Journal of Forensic and Legal Medicine 18 (2011) 246–252

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Clinical practice

Gender determination from hand bones length and volume using multidetector computed tomography: A study in Egyptian people

Ghada A. Eshak MD Assistant professor of Forensic Medicine & Clinical Toxicology [a,*], Hala M. Ahmed MD Assistant professor of Forensic Medicine & clinical Toxicology [a], Enas A.M. Abdel Gawad MD Lecturer of Radiodiagnosis [b]

[a] Forensic Medicine and Clinical Toxicology Department, Faculty of Medicine, Minia University, Egypt
[b] Radiodiagnosis Department, Faculty of Medicine, Minia University, Egypt

ARTICLE INFO

Article history:
Received 27 February 2011
Accepted 20 April 2011
Available online 20 May 2011

Keywords:
Forensic anthropology
Sex determination
Discriminant function
MDCT
Egyptians

ABSTRACT

Determination of sex from incomplete skeletal and decomposing human remains is particularly important in personal identification. Measurements of hand bones length have been shown to be sexually dimorphic in many nationalities. Since the validity of discriminant function equation in sex determination is population specific; the purpose of this study is to assess sex from the hand bones length in a contemporary Egyptian population using data derived from both multiplanar (two-dimensional) and volumetric (three-dimensional) reformatted images of multidetector CT to derive special equations for sex determination in Egyptians. One hundred and twenty two Egyptians (60 males and 62 females) with mean age of 24.1 ± 4.4 were included. An independent samples student's *t*-test and discriminant function analysis were done. Results indicate existence of length differences between the sexes. Males presented with significantly greater mean values than females for distal phalanges of all fingers, 1st and 3rd proximal phalanges and all metacarpal bones measured by 2D images. Metacarpals, proximal phalanges and distal phalanges are sexually dimorphic with accuracies of 80%, 76.6% and 80% respectively. Three-dimensional volume-rendered reconstructed images of metacarpals give more accurate results (92.9%) in correct sex determination when compared with 2D images. From the forensic standpoint, the usefulness of this study rests on the identification of sex among Egyptian based on length and volume differences observed on MDCT examination.

1. Introduction

Identification is the mainstay of any forensic investigation, whether it is of the suspect from the physical evidence at the crime scene or of the victim from dismembered, mutilated and charred remains.[1] Identification of victims from dismembered human remains has always been a challenge for forensic scientists.[2]

Sex determination is the vital part of identification, which is often required in medico-legal practice.[3] Sex is the first demographic factor that is determined because it reduces the number of possible matches by 50%.[4]

Forensic anthropology is a branch of physical anthropology primarily concerned with the postmortem identification of human remains in a medico-legal context.[5] When an individual hand is recovered and brought for examination, somatometry of the hand, osteological and radiological examination can help in the determination of primary indicators of identification such as sex, age and stature.[6]

Previous studies have shown that the metacarpals are useful for the sex determination of skeletal remnants, but they obtained conflicting results in terms of accuracies that were explained by racial, temporary or populational variances.[7] There have been fewer studies on phalanges for the same purpose. Anatomically short tubular bones have some advantages over other bones in a forensic context. The shafts of long bones often stay intact, but their epiphyses are prone to damage because of the overlying fragile cancellous bone. However, the smaller long bones of the hands often remain complete.[8]

Measurements of the hand bones have been shown to be sexually dimorphic in South African males and females,[9] Turkish,[10] South Indians,[11] Greeks[12] and Athens.[13] Since the validity of discriminant function equation in sex determination is population specific,[14] the aim of this study is to assess the accuracy of sex determination from the metacarpals and phalangeal measurement data obtained from

Abbreviations: kVp, Kilovolt; mAs, Milliampere; FOV, Field of View; MDCT, Multidetector computed tomography; 2D, Two dimension; 3D, Three dimension; MPR, Multiplanar reformation.

* Corresponding author. Forensic Medicine and Clinical Toxicology Department, Faculty of Medicine, Minia University, Egypt. Tel.: +20 106363490.
E-mail address: doctorghadaattia@hotmail.com (G.A. Eshak).

1752-928X/$ – see front matter © 2011 Elsevier Ltd and Faculty of Forensic and Legal Medicine. All rights reserved.
doi:10.1016/j.jflm.2011.04.005

multiplanar (two-dimensional) and volumetric (three-dimensional) reformatted images of multidetector CT and to develop equations for Egyptians that would provide the best way to determine sex. The datasets of the left hand were used as the majority of the population is right-handed and therefore left hand will be less influenced by activity.

2. Subjects and methods

A total of 2318 bones from left hands of one hundred and twenty two right-handed adult Egyptians (60 males & 62 females presented to Radiology department of Suzan Mubarak University Hospital from March 2010 to September 2010) were scanned by multidetector CT examination to detect their length. Cases with skeletal immaturity, fracture, pathological lesions such as congenital and developmental dysplasia, metabolic bone diseases, or surgery, as well as tumors, osteoarthritis and arthritis were excluded from this study. The procedures followed were in accordance with the ethical standards of the responsible committee of Faculty of Medicine, Minia University.

