Ain Shams Journal of Forensic Medicine and Clinical Toxicology
July 2014, 23:103-114

Determination of Sex From Sternal Dimensions in Upper Egypt Population By Using Multislice Computed Axial Tomography

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Abstract Sex determination is an important step in personal identification which can be done from bones examination either from their metric measurements or radiograph images especially in difficult identification as dismemberments, mutilations and explosions. The present study was designed to assess the possibility of sex determination from sternal measurements by multislice computed axial tomography (MSCT) and generate statistical equations that can be used to determine sex from sternum in Upper Egypt persons. This study was performed on one hundred and sixty healthy living Upper Egypt persons (80 males and 80 females) of age 18-80 years old during MSCT investigation of the chest region, in department of radiodiagnosis in Assiut University hospital after informed consent. Fourteen sternal measurements were taken including manubrium length, sternal body length, combined length of the manubrium and sternal body, sternal index, manubrium width at tip, width and base, sternal body width at articulation with 2nd, 3rd, 4th, 5th and 6th ribs and two virtual angles of sternum. First angle lies between two intersected virtual lines made along the lateral aspect of the upper part of the sternal body and the lateral aspect of the manubrium. Second angle lies between two virtual lines drawn along the lateral margins of the lower part of sternal body and xiphoid process. The data were analyzed statistically. Results of this study demonstrated that the male measurements showed higher statistical significant values than females measurements except sternal index. Use of the multiple and simple regression equations of relation between sternal measurements and sex demonstrated that the total body length was the most significant parameter for sex prediction. The discriminant function analysis revealed correct sex prediction in known Upper Egyptians by 93%. The multivariant logistic regression can give correct sex prediction in unknown Upper Egyptians by 85.4%. This study concluded that sex determination can be done through sternal measurements including the virtual sternal angles, the MSCT is a trustful method for bone measurement during forensic investigation and sex prediction from measurements of all sternal parts is higher than those from single part.

Keywords Sex, Sternum, Computed axial tomography, Upper Egypt.

Introduction

Sex determination is an important step in personal identification during medico-legal investigations (Changani et al., 2014). Identification may be difficult in cases where the integrity of the body has been compromised such as animal scavenging, burning, dismemberment, criminal mutilations and mass disasters. In such cases the forensic examiner can depend on bone measurements (Sen et al., 2011 and Zheng et al., 2012).

The osseous skeleton which resists putrefaction for a long time is useful for sexing the individual (Hunnargi et al., 2008). The pelvis is considered the most reliable element to be used for sex determination but it is fragile and susceptible to damage (Walker, 2005). The skull has been established to be less accurate than post cranial elements by meteric measurements (Spradley and Jantz, 2003).

The human sternum is a flat bone that forms the middle of the anterior part of the thoracic cage. The manubrium is attached to the upper part body of the sternum at its lower border by the symphysis type of joint, while its upper margin, known as jugular notch. On the sides, manubrium contains facets for the articulation of first and half of the second rib. The body of sternum is attached to the xiphoid process at the lower margin. On the lateral margins it contains facets for the articulation of second to sixth ribs (Standring, 2008).

The sternum is one of such bones which is being extensively used for sex identification either by direct measurement of dried sternums from cadavers or indirect measurement of images obtained from chest radiographs (Torwalt and Hoppa, 2005).

Many studies analyze the applicability of Hyrtl's law for sex determination from sternum. This law states that the mesosternum is greater than twice the length of the manubrium in males and in females the length of the manubrium is greater than half the length of the mesosternum (Bongiovanni and Spradley, 2012).

The modern cross-sectional imaging techniques have revolutionized forensic medicine. Virtual anthropology obtained by the three-dimensional (3D) imaging techniques such as computer tomography (CT) allow us to visualize almost every anatomical and pathological structure with a high resolution and quality (Benazzi et al., 2010).

The multi-slice computed tomography (MSCT) is becoming more and more widely used for post-mortem examinations (Dirnhofer et al., 2006). In certain cultural circles where conventional autopsy is stigmatized or even forbidden, virtual autopsy would allow sound medicolegal practice without violating religious prohibitions or personal reservations (Weber, 2001).

Computed tomography (CT), provides the opportunity for 3D imaging of the skeleton from scans during clinical examination of known individuals in situ (Decker et al., 2011). In addition CT allows investigation of anatomic regions that are not easily available by autopsy and allows fractures and inner organs to be seen "in situ. Also CT provides documentation in digital form (easily stored) which permits review by others and provides pictures that may be more suitable for presentation in court than autopsy photos (Leth, 2009).

Computed axial tomography is used for sex determination from different bones in different countries as first lumber vertebra (Zheng et al., 2012), the medial clavicular epiphysis (Kellinghaus et al., 2010), pubic bones (López- Alcaraz et al., 2013).

Computed axial tomography was used for sex determination from bones in Egyptian studies from different bones as mandible (Kharoshah et al., 2010), hand bones length (Eshak et al., 2011), metacarpal bones (Zaher et al., 2011), proximal end of femur (Mostafa et al., 2012), maxillary sinus (Amin and Hassan, 2012), pars petrosa of ossis temporalis of skull (Abd-elhakim et al., 2012).

