Research Article

The accuracy of sex determination by metacarpal parameters using multi-detector computed tomography scanning in Egyptian population

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Abstract

Prediction of sex from incomplete and decomposing skeletal remains is vital in establishing the identity of an unknown individual. The purpose of this study is to assess the applicability of external and medullary parameters of third and fourth metacarpals using multi-detector computed tomography in sex determination in Egyptian population. All measurements showed significant sexual differences ($P < 0.05$). By simple discriminant analysis, mediolateral diameter of midshaft of the third metacarpal showed the highest percentage of accuracy (69%) in sex determination. This study concluded that metacarpals are useful bones for sex determination and also it imposes new forensic standards for determination of sex in Egyptian metacarpals using various discriminant equations.

Key Words: Sex Determination; Metacarpals; Multi-detector Computed Tomography

Introduction

Sex determination is the classification of an individual as either male or female. To achieve an assignation of sex, anthropologists use biological characteristics that vary between both sexes [1].

The personal identification from extremities becomes very important in cases of mass disasters where there are a recovering hands separated from the body [2]. There extensive uses are because of the high incidence of recovery of these compact bones in both forensic and archaeological situations[3,4].

The real advance toward a more extensive and effective use of imaging techniques in forensic medicine was prompted by the discovery of computed tomography (CT) due to its capability to provide 3D representation of the body structures in a few minutes[5].

The metacarpals are favored because they are the largest, remain complete in most damaged conditions and most easily identifiable bones of the hand[6]. Therefore, the aim of this study was to assess the relationship between the outer and medullary measurements of metacarpals and sex and to allow the sex of an individual to be diagnosed from these measurements in a sample of Egyptian population by using a multi-detector computed tomography (MDCT) scanning and developing a set mathematical models from discriminant function analyses.

Subjects & Methods

This study was conducted on 200 patients (100 males and 100 females) with age ranged from 25 to 65 years at the Radiology Department of Minia University Hospital. These patients were subjected to MDCT for their third and fourth metacarpal bones of right hands. Patients with metacarpal fractures or deformities (acquired or congenital), skeletal immaturity, bone tumors, growth disorders, connective tissue diseases and previous orthopedic surgery of metacarpal bones were excluded from the study.

Axial cuts were taken on the Rt. hand including the metacarpals from MDCT and then reconstructed coronal and sagittal images were generated as well as the 3D reformatted images that were used to obtain the following measurements. The measurements have been modified from Basir[7] and Nathena et al.,[8] as follow:

- Maximum metacarpal length (ML): Is described as the overall external dimension of a metacarpal in its longitudinal direction.

- Medio-lateral diameter of proximal end (MLDPE): Is described as the widest part of proximal end of the metacarpal in the transverse direction.
- Medio-lateral diameter of mid shaft (MLDM): Is described as the widest part of mid shaft of the metacarpal in the transverse direction.
- Medio-lateral diameter of distal end (MLDDE): Is described as the widest part of distal end of the metacarpal in the transverse direction.
- Medullary length of the metacarpals (MdL): The medullary length was obtained by connecting the midpoints of the trans-verse lines.
- Narrowest medullary width (NMdW): It is the narrowest part of the medullary canal perpendicular to the medullary length.
- Proximal medullary width (PMdW): It is defined as the biggest width of the proximal medullary canal in the direction perpendicular to the medu-llary length.
- Distal medullary width (DMdW): It is defined as the biggest width of the distal medullary canal in the direction perpen-dicular to the medullary length.

The collected data were coded, tabulated and statistically analyzed using SPSS program (Statistical Package for Social Sciences) software version 24. Descriptive statistics were done for numerical data by mean, standard deviation and minimum & maximum of the range. Simple discriminant functional analyses were used.

Results

The mean age of tested cases was 49.01 years with standard deviation (SD) ±10.02. Descri-ptive statistics of different measurements of the right third and fourth metacarpals among all cases and independent-samples t test revealed highly significant increase in males when were compared with females (P < 0.05) (Table 1,2).

Simple discriminant functional analysis for sex prediction using right third and fourth metacarpal measurements revealed that the highest accuracy was obtained with usage of MLDM of third metacarpal (69%) and with MLDPE and MLDM of fourth metacarpal (68%) (Table 3,4).

