranean populations and offer better alternatives than formulas based on other population groups.

1. Introduction

There are diverse alternatives to estimate sex of adult human bones through metrical methods; nonetheless, the preservation condition of bones is not always optimal. In contemporary skeletonized remains, the short bones, especially from the feet, can be a good option for sexual diagnosis because their dimensions, forms, protection, and their own structures provide fewer probabilities of fractures or damage for different agents [1–4]. Considering this, analysis of sexual dimorphism in the calcaneus and talus of adult individuals has been conducted in different parts of the world, mainly in the European and African populations [5–12]. Despite this fact, the interest in study of the smaller bones of the tarsus is not as high as that of the larger bones, and few studies are available. Specifically, few works exist about the importance of the navicular bone for diagnosis of sex based on metrical studies. Kidd and Oxnard [13] used nine measures of the navicular to determine differences between sexes and populations (Southern Chinese, Zulu from South Africa, Victorian Britain, and Roman Britain). Moreover, Harris and Case [14], using Euro-American individuals from the William Bass Donated Skeletal Collection, analyzed a series of measurements in whole tarsal bones, including two navicular variables. They used logistic regressions to derive formulas for each bone of the foot as well as combined equations using different bones. Viwatpinyo et al. [15] proposed discriminant functions using 202 pairs of navicular bones from Thai population and obtained a high percentage of correct accuracy. Finally, Navega et al. [16] using machine-learning techniques constructed algorithms to estimate sex from the hind and mid-foot bones in a Portuguese collection (300 individuals).

Therefore, the use of the navicular bone as a sex diagnostic tool is possible, although it has not been intensely studied. To explain

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navicular sexual dimorphism, Eckstein et al. [17] proposed that the differences can be ascribed to the dissimilarity in the articular cartilaginous surface of the talonavicular joint, which is thinner and smaller in females. In addition, they attributed the sexual variation to differences in the foot structure, especially in the arch stiffness, which is lower in females. These findings indicate that the female foot has more elasticity and ligament support in the articular surfaces, implying a great degree of adduction [15].

In addition, the studies of discriminant statistic analysis show that a function can be applied only to the population used to produce it or to those populations that have very similar sexual dimorphism [18,19]; however, to date, no Western Mediterranean series of navicular bones has been analyzed. To meet this need, the present investigation was focused on the navicular bone, searching for metrical parameters for a sexual diagnosis through the study of the contemporary documented bone collections from Spain.

2. Material and methods

The materials used for this analysis were the navicular bones of both sides from 231 contemporary individuals of the 20th century with known sex and age (113 males and 118 females). The skeletal material was obtained from Universitat Autònoma de Barcelona Collection (cemeteries of Montjuic, Collserola, and Granollers, in Barcelona province), Universidad de Granada Collection (Cementerio San José of Granada), and Facultad de Medicina Collection from the Universidad Complutense de Madrid (Cementerio de Alcorcón and Cementerio Sur from Madrid), Spain (Table 1).

The specimens in a bad state of preservation or pathological specimens that prevented accurate measurements were discarded. Measurements were selected considering easily located landmarks in fragmentary or complete bones and replicability. All the landmarks have been described in the classic anthropological literature by Martin and Saller [20] and Kidd and Oxnard [13], except one new dimension described here (measurement #7). To allow replicability with the study of other investigators, all the variables were measured to the nearest millimeter by a non-digital Vernier sliding caliper, except #1 and #2 that were measured using the osteometric board. Therefore, considering the navicular in an anatomic position, the measurements are as follows (Fig. 1):

Table 1
Number of individuals used from the three skeletal collections.

	Individuals			Age			
	Male	Female	Total	Mean	Min	Max	SD
UCM	63	62	125	65.4	20	94	16.9
UAB-1	19	17	36	70.8	32	97	13.6
UGr	31	39	70	68.4	22	90	13.0
Total	113	118	231				

UCM, Universidad Complutense de Madrid; UAB-1, collection from Universitat Autònoma de Barcelona; UGr, Universidad de Granada.