Computed tomography was used for determination of sex from discrete traits of the sternum and ribs in different population such as in Bosnian (Kimmerle et al., 2008), in French (Verna et al. 2013) in Indian and (Changani et al., 2014).

Although there were a lot of articles about determination of sex from sternal measurements have been published abroad, the validity of these sternal measurements for sex determination of Upper Egyptians using computed axial tomography has not been investigated or published.

Aim of the Work

First, to investigate the possibility of sex determination from different sternal measurements of Upper Egypt population by MSCT. Second, to evaluate the significance of every part of sternal measurements and virtual sternal angles in sexual dimorphism. Third to formulate a model equation that can be used for sex determination from certain sternal measurements in unknown Upper Egypt individuals.

Subjects and Methods

Subjects

One hundred and sixty apparently healthy Upper Egypt individuals (80 were males and 80 were females) were included in this study in Assiut University Hospital after giving an informed consent. The individuals included in this prospective study were randomly selected from patients presenting at the radiodiagosis department for thorax CT investigation with various complaints between Jul. to Dec. 2013. Patients aged 18-80 years. Exclusion criteria include persons suffered from congenital or acquired sternal deformities, traumatic chest injuries and pathological diseases as emphysema, tumors, and cysts.

Methods

All MSCT examinations were obtained on a 16-MDCT (multidetector computed tomography) scanner (Bright Speed, General Electric Medical Systems, Milwaukee USA). A standard protocol was implemented for all MSCT examinations. Patients were scanned cranio-caudally from the thoracic inlet through the lung bases within a single breath-hold. The scans were obtained with 16×1 mm collimation and a table feed of 6 mm per 0.8 sec scanner rotation, which resulted in a beam pitch coefficient of 1.5.

Scanning was performed at 120 kV and 200 mAs/slice. The volumetric MDCT data were reconstructed into axial and MPR 0.625 mm-thick sections. Then, volume rendered shaded-surface display (SSD) images were generated and used for the presentation of the sternum and other osseous elements of the chest. Measurement of the distances and angles were done from the axial images as well as from the volume rendered SSD images using electronic cursors.

Morpho-Metric Image Analysis

Fourteen morpho-metric sternal measurements were used including the manubrium length, sternal body length, combined length of the manubrium and sternal body, sternal index, width of manubrium (base, waist and tip) and body width at levels of articulation with 2nd, 3rd, 4th, 5th and 6th ribs (Iscan, 1985, Torwalt et al. 2005 and Ramadan et al., 2010). The first (upper) and second (lower) sternal angles (Saldin, 2010). All sternal measurements were demonstrated in figure (1:a-b-c) which represents schematic diagrams of sternal dimensions.

1. Length of the manubrium (M): The longest distance from the midpoint of the manubrium and manubriosternal junction.
2. Length of the sternal body (B): The longest distance between manubriosternal junction and mesoxiphoid junction.
3. Combined length of the manubrium and body (CL): Sum of M and B (M + B).
4. Sternal index (SI): It is the division of M by B, then multiplied by 100 [(M/B) x 100].
5. Width of the manubrium waist, The manubrium width at the level of the line passing on the upper part of incisura costalis (notches or facets on the lateral edge of the sternum at point of articulation with the first costal cartilage).
6. Width of the manubrium base: The manubrium width at the level of the line passing on the lower part of right and left incisura costalis (notches or facets on the lateral edge of the sternum at point of articulation with the first costal cartilage.
7. Width of manubrium tip. Transverse distance of lower part of manubrium.
8. Width of sternal body at the level of midpoint of articulation with 2nd rib.
9. Width of the sternal body at the level of midpoint of articulation with 3rd rib.
10. Width of the sternal body at the level of midpoint of articulation with 4th rib.
11. Width of the sternal body at the level of midpoint of articulation with 5th rib.
12. Width of the sternal body at the level of midpoint of articulation with 6th rib.
13. First (upper) sternal angle was measured between two intersected virtual lines made along the lateral aspect of the upper part of the body of sternum and another line along the lateral aspect of the manubrium sterni.
14. Second (lower) sternal angle was measured between two virtual lines drawn along the lateral margins of the lower part of the body of the sternum and xiphisternum.

Ethical Consideration

This work was done after approval from the ethical committee of Faculty of Medicine, Assiut University. Informed consent was taken from all individuals participated in this study. Confidentiality of information obtained from all persons included in the study or excluded during CT examination as they required medical interference. Confidentiality was maintained by keeping the medical reports anonymous.

Statistical Analysis

The data collected were organized, tabulated, entered into a computer database program using SPSS (Statistical Package for the Social Sciences) software version 20. Results are expressed as minimum, maximum, mean ± standard deviation (SD). The student's t-test was used for independent samples to compare values between males and females. When p. value ≤=0.01 is highly significant, ≤=0.05 is significant and >0.05 is not significant. The relation between sex and each of sternal measurement in the known studied persons was analyzed by simple logistic regression analysis. The significance of all sternal measurements in the known studied persons and developing a model equation were done by using multivarite logistic regression. Negelkerke R square was used to determine correct percentage of sex prediction in unknown bodies. The expontial B (Odds ratio) was used to quantify the efficiency of each sternal measurements in sex determination in Upper Egyptians (Kirkwood and Sterner, 2003).