TABLE 1. Descriptive Statistics and Independent-Sample t-Test of The Right Third Metacarpal Measurements in Male and Female

3rd metacarpal		**Male**	**Female**	**P value**
		N= 100	**N= 100**	
ML	*Range* *Mean ± SD*	(62.6-68.8) 66.1±0.93	(62.8-65.8) 65.4±0.72	***<0.001****
MLDPE	*Range* *Mean ± SD*	(13.5-15.5) 14.5±0.45	(13.8-14.4) 14.3±0.15	***<0.001****
MLDM	*Range* *Mean ± SD*	(6-8.7) 7.2±0.42	(6.1-7.1) 7±0.15	***<0.001****
MLDDE	*Range* *Mean ± SD*	(15.5-18.5) 17.5±0.48	(16.5-17.5) 17.4±0.29	***0.024****
MdL	*Range* *Mean ± SD*	(44.8-48.8) 46.9±0.66	(45-46.8) 46.7±0.31	***0.003****
NMdW	*Range* *Mean ± SD*	(4.4-6.5) 5.5±0.38	(5-5.4) 5.4±0.06	***0.001****
PMdW	*Range* *Mean ± SD*	(9.1-10.5) 9.8±0.24	(9-9.8) 9.8±0.12	***0.010****
DMdW	*Range* *Mean ± SD*	(9.1-10.5) 9.9±0.23	(9.3-9.8) 9.8±0.10	***0.001****

ML*= Maximum metacarpal length,* ***MLDPE****= Medio-lateral diameter of proximal end,* ***MLDM****= Medio-lateral diameter of mid shaft,* ***MLDDE****= Medio-lateral diameter of distal end,* ***MdL****= Medullary length,* ***NMdW****= Narrowest medullary width,* ***PMdW****= Proximal medullary width,* ***DMdW****= Distal medullary width.*
***:** *P value is significant when P <0.05,* **N=** *number,* **SD=** *standard deviation.*

TABLE 2. Descriptive Statistics and Independent-Sample t-Test of The Right Fourth Metacarpal Measurements in Male and Female

4th metacarpal		Male N= 100	Female N= 100	P value
ML	*Range* *Mean ± SD*	(52.8-58.8) 56±0.96	(53-55.8) 55.5±0.57	***<0.001****
MLDPE	*Range* *Mean ± SD*	(11.8-14.4) 13.3±0.48	(12.8-13.1) 13.1±0.06	***<0.001****
MLDM	*Range* *Mean ± SD*	(5.5-7.2) 6.3±0.35	(5.5-6.2) 6.2±0.11	***<0.001****
MLDDE	*Range* *Mean ± SD*	(13.1-15.6) 14.3±0.46	(13.1-14.1) 14.1±0.14	***<0.001****
MdL	*Range* *Mean ± SD*	(41-44.3) 42.2±0.56	(40-42) 41.8±0.42	***<0.001****
NMdW	*Range* *Mean ± SD*	(4.1-5.6) 4.7±0.31	(4.4-4.6) 4.6±0.04	***<0.001****
PMdW	*Range* *Mean ± SD*	(7.3-9) 7.8±0.33	(7.6-7.7) 7.7±0.02	***0.001****
DMdW	*Range* *Mean ± SD*	(8-9.6) 8.6±0.32	(8.2-8.8) 8.5±0.07	***0.001****

ML*= Maximum metacarpal length,* ***MLDPE****= Medio-lateral diameter of proximal end,* ***MLDM****= Medio-lateral diameter of mid shaft,* ***MLDDE****= Medio-lateral diameter of distal end,* ***MdL****= Medullary length,* ***NMdW****= Narrowest medullary width,* ***PMdW****= Proximal medullary width,* ***DMdW****= Distal medullary width.*
*******: P value is significant when P <0.05,* ***N=*** *number,* ***SD=*** *standard deviation.*

	Wilk's lambda	P value	Constant	Coefficient	Sectioning point	Accuracy In males	Accuracy In females	Accuracy In all cases	Discriminant Functional equation
ML	0.849	***<0.001****	-78.93	1.2	0	88	44	66	**DS= -78.93+(1.2*_ML_)**
MLDPE	0.898	***<0.001****	-43.19	3	0	28	100	64	**DS= -43.19+(3*_MLDPE)_**
MLDM	0.907	***<0.001****	-22.23	3.15	0	40	98	69	**DS= -22.23+(3.15*_MLDM)_**
MLDDE	0.975	***0.024****	-44.45	2.55	0	80	22	51	**DS= -44.45+(2.55*_MLDDE)_**
MdL	0.956	***0.003****	-90.16	1.93	0	86	22	54	**DS= -90.16+(1.93*_MdL)_**
NMdW	0.942	***0.001****	-19.8	3.63	0	34	100	67	**DS= -19.8+(3.63*_NMdW)_**
PMdW	0.967	***0.010****	-51.48	5.25	0	16	100	58	**DS= -51.48+(5.25*_PMdW)_**
DMdW	0.940	***<0.001****	-54.66	5.57	0	20	100	60	**DS= -54.66+(5.57*_DMdW)_**

ML*= Maximum metacarpal length,* ***MLDPE****= Medio-lateral diameter of proximal end,* ***MLDM****= Medio-lateral diameter of mid shaft,* ***MLDDE****= Medio-lateral diameter of distal end,* ***MdL****= Medullary length,* ***NMdW****= Narrowest medullary width,* ***PMdW****= Proximal medullary width,* ***DMdW****= Distal medullary width.********: P value is significant when P <0.05.*
Discriminant score (DS) = constant + (coefficient x measure).
If the discriminant score ≥ sectioning point = (male).
If the discriminant score < sectioning point = (female).

