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Sex estimation of the tibia in modern Turkish: A computed tomography study

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ABSTRACT

The utilization of computed tomography is beneficial for the analysis of skeletal remains and it has important advantages for anthropometric studies. The present study investigated morphometry of left tibia using CT images of a contemporary Turkish population. Seven parameters were measured on 203 individuals (124 males and 79 females) within the 19–92-years age group. The first objective of this study was to provide population-specific sex estimation equations for the contemporary Turkish population based on CT images. A second objective was to test the sex estimation formulae on Southern Europeans by Kranioti and Apostol (2015). Univariate discriminant functions resulted in classification accuracy that ranged from 66 to 86%. The best single variable was found to be upper epiphyseal breadth (86%) followed by lower epiphyseal breadth (85%). Multivariate discriminant functions resulted in classification accuracy for cross-validated data ranged from 79 to 86%. Applying the multivariate sex estimation formulae on Southern Europeans (SE) by Kranioti and Apostol in our sample resulted in very high classification accuracy ranging from 81 to 88%. In addition, 35.5–47% of the total Turkish sample is correctly classified with over 95% posterior probability, which is actually higher than the one reported for the original sample (25–43%). We conclude that the tibia is a very useful bone for sex estimation in the contemporary Turkish population. Moreover, our test results support the hypothesis that the SE formulae are sufficient for the contemporary Turkish population and they can be used safely for criminal investigations when posterior probabilities are over 95%.

1. Introduction

Morphometric and morphological analyses of skeletal remains are very important to determine sex when fingerprints and DNA cannot be obtained. Previous anthropological studies have reported that the most accurate sex estimation methods are based on the pelvis and the cranium [1–3]. Despite the advantages of these two skeletal regions for sex estimation, they are not always available in all forensic and archeological investigations. Only one part of skeleton or parts of bones may be resources for researchers as a result of the type and severity of trauma before or after death, geographic factors, and secondary factors associated with decomposing human remains [1–3]. Therefore, long bones, particularly the femur and tibia with thick cortical structures and a wide volume, are more robust than other long bones and are useful for sex estimation [1–5]. In addition, new research supports that several postcranial elements are actually better indicators of sex compared to the cranium [2]. In this vein, many population-specific studies have investigated the utility of the tibia as an indicator of sex and the accuracy of sex estimation when using the tibia as assessed by several morphometric parameters is over 84% [6–17].

According to the religion of Islam, when a person dies, the first stage of the afterlife starts in the grave. Therefore, the use of dead bodies for scientific study purposes other than legal obligations is often impossible. In addition, prior to 1923, access to archival information of burials has been a challenge for researchers because

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the death records are written in the Ottoman language-Arabic alphabet and usually records of the Ottoman Empire period were not available [18]. Currently, researchers are in need of contemporary anthropological data for identification since a large number of mass graves have been found recently and there is a lack of anthropometric data in Turkey. The Human Rights Association has prepared a map of the locations of the verified mass graves [19]. According to the report released on 2014, 348 mass graves were recorded containing the remains of 4201 people since 1989 and these individuals require identification [20].

In recent years, computed tomography (CT) has been used to investigate human remains [21–28]. CT and three-dimensional reconstruction software with workstations are advantageous for cases where difficulties arise from maceration or if ethical concerns are raised for handling human remains [21,25–28]. Additionally, these tools are useful to retain accurate measurements and virtual data records. Morphometric analyses using CT images from living individuals with different clinical indications are very helpful for generating contemporary population-specific data [21–25,28]. A study by Stull et al. [28] compared osteometric and virtual measurements of the same skeletal elements and confirmed that accurate measurements can be obtained from CT scan data. A number of sex estimation studies from the mandible [29], cranium [30], sternum [31], maxillar sinus [32], and femur [33] of the contemporary Turkish population have been published recently. There is one cadaveric study published on the tibia by Kirici and Ozan [34] which is based on a very small sample (N = 55) which makes the results questionable for forensic application.