Results

Table (1) and figure (2): Show the mean, standard deviation (SD) and percentage of sex distributions among different age groups of the studied Upper Egyptian sample used in sternal measurements. The ages range between 18-80 years. The maximum percentage of cases were between > 40-60 years. The mean age of males is 46.21+3.4 years and that of females is 47.1+3.3 years.

Table (2): Shows student "t' test statistical analysis of sternal measurements of the studied Upper Egyptian sample by MSCT. The means of all sternal measurements were higher in males than females except the sterna index. There was a highly significant difference between males and females as regard the mean of manubrium length was (53.63±5.45 mm) in males and (48.92±4.29 mm) in females, sternal body length (110.00±11.70 mm) in males and (85.22±8.59 mm) in females, combined length of manubrium and sternal body (159.91±14.13 mm) in males and (134.25±9.16 mm) in females, sternal index (49.34±7.54) in males and (58.02±8.01) in females, width of manubrium base (63.33±6.16 mm) in males and (51.78±6.28 mm) in females, width of manubrium waist (61.84±8.36 mm) in males and (52.56± 8.58 mm) in females, width of sternal body at 2nd ribs (32.44±3.32 mm) in males and (25.67±3.74mm) in females, width of sternal body at 4th ribs (38.22±6.24 mm) in males and (34.08±6.73 mm) in females, width of the body at 6 th ribs (33.67+6.1 mm) in males and (27.06±5.7) in females, Angle 1 was (170.22±2.9°) in males and (163.7±5.7°) in females (P value ≤=0.01). There was a significant difference between males and females as regard the mean width of manubrium tip (30.33±6.46 mm) in males and (25.22±3.75 mm) in females, width of body at 3rd ribs (32.56±4.22 mm) in males and (27.89±3.26 mm) in females, width of the body at 5th ribs (36.92±5.64 mm) in males and (33.77± 6.43 mm) in females. Angle 2 was (34+5.1°) in males and (28.1+6.2°) in females (P value ≤=0.05).

Table (3): Shows discriminant function equations and cross-validated classification accuracies for sternal measurements of the studied Upper Egyptians. The correct percentage of sex prediction by multivariate logistic regression 92.3% in males and 93.7% in females and 93.3% of overall sex percent.

Table (4): Shows the multivariate logistic regression to predict sex from all sternal measurements in studied Upper Egyptian sample. Significance was found with manubrium length, body length, combined length, width of manubrium waist, width of body at 4th rib, width of body at 6th rib and angle 2. The obtained model formula Sex=51.64-1.55 length manubrium – 1.48 length body + 1.26 combined length – 0.15 width of manubrium waist - 0.113 width of sternal body at 4th ribs – 0.23 width of body at 6th ribs – 0.14angle2.

Table (5): Shows the correct percentage of sex prediction from sternal measurements by multivariate logistic regression in unknown Upper Egyptians. The model equation gives over all 85.4% correct percentage in unknown bodies.

Table (6) and figure (3): Show the percentage for the significant sternal measurements in the studied Upper Egyptian sample using simple logistic regression equation. The combined manubrium and body length represented the highest significant parameter which represented 92% in males, 92.4% in females, and 92.2% of total followed by manubrium waist width which 90.7% in males, 91.6% in females, and 89.9% of total.

Table (7): Shows equation for sex determination for every significant parameter of sternal measurements in studied Upper Egyptian population. Sex can be determined by the following equations. 11.7-21x Manubrium length, 20.6-0.21x Body length, 8.4-0.34 x Combined (M+B) length, (22.1-0.18 x Width manubrium waist), (18.7-0.18 x Width of sternal body at 4th rib), (20.1-0.21 x Width of body at 6 th rib), (23.4-0.16 Second sternal angle). The most significant is combined manubrium and body length where Exp. (B) is 0.911 then Width of sternal body at level of 4th rib where Exp. (B) is 0.857.

Figure (4): Shows photographs of sternum belongs to Upper Egyptian males in different age groups by MSCT.

Figure (5): Shows the photograps of females sternum in different age groups by MSCT.

Model equation

Sex=51.64-1.55x manubrium length – 1.48 body length ± 1.26 x combined (M+B) length - 0.15x width of manubrium waist - 0.113 x width of the body at 4th ribs – 0.23 x width of the body at 6th ribs – 0.14 x lower (second) sternal angle Exp. = Exponential

Table (1): Mean, standard deviation (SD) and percentage of sex distribution among different age groups of the studied Upper Egyptian sample.

