



Sternal morphometry comparison to chest measurements and using roentgenography

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Abstract

Objective: Studies such as this are conducted for the purposes of creating a forensic anthropology databank on age estimation and sex determination of skeletonized remains in Turkey.

Material and Method: 75 sternum bones were gathered for this study, 54 male and 21 female (mean age: 49 ± 17.12), all belonging Turkish individuals. There were significant differences on measurement values of sternum length on individuals in this study and indirectly in roentgenography. Besides measurements of sternum, chest circumference, chest front and back diameter, length and width values of both lungs were also measured.

Results: Measurements from radiographs and wet sternum samples were not very different. This means radiographs are good resource of information. The total length was found to be the best parameter among all the criteria and methods considered. The changes in the body proportions, nutritional, environmental, climatic changes etc, are attributable to secular changes in sternum measurements.

Conclusion: When determining biological identity of a dead body osteometric techniques gives best results. Because there may be some defects with radiographic methods. As there are other bones to determine the sex of the dead body, sternum also helps to predict the sex of the body.

Keywords: biological, body, comparison, measurements, anthropology

Introduction

Anthropometric studies that focused on skeletal structures have given important data for identification of individuals. To predict the sex of a dead body various skeletal elements should be used, since they can be source of information on post-mortem determinations. When the bones are highly destructed pelvic and cranio-facial morphometric studied give valuable information [1, 7]. There are different factors that may change the remains of skeletons, like accidents, natural causes etc. Those factors may slow down the investigations. There are also studies that claim pelvis and skull bones may not be reliable source for determining the sex of a dead body [3, 6]. But integrity of the sternum bone can be kept in many cases. Bongiovanni and Spradley [8] reported that condition levels of the manubrium and sternum were higher than 59% in the Forensic Anthropology Data Bank. Wenzel [9] brought some information about sexual dimorphism in the manubrium and sternum. He wrote that the length of the manubrium was nearly same in both sexes and the mesosternum was longer in male. So, the manubrium of the female sternum exceeds half the length of the body, and the body in the male sternum is at least twice as long as the manubrium description became known as Hyrtl law [10].

Morphometric analyses of the sternum may be conduct with dry bone direct measurements and also radiological methods during the post-mortem period [11, 21]. But radiological studies and morphometric analyses were also conducted in living individuals [22, 25]. In such studies some values of manubrium, mesosternum, and total sternum length, manubrium, sternabra 1, and sternabra 3 width, sternal area, and the sternal index (SI) were used. However there have been some method differences among the studies, morphometric analyses of sternum, usually give information

80% or greater accuracy [8, 24].

It has been more than thirty years that Jit *et al.* [26] stated in their study that sexual dimorphism in dry human sternums of the same heterogeneous population considered. Since the time of Jit *et al.* study [26], environment and nutritional conditions have changed and their standards to be applied are not useful today. There have been many changes along with body propotions, environmental and climatic factors. In this study we attempted to cover secular changes in sternal dimensions, and questioned their efficiency since 1980, and apply the data on the population today. The sample drawn from different states considered as one population sample by Jit *et al.* [26] based on their similarity in morphometric physical dimensions and body proportions [26, 27] and similar dietary patterns.

Material and Method

This study was performed on 75 Turkish adult who have been in the Radiology Department of Meram Faculty of Medicine, Necmettin Erbakan University for radiological investigations. It has been approved by ethical committee of Necmettin Erbakan University according to Copenhagen criteria (2019/212). Individuals that had any anomaly on their chest were not included in the study. They were chosen randomly from the group and informed written consent was gathered from each of them. Before the scanning, body measurements of individuals were recorded by the forensic age estimation expert.

75 chests were examined on the anterior view to detect;

1. Sternal length: The length between the top end and bottom end of the sternum
2. Chest circumference: Circumference measurement of chest by the nipple line
3. Chest front and back diameter: Maximum front and

- back diameter of chest
- 4. Lung width: Width of the lung measured from the widest part
- 5. Lung length: Maximum length of lung.

Statistical analysis

The data obtained from the study was analyzed by using Statistical Package for Social Sciences (SPSS/version 17) software.

Results were expressed in the form of arithmetic mean and standard deviation. Pearson Correlation Coefficient test was performed for correlation between parameters.

Result

75 adult Turkish individuals were included in the study. Their ages varied from 18 to 83. The age of male individuals ranged from 18 to 83 years with a mean of 46.51

± 16.91, and the age of female individuals ranged from 20 to 74 years with a mean of 45.11 ± 12.74. There was no significant difference between both sexes related to the age, where t: 0.52 and P: 0.75.