Discriminant function analysis (DFA) is the most frequently used statistical method for classification by the researchers [35]. It has been used to produce population specific formulae for several different skeletal elements, including the tibia. Indeed, osteometric studies for sex estimation from the tibia have been conducted for several populations such as Northern Americans [11,12], medieval and modern Croatians [13,14] Portuguese [15], Southern Europeans [4], Czech [16] and Greek-Cypriots [17]. The high classification results (up to 95%) achieved in the abovementioned studies clearly makes the tibia a very successful sex indicator.

In the present study, we measured seven anthropometric parameters of the left tibia on virtual CT images. The first objective of this study was to provide population-specific sex estimation equations for the contemporary Turkish population based on CT images in a large enough sample to provide accurate and reliable estimations. A second objective was to test the sex estimation formulae on Southern Europeans by Kranioti and Apostol [4].

2. Material and methods

2.1. Sample description

The present study was conducted at the Tepecik Training and Research Hospital. All medical records and CT images of patients admitted to the different clinics of the hospital, from June 2014 and July 2016, were retrospectively evaluated. Cases that had fracture, surgery, congenital or an acquired anomaly in the tibia were excluded from the study (41 cases). The sample consists of 203 left tibia, 124 males and 79 females from Izmir, which is located in the South West of Turkey. Demographic information for the sample can be found in Table 1. The study protocol was approved by the Tepecik hospital Ethics Board.

2.2. Data acquisition

All examinations were performed by a 64-slice CT scanner (Siemens Medical Solutions, Erlangen, Germany). A routine peripheral angiography multi-detector row computed tomography (MDCT) protocol was followed. The scanning parameters included 80 kV, 115 mAs, slice thickness 1 mm and 512 × 512 matrix.

Table 1
Summary table of the sample used in the study.

Sex	Total	Mean age	SD	Minimum age	Maximum age
Male	124	59.81	12.20	19	82
Female	79	60.20	14.54	29	92

In preparation for the study readings, all multidetector CT angiography data were transferred from the archive to a workstation (Aquarius Workstation; TeraRecon, San Mateo, CA) via internal network connections, providing 3D postprocessing options, multiplanar image reformatting (MPR), and maximum intensity projections. CT scan data was used to create 3D reconstruction of the tibia and four measurements (ML, UB, LB and IntCondB) were taken on each bone (Figs. 1 and 2). In addition, measurements related to the nutrient foramen (NFap, NFtrv and NFCirc) were taken on axial CT images (Figs. 3 and 4). Each measurement was performed by researchers manually at the workstation. Description of each measurement can be found in Table 2. Figs. 1–4 illustrate the measurements.

Inter- and Intra-observer error was estimated in a sample of N = 20 tibia using technical measurement error (TEM), relative TEM (rTEM) and coefficient of reliability (R) of the measurement. rTEM, which expresses the error as a percentage of TEM divided by the average value for each measurement, was also taken in order to scale the error. The coefficient R of the measurement is calculated as suggested by Ulijaszek and Kerr [36].

2.3. Validation of published formulae for Southern Europeans

Equations F1-F4 (Table 4) for Southern Europeans were tested using three measurements (ML, UB, LB) on this sample. Percentages of correct classification were calculated for males and females separately and for the pooled sample.

2.4. Data analysis

Variables were tested for normality and equal variances between the two groups (males and females) and parametric and non-parametric tests (e.g. ANOVA, Wilcoxon test) were used to explore if there are statistically significant differences between the sexes.

Univariate and multivariate discriminant function analysis was used to create population specific formulae for the Turkish population. Data analysis was done using SPSS 22.

3. Results

Inter- and Intra-observer error was estimated using technical measurement error (TEM), relative TEM (rTEM) and coefficient of reliability (R) of the measurement. The results are illustrated in Table 3. Intra-observer error is low and inter-observer error is relatively higher. Interestingly the variable with the highest error in both cases is TUB with R = 0.73 between two different observers.

Four equations based on all possible combinations of three variables of the tibia were published by Kranioti and Apostol [4] on a pooled Southern European sample consisting of populations from Spain, Italy, and Greece. Applying the formulae in our sample resulted in very high classification accuracy ranging from 81 to 88%. These results are only 0.1–2% lower than the accuracy reported in the original study (see Table 4). In addition, 36.5–47% of the total Turkish sample is correctly classified with over 95%