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Sex estimation from the talus in a Thai population

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ABSTRACT

Previous research on sex estimation from the tarsals has shown that the talus is the most sexually dimorphic tarsal bone in most populations. In order to assess the sexing potential of the talus in a Thai population, 252 skeletons (126 male, 126 female) from the Chiang Mai University Skeletal Collection were measured. The sample represents Thai people who come from the local Chiang Mai area and who died within the past ten years. Ten measurements were taken on the left and right tali from each skeleton. Seven of these measurements are similar, or identical, to measurements used by other researchers. Three experimental measurements were also taken. Logistic regression equations were calculated for each measurement, and for pairs of measurements. The individual measurements were also examined using ROC analysis. Averaging the results from both sides, the individual measurements with the highest correct allocation accuracies based on logistic regression analysis were trochlear length (88.2%), trochlear breadth (87.3%), talar length (85.5%), and inferior articular surface length (84.5%). The ROC results followed a similar pattern, with Area Under the Curve values as follows: trochlear length (0.952), inferior articular surface length (0.937), trochlear breadth (0.935), and talar length (0.914). When pairs of measurements were considered by means of logistic regression, four equations produced predicted allocation accuracies greater than 90% – three from the right talus, and one from the left. The highest accuracy on both sides resulted from a combination of the two most sexually dimorphic individual measurements of trochlear length and trochlear breadth. Together, they produced predicted allocation accuracies of 91.3% on the right side, and 91.4% on the left side. Unlike many past studies that have found talar length to be the most sexually dimorphic measurement of the talus, our study found trochlear length and breadth to be the most accurate measurements for distinguishing the sexes. Researchers developing sexing equations for use with other populations should consider including trochlear length and breadth in their analyses.

1. Introduction

Studies concerned with sexing from the tarsal bones have become increasingly common over the last two decades. The tarsals are good candidates for sex estimation because they often preserve well in forensic contexts, due to their generally dense structure and thick cortices, and because of the protection from scavengers and taphonomic forces often afforded by footwear [1–3]. Tarsals are also good candidates because they are weight-bearing bones, and sexual dimorphism in human weight is considerably higher than dimorphism in height [4]. The talus clearly exhibits the greatest size dimorphism in the tarsus [2,4–7]. Among all five past sex estimation studies that have included at least the calcaneus and talus, the talus has produced the highest allocation accuracies (88–94%), and the single most dimorphic measurement has generally been talar length. In a study by Harris and Case [2] that included all seven tarsals with no missing measurements, the only single measurement to achieve 90% allocation accuracy was talar length on the right side. Talar length and height together produced 90.9% allocation accuracy on the right side, and breadth and height together produced 92.4% allocation accuracy on the left side. The cuboid exhibited a slightly higher allocation accuracy on the right side (91.8%) than the talus, but a considerably lower accuracy on the left (84.7%). Therefore, the weight of evidence from past studies, including modern American, 19th Century Italian, and prehistoric Native American

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samples suggests that the talus is likely to be the most sexually dimorphic tarsal bone in most populations.

The purpose of this study is to examine sexual dimorphism of the talus among skeletons from a modern Thai population, and to generate equations for sex estimation in a modern forensic context. To date, no studies of sex estimation have been published for the lower limbs of Thai individuals except for the femur [8]. This study will add a new tool for the analysis of forensic cases in Thailand.

2. Materials and methods

The sample for this study consists of 252 skeletons (126 male, 126 female) from the Chiang Mai University Skeletal Collection housed in the Faculty of Medicine's Forensic Osteology Research Center. The Chiang Mai collection is a documented sample of recently deceased individuals from the local area around Chiang Mai, Thailand. Initially, a reference sample of 200 skeletons (100 female, 100 male) was measured to generate equations for sexing. Age at death in the sample ranged from 22 to 91 years of age for males, 26 to 93 years of age for females. The mean age was 66 years for both sexes. Later, an additional 52 skeletons (26 male, 26 female) were measured to test the sex estimation equations. The skeletons in the collection represent people from various socioeconomic backgrounds, including many professionals from the middle class.

Ten measurements of the talus were taken to the nearest 0.01 mm using either sliding calipers, or a mini-osteometric board (MOB) from Paleotech Concepts. Descriptions of all ten measurements are presented in Table 1 and drawings of each are provided in Fig. 1.