Age Groups	Sex distribution					
	Males			Females		
	No.	%	Mean±SD	No.	%	Mean±SD
18-20Y.	3	3.75	19.3 ± 0.5	3	3.75	19 ± 0.8
>20-30 Y.	8	10	24.6±3.9	7	8.75	26.8±3.3
>30-40 Y.	12	15	35.9±3.2	12	15	36.5±3.2
>40-50 Y.	17	21.25	46.16±3.1	18	22.5	45.8±3.4
>50-60 Y.	18	22.5	55.53±2.8	19	23.75	56.2±3.1
>60-70 Y.	13	16.255	65.9±3.6	15	18.75	67.1±3.6
>70-80 Y.	9	11.25	76.4±3.5	6	7.5	77.4±3.2
Total	80	100.0	46.25±3.5	80	100.0	47.1±3.3

Table (2): Student "t" test statistical analysis of sternal measurements of the studied Upper Egyptian sample by MSCT.

Sternal measurements	Males	Females	t. value	P. value
	Mean ± SD (mm)	Mean ± SD (mm)		
Manubrium (M) length	53.63±5.45	48.92±4.29	6.76	<0.001**
Sternal body (B) length	110.00±11.70	85.22±8.59	15.22	<0.001**
Combined (M+B) length (Total length)	159.91±14.13	134.25±9.16	16.45	<0.001**
Sternal index	49.34±7.54	58.02±8.01	13.41	<0.001**
Manubrium base width	63.33±6.16	51.78±6.28	7.15	<0.001**
Manubrium waist width	61.84±8.36	52.56±8.58	6.94	<0.001**
Manubrium tip width	30.33±6.46	25.25 ±3.75	2.15	0.048*
Body width at 2th ribs	32.44±3.32	25.67±3.74	8.42	<0.001**
Body width at 3th ribs	32.56±4.22	27.89±3.26	2.41	0.018*
Body width at 4th ribs	38.22±6.24	34.08±6.73	5.45	<0.001**
Body width at 5th ribs	36.92±5.64	33.77±6.43	2.01	0.049*
Body width at 6th ribs	33.67±6.1	27.06±5.7	4.45	0.007**
Upper (1st) sternal angle (Rt+Lt)	170.22± 2.9	163.7±5.7	4.22	0.005**
Lower (2nd) sternal angle	34± 5.1	28.1±6.2	2.18	0.028*

*P. value ** ≤=0.01 highly significant, * ≤=0.05 significant, >0.05 not significant (Ns)*

Table (3): Discriminant function equations and cross-validated classification accuracies for sternal dimensions of the studied Upper Egyptian sample by MSCT.

Studied populations		Predicted Sex No.		Percentage Correct of equation
		Males	Females	
Observed	Males (n=80)	74	6	(92.3)
	Females (n=80)	5	75	(93.75)
Overall Percentage				(93)

Table (4): Multivariate logistic regression to predict sex from sternal dimensions of the studied Upper Egyptian sample by MSCT.

Sternal measurements	B	Exp. (B) (Odds ratio)	P. value
Manubrium (M) length	-1.550	1.092	0.000**
Sternal body (B) length	-1.480	1.279	0.001**
Combined (M+B) length or total length	1.256	3.513	0.000**
Width of manubrium base	-0.006	0.694	0.978
Width of manubrium waist	-0.150	1.981	0.019*
Width of manubrium tip	-0.019	0.661	0.897
Width of body at 2nd rib	-0.157	0.563	0.706
Width of body at 3rd rib	0.246	0.363	0.369
Width of body at 4th rib	-0.113	0.981	0.042*
Width of body at 5th rib	0.179	0.771	0.101
Width of body at 6th rib	-0.231	0.861	0.044*
Upper (1st) sternal angle (Rt+Lt)	-0.142	0.779	0. 493
Lower (2nd) sternal angle	0.088	1.092 **	0.022
Constant	51.638		0.001

*P. value ** ≤=0.01 highly significant, * ≤=0.05 significant, >0.05 not significant (Ns).*

Table (5): The correct percentage of sex prediction from sternal measurements by multivariate logistic regression in unknown Upper Egyptian persons by MSCT.

Model Summary		
-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
67.174	0.598	0.854 x 100

Sex prediction= Nagelkerke R Square x 100= 85.4%

Table (6): Simple logistic regression equation for the significant sternal measurements in the studied Upper Egyptian sample by MSCT.

Sex Vs.	Nagelkerke R Square	Predicted (Percentage Correct)		
		Male	Female	Total (%)
Manubrium length	0.768	88.6	87.6	88.1
Sternal body length	0.779	89.4	89.2	89.3
Combined (M+B) length (total length)	0.871	92	92.4	92.2
Manubrium waist width	0.857	90.8	91.2	91
Sternal body width at 4th ribs	0.847	90.2	91.4	90.8
Sternal body width at 6th ribs	0.817	90.1	91.2	90.6
Second sternal angle	0.812	89.8	91.1	90.4

Table (7): Equation for sex determination for the significant sternal measurements in studied Upper Egyptian sample by MSCT.