It has been shown on Table 1 that all sternal measurements such as sternum length (physical and radiographical) were significantly higher in males than in females (P :< 0.001).

All the values have been found to be higher on male individuals, excluding chest front - back diameter, chest circumference, right lung width and left lung length, shown in Table 1.

Mean, standard deviation (SD), minimum and maximum values of the measurements were shown in Table 2.

Correlation coefficient test has been performed to show correlation between parameters and r values has been shown in Table 3.

Table 1: Comparison of the measurements related to sternum according to sex (female-male) (n: 54 male, n: 21 female) (cm).

Parameter	Male			Female			t	P
	n	Mean	SD	n	Mean	SD		
Radiograph	54	21,05	1,78	21	19,47	1,74	,001	,999
Physical	54	20,59	2,39	21	20,02	2,44	,369	,824
Chest front-back diameter	54	22,97	2,55	21	25,33	3,60	,010	,147
Chest circumference	54	94,16	7,68	21	96,76	10,54	,244	,531
Right lung width	54	11,17	1,55	21	13,11	1,83	,001	,732
Right lung length	54	23,12	2,35	21	21,01	2,76	,361	,814
Left lung width	54	19,80	1,18	21	19,01	2,18	,003	,201
Left lung length	54	22,01	24,01	21	22,04	2,83	,313	,312

Table 2: Mean-SD, minimum and maximum values of parameters related to sternum (n: 54 male, n: 21 female) (cm)

Parameter	n	Mean	SD	Minimum	Maximum
Physical	75	20,43	2,40	15,50	26,50
Radiograph	75	20,61	1,90	16,00	25,00
Chest circumference	75	94,89	8,60	74,00	116,00
Chest front-back diameter	75	23,64	3,06	17,00	32,00
Right lung width	75	10,78	2,07	7,00	24,00
Right lung length	75	21,86	3,17	11,50	30,50
Left lung width	75	9,61	2,03	8,29	22,15
Left lung length	75	19,18	2,01	10,25	28,50

Table 3: Correlation coefficient r between the sternal anthropometric measurements

	Physical	Radiograph	Chest circumference	Chest front-back diameter	Right lung width	Right lung length	Left lung width	Left lung length
Physical								
Radiograph	0,319							
Chest circumference	-0,084	0,195						
Chest front-back diameter	0,035	0,064	0,796**					
Right lung width	0,124	-0,012	-0,070	-0,056				
Right lung length	0,423	0,494**	-0,191	-0,318	0,002			
Left lung width	0,121	-0,011	0,060	-0,043	0,001	0,003		
Left lung length	0,324	0,322	0,180	-0,224	0,002	0,002	0,001	

Discussion

Morphometric analyses of various bones by direct measurements from skeletal remains or radiological methods are the basic anthropological traits for sex prediction. Trauma, putrefaction, and disappearance for various reasons are the main reason that prevents to obtain bones with high integrity [3, 6].

In these circumstances, data collected from a single bone can be important for sex prediction. In the literature, studies on pelvic bones give 95% accurate information for sex prediction [7, 28]. Morphometric parameters of the

craniofacial region also give accurate results [29, 33].

The accuracy was found to be as 80% on female and on 74.3% for male, with an overall level of 77.15% for the morphometric analysis of maxillary sinuses in a Turkish population [29]. Especially terrorist attacks may cause mass mortality. In this kind of situations the speed of identification has more importance. Also if mass graves investigations are taken into consideration, single preserved bone pieces in disintegrated skeletons could give a fast classification in disaster victims' identification (DVI) [34, 35]. Sternum bone has a solid structure and its preserved

integrity is the main bony structural advantages. As identified in our study, sternum may give over 80% sex discrimination properties. Fast and easy CT scanning of preserved single bony parts “like sternum” may make it possible an efficient identification method for researchers on the field [35].