All measurements on the reference sample were taken by authors SP, PS, and PD. SP took the MaxLg measurement, PS took the MaxBr and MaxHt measurements, and PD took the MaxTrLg, MaxTrBr, MaxIASLg, and MaxIASBr measurements. The three experimental measurements, MinIID, MaxLMSHt, and MinIDNk were also taken by PD. Each measurement was taken three times non-consecutively, and the mean of these three measurements was recorded for each individual. Left and right tali were treated separately. Measurements were not taken if the bone exhibited significant osteophytosis or damage that would affect a specific dimension. Thus, some dimensions have a lower sample size than others. The talar length dimensions in particular were often affected by osteophytes around the trigonal process, and occasionally by abnormally large trigonal processes.

Measurements 1–3 were taken with a mini-osteometric board following procedures described in Harris and Case [2]. The rest of the measurements were taken using calipers. Two of these measurements (4 and 5) follow procedures described in Murphy [9], which were borrowed from Steele [10] and originally derive from Martin [11]. Two additional measurements of articular dimensions (6 and 7) were based on figures in Bidmos and Dayal [12], which were in turn adapted from Martin and Knußmann [13]. Three experimental measurements were also taken. These are Measurements 8, 9, and 10 in Table 1.

Intra- and Inter-observer error was calculated for the six measurements found to be most useful for sex estimation. Intraobserver error was calculated from the first two rounds of measurement taken on the reference sample of 200 skeletons. Interobserver error was calculated from a random sample of 10 males and 10 females with no missing measurements from the test sample. For the interobserver error analysis, the second observer was not given any instruction on how to take the measurements beyond the written descriptions from Table 1 (excluding the italicized text) and Fig. 1. The median absolute difference, median percent difference, and technical error of the measurement (TEM) were calculated. The TEM provides an estimate of the standard deviation of repeated measurements and is often used by anthropologists to assess intra- and inter-observer precision [14]. The median percent error was determined by calculating the difference between repeated measurements for each skeleton and then dividing the median of these values by the average of the male and female mean size for each dimension.

Binary logistic regression analysis was performed on each individual measurement for both the right and left sides, and regression equations for sexing of modern Thai individuals were

Table 1
Description of measurements and instrument used.

Measurement	Description
(1) MaxLg	Maximum talar length (identical to Harris and Case [2]): The distance from the most anterior point on the head of the talus to the most posterior point on the trigonal process using a mini-osteometric board.
(2) MaxBr	Maximum talar breadth (identical to Harris and Case [2]): The distance from the most lateral point on the articular facet for the lateral malleolus of the fibula to the medial surface of the talus using a mini-osteometric board.
(3) MaxHt	Maximum talar height (identical to Harris and Case [2]): The distance from the most superior point on the medial trochlear articular surface to the inferior surface of the talus using a mini-osteometric board.
(4) MaxTrLg	Maximum trochlear length (after Steele [10]; Murphy [9]): The maximum distance between the anterior edge of the trochlear articular surface and the posterior edge of the same surface. The measurement is taken parallel to the long axis of the trochlea using a caliper. *Begin with the caliper at the posterior edge and the talar head directed away from the researcher*.
(5) MaxTrBr	Maximum trochlear breadth (after Murphy [9]): The maximum distance between the medial edge of the trochlear articular surface and the lateral edge of the same surface. Because the superomedial edge of the trochlear surface is beveled, the caliper jaws are placed slightly below the highest point of the trochlear edge. The measurement is taken perpendicular to the long axis of the trochlea. *Placement of the fingers along the medial and lateral sides of the trochlea help to hold the tips of the calipers in place. This measurement should be taken with the long axis of the trochlea directed mediolaterally*.
(6) MaxIASLg	Maximum length of the inferior articular surface (modified from Bidmos and Dayal [12]): The longest distance between the medial edge of the inferior articular surface (subtalar joint surface) and the lateral edge of the same surface. The measurement is taken parallel to the long axis of the surface using a caliper. *Begin with the caliper at the posterior edge and the talar head directed away from the researcher*.
(7) MaxIASBr	Maximum breadth of the inferior articular surface (modified from Bidmos and Dayal [12]): The maximum distance between the anterior edge of the inferior articular surface (subtalar joint surface) and the posterior edge of the same surface. The measurement is taken perpendicular to the long axis of the surface using a caliper. *This measurement is best taken by first placing the caliper jaws along the posterior edge of the surface*.
(8) MinIID	Minimum inferior interarticular distance: The minimum distance between the anterior edge of the subtalar joint surface and the posterior edge of the middle articular surface using a caliper.
(9) MaxLMSHt	Maximum lateral malleolar surface height: The maximum height of only the articular portion of the lateral malleolar surface using a caliper.
(10) MinIDNk	Minimum interarticular distance across the neck: The minimal distance between the edge of the medial malleolar surface and the edge of the articular surface of the head of the talus using a caliper.

Note: Comments in italics were added after the test and error samples were measured.

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