Parameters	Sig.	Exp. (B)	Equation (sex=)
Manubrium length	0.003	0.808	11.7-21 Manubrium length
Body length	0.005	0.815	20.6-0.21 Body length
Combined (M+B) length or total length	0.001	0.911	8.4-0.34 Combined (M+B) length
Manubrium waist width	0.031	0.764	22.1-0.18 Width manubrium waist
Body width at 4th rib	0.019	0.857	18.7-0.18 Width of body at 4th rib
Body width at 6th rib	0.041	0.521	20.1-0.21 Width of body at 6th rib
Second sternal angle	0.022	0.761	23.4-0.16 Second sternal angle

*P. value ** ≤=0.01 highly significant, * ≤=0.05 significant, >0.05 not significant (Ns).*

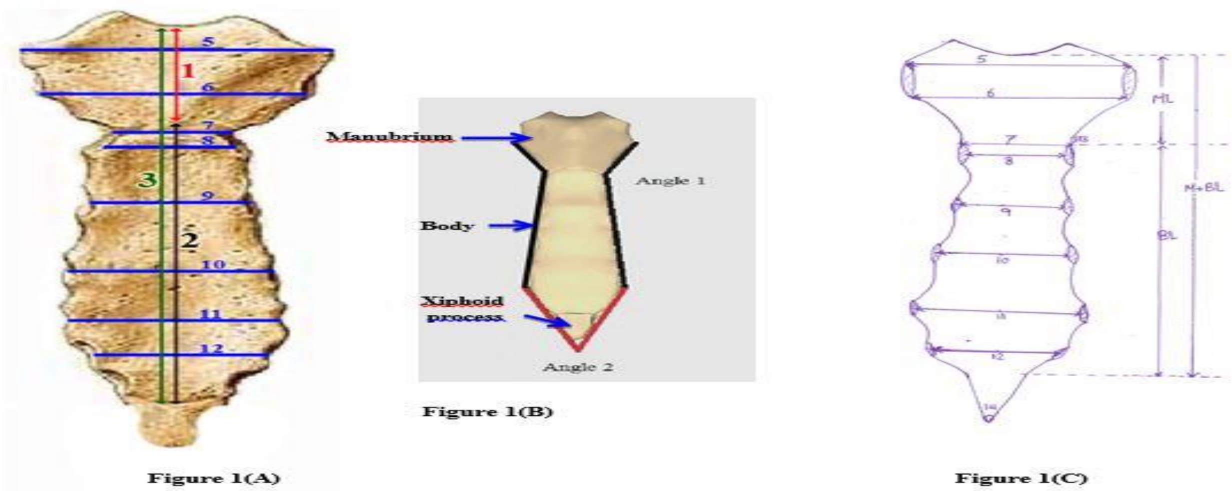

Figure 1 (a-b-c): Schematic diagrams of all sternal measurements(1) manibrium length (ML), (2) body length (BL), (3) combined manubrium and body length(M+B L), (4) sternal index [(M/B) x 100], (5) width of manubrium base, (6) width of manubrium waist, (7) width at tip of manubrium (8) width body at articulation of 2nd rib, (9) width body at articulation of 3rd rib, (10) width body at articulation of 4th rib, (11) width of body at articulation of 5th rib, (12) width body at articulation of 6th rib.(13) first or upper sternal angle (14) second or lower sternal angle.

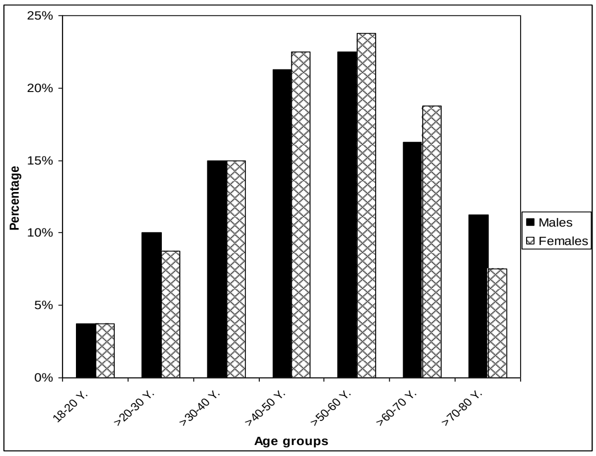

Figure (2): Shows the percentage of sex distribution among different age groups of the studied Upper Egyptian sample.

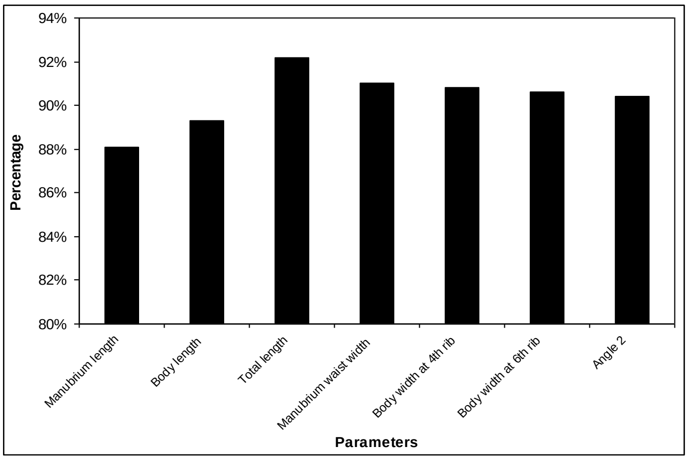

Figure (3): The percentage of the significant sternal measurements in studied Upper Egyptian sample by MSCT.