	Wilk's lambda	P value	Constant	Coefficient	Sectioning point	Accuracy In males	Accuracy In females	Accuracy In all cases	Discriminant Functional equation
ML	0.919	***<0.001****	-70.58	1.27	0	86	28	57	**DS= -70.58+(1.27*_ML_)**
MLDPE	0.894	***<0.001****	-38.86	2.95	0	36	100	68	**DS= -38.86+(2.95*_MLDPE_)**
MLDM	0.915	***<0.001****	-24.34	3.9	0	36	100	68	**DS= -24.34+(3.9*_MLDM_)**
MLDDE	0.885	***<0.001****	-41.38	2.92	0	34	100	67	**DS= -41.38+(2.92*_MLDDE_)**
MdL	0.897	***<0.001****	-84.87	2.02	0	94	16	55	**DS= -84.87+(2.02*_MdL_)**
NMdW	0.939	***<0.001****	-21.11	4.55	0	20	100	60	**DS= -21.11+(4.55*_NMdW_)**
PMdW	0.945	***0.001****	-23.7	4.22	0	28	100	64	**DS= -23.7+(4.22*_PMdW_)**
DMdW	0.942	***0.001****	-37.18	4.35	0	24	96	60	**DS= -37.18+(4.35*_DMdW_)**

ML*= Maximum metacarpal length,* ***MLDPE****= Medio-lateral diameter of proximal end,* ***MLDM****= Medio-lateral diameter of mid shaft,* ***MLDDE****= Medio-lateral diameter of distal end,* ***MdL****= Medullary length,* ***NMdW****= Narrowest medullary width,* ***PMdW****= Proximal medullary width,* ***DMdW****= Distal medullary width.* ********: P value is significant when P <0.05.*

Discriminant score (DS) = constant + (coefficient x measure).
If the discriminant score ≥ sectioning point = (male).
If the discriminant score < sectioning point = (female).

Discussion

Sex determination is one of the crucial steps when it comes to establish an individual's biological profile. A significant problem with relying on these bones is that they can be fragmented, damaged or poorly preserved which makes it necessary to search for new bones to identify the individual[9].

All the studied subjects were adult because sex differences become evident only after the end of puberty when the skeleton has completed its growth[10]. Sex differences in the shape, size and appearance of bones arise during development according to individual genetic markers and in response to sex hormones during puberty[11].

The current study is in acceptance with Navsa et al.,[12] who conducted a study on 200 hand bones from sex-race group (50 white males, 50 black males, 50 white females and 50 black males) (age 21-80 years) from a South African population.

These results are in harmony with that of Eshak et al.,[13] who measured the lengths (2D measurements) of all metacarpal bones and the volumes (3D measurements) of the 2nd and 4th metacarpal bones from 122 Egyptian individuals (60 males and 62 females). They stated that males presented with significantly greater mean values than females for the lengths of metacarpal bones and the accuracy was ranged from 71.4 % to 92.9%. They also proved that the 2nd & 5th metacarpals had the highest accuracy.

The mentioned results correspond with previous results of Khanpetch et al.,[14] who used 249 skeletons (154 males and 95 females) from a Thai population. Six measurements were taken on each metacarpal, namely maximum length, medio-lateral base width, antero-posterior base height, medio-lateral head width, antero-posterior head height and mid-shaft diameter.

These results are consistent with the results of Singh et al.,[15] who studied 143 metacarpals after obtaining x-ray of both hands from North Indian population sample.

The present results go with this of Ameri et al.,[16] who investigated the possibility of estimating gender using metacarpals dimensions in 200 Iranian adult persons (100 male and 100 female) without any background of specific disease. The length metacarpal was measured in millimeter and reported in ratio.

The current study comes in conjunction with what was mentioned by Kusec et al.,[17] who conducted a morphometric analysis of six metacarpal bones (second, third and fourth of right and left hands) on hand radiographs of 434 male (aged between 19 and 86 years) and 549 female (aged between 19 and 79 years).

The reverse was found by Zanella & Brown[18] who estimated the applicability of discriminant function analysis comparing the correspondence results of the equations of previous studies based upon measurements from metacarpals. They used 23 adult cadavers and data were subjected to regression equations and linear discriminant analysis.

Conclusions

The present study proved that the right third and fourth metacarpals have a considerable value in predicting sex among Egyptian population by using discriminant function analysis. These will help in medico-legal cases for establishing the identity of an individual when only some remains of the body are found. This study has decreed new significant parameters of third and fourth metacarpals to be used in forensic medicine.

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