2.1. MDCT protocol for image acquisition

CT studies were performed using a 16-detector CT scanner (BrightSpeed 16; GE Medical Systems) without contrast material. Scanning along the axial axis of the entire left hand including the carpal joint was performed using the following parameters: 120 kVp, 260 mAs, a helical pitch of 0.562:1, 0.8 s scan time, 16 $\times$ 1.25 mm detector configuration, 8.8 s total exposure time, 1.25 mm helical slice thickness, and 0.6 mm reconstruction interval with a small FOV. The images were reconstructed using a bone algorithm. The protocol used for scan acquisitions was identical for all patients to avoid technical variations in length and volume measurements.

2.2. Reconstruction and post-processing considerations

For 2D and 3D reconstruction images, the axial source images with a 1.25-mm slice were transferred to an Advantage Workstation (AW) Volume Share 2 (GE Healthcare).

2.3. 1-Two-dimensional reconstruction

Multiplanar reformatted (MPR) images were obtained in coronal plane through the entire left hand with a section thickness of 1.2 mm, and a section reconstruction interval of 1.0 mm. The lengths of all metacarpals and phalanges (proximal, middle and distal) were measured from the midpoint of the base to the distal tip point of each bone by measure distance tool.

2.4. 2-Three-dimensional reconstruction

Three-dimensional (3D) CT images were obtained by using 3D volume rendering technique. 3D reconstruction image of the entire left hand was performed using The Volume Viewer 3.1 which is powerful 3D analysis software which runs at the AW workstation; it enables fast volumetric review of CT datasets. This software creates a 3D volume of slice data that is displayed automatically as volume-rendered (VR) view.

The Paint tool is used to define manually the volume of the 2nd and 4th metacarpal bones which isolated from the original 3D volume of the entire left hand. After their segmentation and isolation, their volumes were calculated by clicking the volume measurement tool and then by clicking the viewport where was the segmented bone, the volume was then displayed automatically on the 3D viewport.

3D volume measurements were performed for only the 2nd and 4th metacarpal bones as a representative example of hand bones to compare its accuracy with that of 2D measurement in correct sex determination. Volume calculation could not be performed for all hand bones because while 3D volume-rendered reconstruction CT images of the entire left hand were obtained automatically and rapidly, isolation of individual hand bones were performed manually and it is time consuming process because of large number of slices produced per examination[15] so we use the second and fourth metacarpals bone only as a separate bone. In this study approximately 400 slices produced per examination.

2.5. Statistical analysis

Data were analyzed using SPSS statistical package version 17. Results were expressed as mean $\pm$ standard deviation (SD). Independent samples students *t*-test was performed to establish existence of significant difference between male and female bone lengths. Univariate discriminant function analysis was performed to obtain demarking points for male and female that could be used for fragmentary bones. All measurements were used to select the variable or combination of variables that best discriminates between sexes. Direct analysis of data was performed to develop formulas to allow accurate sex determination from fragmentary remains for Egyptians. A p-value of <0.05 was considered as statistically significant.

3. Results

Age and sex distribution of the studied subjects is shown in Table 1. Males presented with significantly greater mean values than females ($P < 0.05$) for the lengths (2D measurements) of the distal phalanges of all fingers, 1st and 3rd proximal phalanges and all metacarpal bones. (Table 2) (Figs. 1 and 2). Neither the middle phalanges nor the 2nd, the 4th or the 5th proximal phalanges showed significant differences between males and females. The calculated volumes (3D measurements) of the 2nd and 4th metacarpal bones (Figs. 3 and 4) showed significant difference between males and females (Table 3) indicating presence of significant sexual dimorphism in hand measurements of Egyptian people.

The cut off value and the accuracy percentage in correct sex classification for males and females in individual and grouped bones are presented in Tables 4 and 5. A measured value higher than the demarking point classifies an individual as male and a lower value suggests female. Metacarpals, proximal phalanges, middle phalanges and distal phalanges are sexually dimorphic with accuracies of 80%, 76.6%, 70% and 80% respectively, while the volume of metacarpal bones by 3D gave sexual dimorphic accuracy of 92.9%. Tables 6 and 7 show discriminant function analysis for individual and grouped bones.

In our study volumetric measurement of the 2nd & 4th metacarpals are more accurate in correct sex determination when compared with 2D CT measurement with a total accuracy of 92.3% and 71.4% for the 2nd & 4th metacarpals respectively. (Table 8).

The following equation was applied for sex determination from hand bones calculating their score in the discriminant function.

$$\begin{aligned}\text{Df for}(X) = {} & \text{mean of X1} \times \text{dfc1} + \text{mean X2} \times \text{dfc2} + \text{mean X3} \\ & \times \text{dfc 3} + \text{meanX4} \times \text{dfc4} + \text{mean X5} \times \text{dfc5}\end{aligned}$$

Table 1
Descriptive statistics of the subjects by means of age ($N = 122$).

Sex	Minimum	Maximum	Mean	SD
Male ($n = 60$)	18	30	23.3	4.4
Female ($n = 62$)	19.5	30	24.8	4.5
Total ($n = 122$)	18.75	30	24.1	4.4