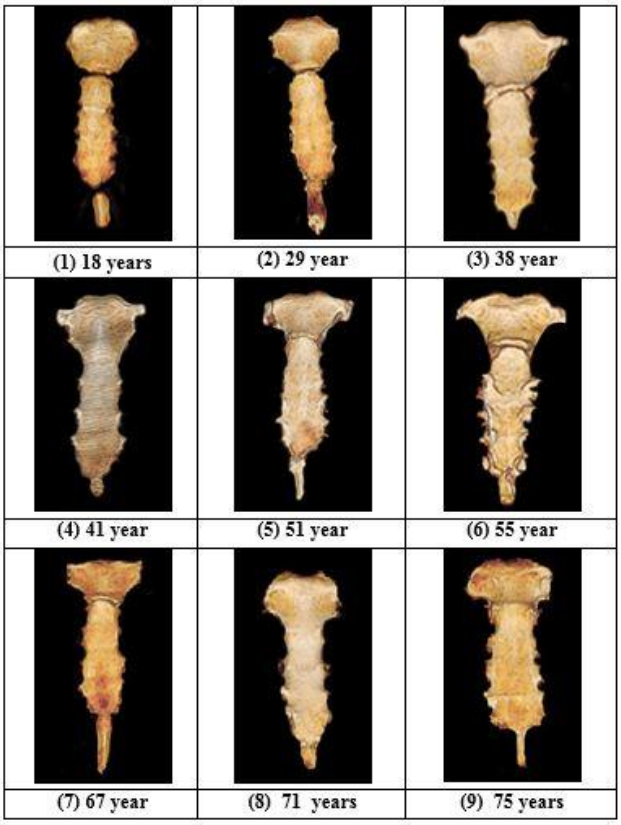

Figure (4): Photographs of sternum belongs to Upper Egyptian males of different ages by MSCT

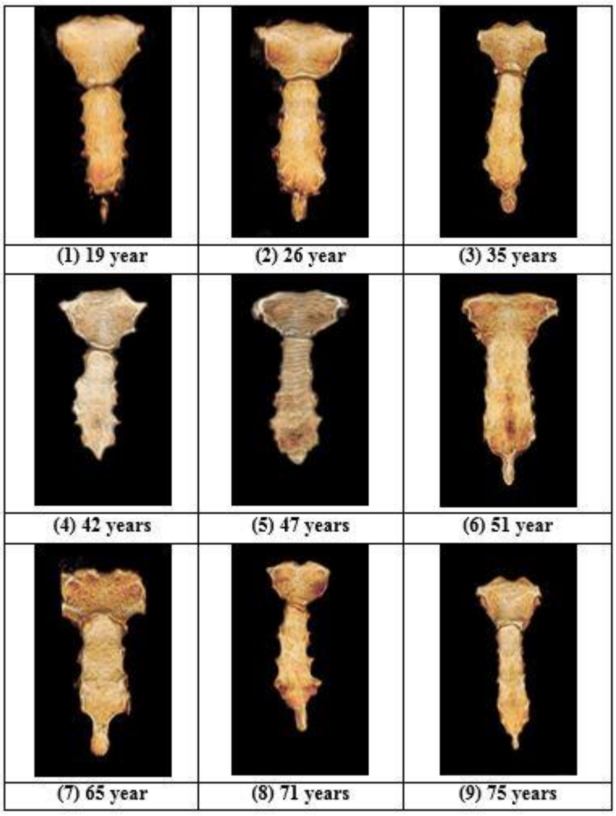

Figure (5): Photographs of sternum belongs to Upper Egyptian females of different ages by MSCT

Discussion

Proper personal identification of living or deceased persons is important in civil and criminal proceedings. The techniques of identifying an individual are varied and depend upon the circumstances of each particular case and whether a complete or dismembered body parts or only bones are available (Singh et al., 2012). Sex determination is an important process in establishing the identity of an individual. This can be helped by use of MSCT (Uthman et al., 2011).

The multidetector computed tomography can give rapid and accurate results in identification of victims in mass disasters and juridical reasons. It can be used effectively for analysis skeletal structures, provides clear unambiguous images in different areas without distortion or overlapping of other anatomical structures, capable of distinguishing finer details than conventional radiography and able to provide slice thickness down to 1mm or less (Sidler et al., 2007).

Discriminant function analysis of bone measurements has become important step in forensic anthropology. It is always used for sex determination from different bone measurements (Kranioti et al., 2009). Studies conducted so far have demonstrated that populations differ from one another in size and proportion. Therefore, the discriminant formulae developed for determining sex for one population group cannot be applied on another (Bongiovanni and Spradley 2012).

The present work investigated the possibility of determination of sex from various sternal measurements in known Upper Egypt sample population by MSCT. Then to develop equations for sex determination for unknown Upper Egyptians.

The results of the present work demonstrated that the manubrium length, sternal body length, manubrium width and combined length of manubrium and sternum were found to be larger in male than females. The sternal index is found to be significantly higher in females than males.

