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A new computer-tomography-based method of sex estimation: Development of Turkish population-specific standards

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ABSTRACT

The identification of victims involved in mass fatality incidents has become an increasingly important issue nowadays, and identification of unknown individuals is an important aspect in criminal cases and Disaster Victim Identification scenarios. Therefore, the sex estimation is one of the most important biological attributes towards establishing personal identity. In addition, several studies have demonstrated that metric sex determination methods of the skeleton are population-specific due to variation in size and patterns of sexual dimorphism. Unfortunately, the modern Turkish population still lacks wide and representative population standards for identification. Previous research has shown that modern technologies, such as CT scanning appear to offer promising means for the establishment of new standards for contemporary populations. The main aim of this project is to examine the application of measurements taken from the femur in order to assess sex, as well as to contribute to the establishment of discriminant function equations for the Turkish population for forensic applications.

The sample population was composed of CT images taken from 200 adult hospital patients. The images of the femora were segmented from the surrounding bones to ensure correct usage of landmarks as accurately as possible. The 3D reconstructions were then created using the volume-rendering function in OsiriX (v.5.6.). Thirteen measurements were acquired using a 3D viewer and were located and marked on each of the CT reconstructed femora.

Thirteen anthropometric parameters were measured and analysed by basic descriptive statistics and discriminant analysis methods using the SPSS 21.0 software package. The intra-observer variation was assessed by obtaining the inter-cross correlation coefficient in order to evaluate the accuracy of the linear measurements taken. The accuracy of sex prediction ranged from 63.5 to 88% with single variables. In stepwise analysis, Epicondylar Breadth, Femur Vertical Diameter of Neck and Medial Lateral Subtrochanteric Diameter were found to be the most discriminating variables providing an accuracy of 91%.

Ultimately, it is envisaged that this research study will produce data and interpretations that will inform on and improve standards of sex estimation from postcranial osteometric landmarks. Additionally, this research will consider how this data provides value for a developing discipline of forensic anthropology and how it integrates within the existing systems of criminal investigation and Disaster Victim Identification practices in Turkey.

1. Introduction

Estimation of sex is an essential step in the identification of human skeletal remains in anthropology and forensic investigations [19]. The identification of unknown individuals is one of the most important aspects in routine criminal investigations and disaster victim identification. Unidentified human remains may create numerous problems at both legal and emotional levels for victims' families. Forensic anthropologists have an important role to facilitate the identification of human remains by creating a biological profile through the analysis of age, sex, ancestry and stature in such investigations [12,18].

Estimation of sex from limbs and body parts plays an important role in identifying the dead in forensic examinations [1,4,18]. In this regard, many studies have focused on features of the femur

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[2,12,15,21,26,34]. Because of its robustness and strength, it is likely to resist environmental effects and animal activity. Femur keeps its anatomical shape for a long time and it is commonly present at a crime scene or a mass disaster [20,24]. Sexual dimorphism in the femur indicates not only the general growth and the strong muscular attachment activity, but also the genetic structure of the population. Thus, metric analysis of femur is typically the preferred indicator of sex with a high degree of reliability [6]. The following studies have also shown that the sex estimation equations provided are generally not appropriate for populations outside their country of origin because of the increased error of estimation [2,13,29].

Robinson and Bidmos [29] showed that osteometric measurements are moderately to strongly heritable and could provide evidence for population continuity or difference. Furthermore, several studies have shown that sex estimations from the bones of the limbs are population specific due to size differences between population groups [33].

Until recently, these anthropological standards were generally formulated from skeletal collections belonging to more historical populations [2]. Thus, standards derived from anthropometric measurements of the skeletal collections are unable to provide comparable accuracy to modern population due to recent secular demographic changes. It is no longer possible to rely on the previous centuries' collections for forensic criteria [32]. Therefore, many studies have already been carried out to collect new data for modern population groups [11]. Modern digital imaging techniques can be used non-invasively to gather anthropological information allowing access to a truly living population. For this reason, in recent years, Computed tomography (CT) and magnetic resonance (MR) have become more acceptable in the forensic field [25].

The current literature demonstrates that there is considerable amount of research into the accuracy of estimation of biological characteristics from radiographic images [13]. To date, however, few authors have applied CT scan in the field of anthropometry to achieve accurate standards measurements *in vivo* using femur [10].