1. Maximum width of navicular (WMAX) (Martin and Saller No. 1): Coronal maximum width. It is measured with an osteometric board where the specimen is laid down on the edges of the talar facet.
2. Maximum height of navicular (HMAX) (Martin and Saller No. 2): Maximum distance between the tangent to the edge of the talar facet and the highest point of the cuneiform surface.
3. Maximum length of the talar facet (LMAXTAL) (Martin and Saller No. 4): Defined as the maximum dimension of the talar facet.
4. Sagittal length of the talar facet (LSAGTAL) (Martin and Saller No. 3): Perpendicular dimension to the LMAXTAL, measured in a central point.
5. Maximum length of the cuneiform surface (LMAXCUN) (Martin and Saller No. 6): Defined as the maximum dimension of the cuneiform surface in a transverse plane.
6. Maximum sagittal length of the second cuneiform facet (LSAGCUN) (Kidd and Oxnard No. 4): Maximum sagittal length of the second cuneiform facet, considering its limits without pathologies or little osteophytes that can confuse the observer.
7. Width of the navicular tuberosity (WTUBER): Maximum dimension of the navicular tuberosity, considering anterior and posterior maximum points.

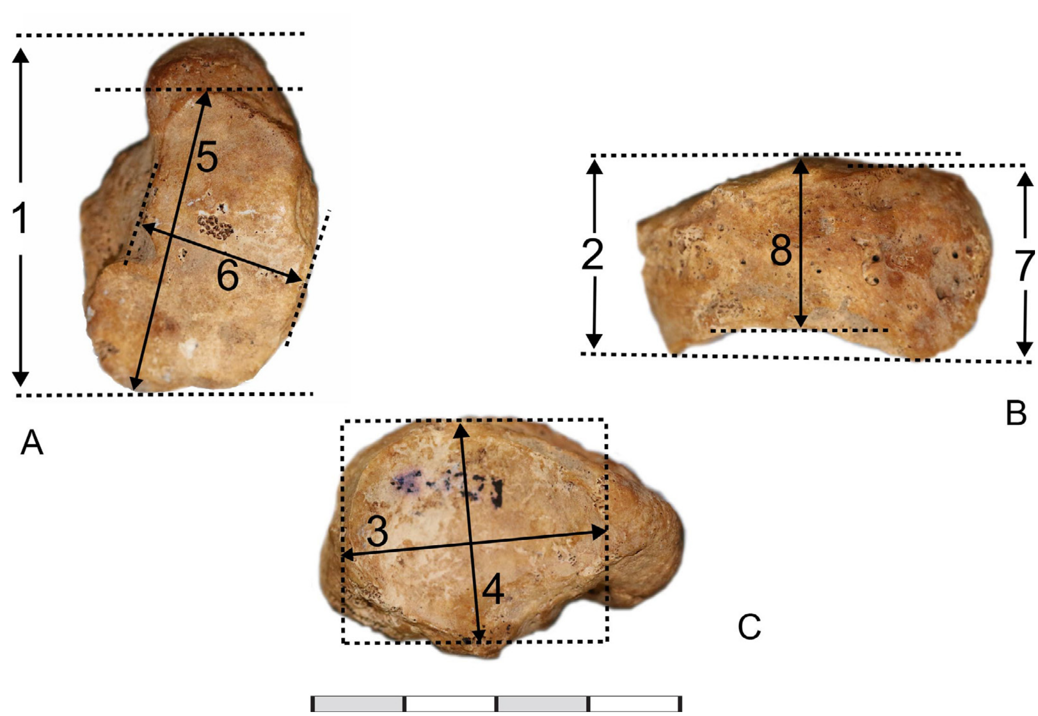

Fig. 1. Left navicular bone. Measurements numerated 1–8 according to the explanation in text. (A) Anterior view, (B) dorsal view, (C) posterior view. Scale bar: 4 cm.