In harmony with results of the present work was study of Changani et al. (2014) for determination of sex from sternal measurements by CT in Indian population found that the manubrium length, sternal body length, manubrium width and combined length of manubrium and sternal body were found to be larger in male than females and the difference was statistically significant.

Also in agreement the results obtained by Osunwoke et al. (2010) who studied sexual dimorphism from sternum in Nigerian population. Similar results obtained by study of Ankit et al. (2013) in population of Saurashtra region in Indian.

The sternal index is derived by dividing the length of manubrium by the length of mesosternum and multiplying it by 100. In agreement with results of present work, the sternal index was found to be significantly higher in females (Hunnargi et al., 2009).

In the present study the combined length of manubrium and sternum was found to be the most accurate for determination of sex among all studied parameters which gives 92.2% by simple logistic regression equation.

Sex determination from sternal measurements in a Maharashtrian population of India demonstrated that the manubrium confirmed sex in 77.3% male and 77.5% female bones, the mesosternum confirmed sex in 73.3% male and 75% female bones accurately. The combined length of manubrium and mesosternum confirmed sex in 85.3% male and 77.5% female sternums correctly (Hunnargi et al., 2008).

In the present study the discriminant function equation and cross validated classification accuracies can predict sex in the studied Upper Egyptian population by (92.3%) in males and (93.75%) in females with average (93%).

In the present work the multivariate logistic regression equation to predict sex was 85.4% in unknown Upper Egyptian population.

The following multivariate logistic regression equation for sex prediction in unknown Upper Egyptian population.

Sex=51.64-1.55 Length manubrium – 1.48 length body + 1.26 total length -0.15 width manubrium waist-0.113 width body at 4th rib – 0.23 width body at 6th rib – 0.14 angle1.

Significant differences were noticed between the mean of sternal measurements measured directly on bone specimens in present study and those measured by CT scan images. Comparative analysis of sternal measurements showed higher sex accuracy in Indian population. The calculated multivariate DFA equation (y=-14.222+0.076MBL+0.137WS_1) and regression equation (y=36.675-0.198MBL-0.405WS_1) correctly estimated sex of 84.8% (males) and 89.8% (females sternums, respectively.

Multivariate analyses gave more striking results than the univariate ones. Although logistic regression analysis gave higher accuracy rates but discriminant function analysis was found to be a more reliable statistical tool for sex determination because of low sex biases (Singh and Pathak, 2013).

A study of sterna measurements in American (Black and American). The discriminate function analysis produced an overall cross-validation classification rate of 84.12% for sex estimation. The cross-validation classification rate for males and females was 80% and 88.24%, respectively (Bongiovanni and Spradley 2012).

In South Africa a stepwise discriminant function procedure, which selected corpus sterni length and manubrium width, correctly identified sex by 86.4% of the individuals in the study sample. Additional multivariate discriminant equations incorporating dimensions for either the manubrium or corpus sterni yielded sex prediction rates of 80.6% and 84.5%, respectively. Sternal area, when used in isolation, produced the highest sex classification accuracy with 86.9% of specimens correctly. The remaining single variable functions, which can be applied when well-preserved or complete sternum are not available for analysis, provided classification accuracies ranging from 68.4% to 83.5% (Macaluso, 2010).

A study of sexual dimorphism n Spanish population in which the sternal measurements were recorded from posteroanterior digital radiographs of the chest plate of living Spanish individuals. Results demonstrated that all linear dimensions of the manubrium and mesosternum, combined length, and sternal index were significantly sexually dimorphic in this population group. Discriminant function analyses incorporating several of these variables, individually or in combination, provided sex classification accuracy rates greater than 80.0%, with associated sex biases below 5.0%. A stepwise procedure, which can be used when a complete sternum is present, yielded the highest correct sex classification rate at 89.7% (Macaluso and Lucena, 2014).

Logistic regression analysis of measurements of the sternum and 4th rib width through thoracic radiograhs was undertaken to determine sex. Showed that sex was predicted at an accuracy of 95.8% for males and 90.3% for females (Torwalt and Hoppa, 2005)

In Australia, multislice spiral computed tomography) descriptive statistics and discriminant function analyses. The combined length of the manubrium and body, sternal body length, manubrium width, and corpus sterni width at first sternebra contribute significantly to sex discrimination and yield the smallest sex-biases. Cross-validated classification accuracies, i.e., univariate, stepwise and direct function, are 72.2-84.5% (Franklin et al., 2012).

In this study the multivariant logistic regression females showed a slightly greater tendency of being correctly classified. This was in agreement with the study of Singh et al. (2012) who reported that the females showed a slightly greater tendency of being correctly classified. DFA correctly classified bout 84% sternums (males =82.1%, females =89.0%) and on cross-validation, about 82.8% cases were correctly assigned to their correct sex. So, we can say that if an unknown sternum is encountered in any forensic situation, then its sex can be estimated with about 84% accuracy by placing the values of its measurements.

In the present work. The simple logistic regression equation for every significant parameter of sternal measurements in studied Upper Egyptian populations was done. The results revealed possibility of sex prediction from manubrium or body when they present separate. The manubrium length (88.1%), manubrium waist width (91%), sternal body measurements (body length (89.3%), total body and manubrium (92.2%), body width at 4th rib (90.8%), body width at 6th rib (90.6%), sternal angle 2 (90.4%).