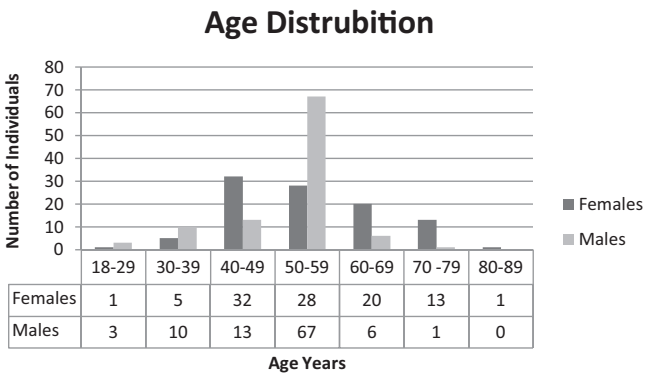
The present study provides radiological measurements for 13 different parameters in relation to sexual dimorphism on a contemporary Turkish population. The importance of this research is its potential to contribute to population-specific standards for representative Turkish populations as well as to examine the correlation between metric measurements and sex estimation of femur on Volume-Rendered images.

2. Materials and methods

2.1. The source of the data

The images of 200 human femora (100 male and 100 female) of known age were procured from the Department of Radiology, Istanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital during 2012–2014. Ethical approval was granted from the Cranfield University Ethics Committee prior to any data collection.

The sample population is composed of CT images taken from living hospital patients, age ranging from 20 to 80 years during 2011–2014, with no visible signs of pathological changes. The identity of the images was anonymous when received by the researchers, with only sex, age and place of birth data retained. Fig. 1 shows the age distribution by sex of dataset. The earliest year of birth represented in the dataset is 1934, and the latest 1994. The mean age across the sample is 51. A descriptive analysis of the sample is provided in Table 1. The mean age of adult men and women was 51.74 and 54.95, respectively. The sample population consists of people from different parts of Turkey that are assumed to be a representative example of the Turkish population.



	18-29	30-39	40-49	50-59	60-69	70 -79	80-89
Females	1	5	32	28	20	13	1
Males	3	10	13	67	6	1	0

Fig. 1. Sample distribution by age and sex.

2.2. Data acquisition

All Cardiac CT angiographies were performed in the radiology department at Mehmet Akif Ersoy Hospital during 2011–2014. Each scan was undertaken on a 256-slice dual source computed tomography scanner (SOMOTOM Definition Flash, Siemens Medical Solutions, Forcheim, Germany).

2.3. Methods

Images were saved as DICOM files (Digital Imaging and Communications in Medicine), and then processed using OsiriX ® 5.6. Software (Pixmeo, Geneva, Switzerland). The raw data of CT images were transferred to OsiriX software and these tomographic images were reconstructed to Volume-Rendered images. All the Volume-Rendered images were reconstructed by 5.00 mm thicknesses slice CT scan.

Firstly, each DICOM data set was imported in to OsiriX (v.5.6.). Image processing then began with the segmentation of the femur from other adjacent parts. Segmentation is a process that allows the virtual separation of regions with different density in the image and it can be performed manually, semi automatically or automatically. In this research, the authors utilised a manual segmentation method, due to extremely narrow inter-bone regions of the acetabulum and femoral head. This manual segmentation method is time-consuming and requires considerable effort [9]. Accurate segmentation of the femur from the three-dimensional (3D) data is an important prerequisite of taking accurate measurements for this research. The manual segmentation can be performed either slice by slice or in 3D. Both methods have been tried; however, the manual segmentation of femur was only applied by creating a region of interest (ROI) model. The segmentation was performed by manually identifying regions of interest from serial sections by the same researcher. This segmentation was performed in the 2D viewer of OsiriX, which allowed the establishment of the pixel value range for each area of interest. After segmentation, the software combined all slices to generate 3D volume-rendering images. The 3D reconstructions were created using the volume-rendering function in OsiriX (v.5.6.) with software settings optimised; Windows length (WL): 127, Windows width (WW): 255, Slice thickness: 5.00 mm.

Table 1
Descriptive analysis of the sample.

	N	Mean age	Minimum	Maximum	Median	Standard Deviation
Male	100	51.74	20	74	54	8.556
Female	100	54.95	29	80	54	12.075