The importance of the present study lies in the fact that this is the first study to report the use of sternal dimensions in sex determination in Upper Egyptian populations, by use of multislice computed tomography and to develop a model equation for sex prediction. Also the first study use the measured virtual sternal angles by MSCT. The use of sternum may be of value in cases of difficult identification as dismembered human remains which may be found in mass disasters and criminal mutilation is a difficult task for the medicolegal experts (Kanchan and Krishan, 2011).

Conclusions and recommendations

The different sternal measurements are reliable predictors for sexual dimorphism. The virtual sternal angles used in the study are of value in sex prediction. Although there is possibility of sex prediction if the manubrium or the body alone was available but the high percentage was obtained when the measurements were taken from the whole sternum. The model equation for sex estimation in Upper Egyptian population sample from sternal dimensions can be used by medicolegal physicians in living and dead, whether complete skeleton or dismembered remains related to chest regions are brought for forensic examination and can be accepted by law agencies. These equations should be applied only to Upper Egyptian population. The MSCT scanning is a very helpful tool for imaging the sternum and effective in sex identification.

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الملخص العربي

تحديد الجنس من قياسات عظمة القص لأهالى صعيد مصر باستخدام الأشعة المقطعية متعددة المقاطع

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تحديد الجنس يعتبر خطوة هامة في الإستعراف على الأشخاص و يمكن أن يتم ذلك من خلال فحص العظام اما بقياسها متريا مباشرا أو من خلال صورالأشعة خاصة فى حالات صعوبة الأستعراف كتقطيع الجثة والتشوهات والأنفجارات. هدفت هذه الدراسة إلى إمكانية تحديد نوع الجنس من قياسات عظمة القص باستخدام الأشعة المقطعية متعددة المقاطع وإنشاء معادلات احصائية للعلاقة بين نوع الجنس والقياسات المختلفة لعظمة القص لأهالى صعيد مصر. أجريت الدراسة على مائة وستون شخصا (٨٠ من الذكور و ٨٠ من الإناث) من أهالى صعيد مصر الأصحاء فى المراحل العمرية ١٨-٨٠ عاما بعد أخذ موافقتهم الواعية أثناء فحص منطقة الصدر لهم بالأشعة المقطعية متعددة المقاطع فى قسم الأشعة التشخيصية بمستشفى أسيوط الجامعى. استخدم أربعة عشرة قياسا لعظمة القص هى أطوال رأس عظمة القص وجسم عظمة القص ، ومجموع طول رأس وجسم عظمة القص ، ومعامل عظمة القص (حاصل قسمة طول الرأس على جسم عظمة القص X ١٠٠) ، وعرض رأس عظمة القص عند القمة والقاعدة وعرض جسم عظمة القص عند مستوى الضلوع الثانى، الثالث،الرابع، الخامس،السادس والزاويتن الأفتراضيتين لعظمة القص. الزاوية الأولى عند إلتقاء الخطين الافتراضيين المتقاطعين المارين بالجانب الوحشي للجزء العلوي من جسم عظمة القص والجانب الوحشي لرأس عظم القص. والزاوية الثانية عند إلتقاء الخطين الأفتراضين المارين بالجانبين الوحشين للجزء السفلي لجسم عظم القص والنتوء الغضروفى الخنجرى). و بتحليل البيانات احصائيا وجد أن القياسات أكبر و ذات دلالة احصائية فى الذكور عن الأناث ماعدا معامل عظمة القص. تم استخدام معادلات الانحدار المتعددة والبسيطة لمعرفة نسبة صحة ومعامل تأثير كل القياسات مجتمعة أو منفردة فى تحديد الجنس أن مجموع طول رأس وجسم عظمة القص مثل أعلى معامل تأثير وأعلى نسبة بين القياسات المختلفة لتتحديد الجنس. أظهرت معادلة الانحدار المتعددة أن التنبؤ بنوع الجنس من قياسات عظمة القص كان صحيحا بنسبة (٩٣٪) ٩٢,٣ ٪ للذكور و ٩٣,٧٪ للإناث لأهالى صعيد مصر المعروفين فى الدراسة . أثبتت المعادلة اللوجستية متعددة التغيرات أنه يمكن تحديد الجنس من قياسات عظمة القص بشكل صحيح فى لأهالى صعيد مصر مجهولى الهوية بنسبة ٨٥,٤٪ من قياسات عظمة القص . وخلصت هذه الدراسة إلى أنه يمكن إستخدام قياسات عظمة القص شاملة الزاويتن الأفتراضيتين لعظمة القص فى تحديد الجنس وأن أخذ القياسات بالأشعة المقطعية متعددة المقاطع هى طريقة موثوق بها ويمكن الأعتماد عليها تحديد الجنس من العظام فى الفحص الطبي الشرعي وتكون النسبة أفضل فى حالة توافر القياسات مجتمة لكل أجزاء عظمة القص عن وجود جزء بمفرده.

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