Discrimination analysis with the sternal measurement parameter is an accurate method for sex prediction. Studies used direct discrimination analysis and different combinations of analysis methods for measurement data. Maculoso and Lucena [20] researched a Spanish population and showed a stepwise analysis of 5 linear dimensions. ML (corpus sterni length), manubrium width, CSWS1 (corpus sterni width at first sternebra), and CSWS3 (corpus sterni width at third sternebra), gave a sex prediction with 89.7% success. For the manubrium, both length and breadth measurements were selected in the step-wise analysis, providing a sex prediction accuracy of 87.1%. Franklin *et al.* [23] in their Western Australia study combined the length of the manubrium, body, and corpus sterni width at the first sternebra; the accuracy of sex prediction was 84.5%. Morphometric dry bone or sternum imaging studies have reported 80% to 90% accuracy with combined analyses of multiple parameters [8, 11, 13, 20, 24]. We obtained highest accuracy rate in the step-wise 1 (ML, MSL, SIW, S3W) discrimination analysis; 86.1% for females and 83.8% for males, and accuracy was greater than 80% after 3 step-wise discrimination analyses for both sexes like in the study of Ramadan *et al.* [22]. We used 6 combinations in our study. Ramadan *et al.* [22] stated 81.8% to 88.2% accuracy. Despite the differences between the combinations, the accuracy levels for Turkish populations were similar in both studies.

Analyses of direct measurement can be done on skeletal remains; but it is not possible every time [2, 6]. The high number of clinical diagnostic importance of radiological methods caused the existence of variety of images. CT and MRI methods help to get high resolution images, which also help to make three-dimensional models. The properties may bring detailed information for morphometric studies. The Royal College of Radiologists stated an increase of 26.5% in numbers of radiological images compared with 2004/2005. They stated an 86% increase in use of CT and a 125% increase in MRI [36]. Based on the increased numbers of radiology-based studies and appropriate analyses, we think other bones like sternum may also be helpful for forensic anthropologic evaluations.

Sexual dimorphism on human sternum were extensively examined by evaluating both its metric and non-metric features [8, 11, 12, 13, 17, 22, 23, 25, 26, 37, 45, 46], but the metric analysis is more objective, reproducible / duplicable, statistically analyzable, and yields more reliable identification of the deceased even from fragmentary remains [37, 22, 47, 48]. Some people used the individual or the combined lengths of sternum for sex determination, and others devised the demarking and limiting points or have calculated discriminant functions or regression equations based on the metric measurements of sternum. Different criteria and variables have been selectively/arbitrarily used by different people for taking measurements, either directly on the bone specimens or indirectly on the radiographic or computed-tomographic images of the thoracic region housing the sternum.

Macalusa [11], Bongiovanni and Spradley [8] used some bones in their studies. Results from Singh *et al.* study were

on fresh wet sternums, and Franklin *et al.* [23] and other Indian researchers [12, 13, 17, 26, 42, 45] studied dry sternum bones from dead bodies.

Considering the two discriminating points (demarking and limiting points) sternal area and combined length were better parameters to define sex. So these points, especially demarking points, were not thought to be an accurate source for sex prediction. And limiting points had better sex prediction rates. Also these results were in the same course with other studies [12, 17, 39, 42, 45].

Singh *et al.* [15] reported that success rate of 87 % on male and 79 % on female determining sex by using limiting points of combined length, and sternums used to determine sex with 93 % success on male and 69 % success on female by limiting point of sternum. The maximum sex bias was found for manubrio-corpus index (-39.0), also by the sternal area (23.5) and the first sternubrial width (12.5).

The limiting points of the combined length of the sternum was the better sex determining variable than that of the individual manubrial or mesosternal values, that is also in agreement with the findings of Hunnargi *et al.* [12].

Jit *et al.* [26] approximately 85% male individuals and 89% female individuals determined sexes of individuals from the multivariate discriminant function analysis (DFA) of seven sternal dimensions and indices in a North Indian heterogeneous population in their study. The stepwise multivariate DFA and logistic regression analysis (LRA) of all the parameters gave successful sex determination rate of 84.8% (81.7% male individuals and 93.4% female individuals) and 89.8% (94.0% male individuals and 78% female individuals). However, these findings are in the same course with study of Jit *et al.* [26], they bring secular trends in various sternal measurements and their sex determining efficiency. More than 80% sternum bones were accurately sex determined in each of the multivariate function where mesosternal length was used as a variable (Functions III-5). In the same manner, in all the multivariate logistic regression functions, more than 80% sternums were accurately sex determined. The ‘major’ sternum lengths (M.B. and MBL) accurately sex determined with the rate of 83.7% (81.3% on male and 90.1% on female) and 85.1% (93.3% males and 62.6% females) sternums from DFA and LRA, respectively. The width values of the transverse manubrial or sternubrial were the least reliable predictors of sex. In a present Turkish sample [22], 88% male and 80% female sternums were accurately sex determined by the help of LRA. The Macaluso [11] study stated an overall accuracy of about 86% and 90.8% from the stepwise discriminant function analysis and LRA, respectively (with sex biases ranging from 4.7% to 13.8%). The accuracy levels of the study by Singh *et al.* (15) were close to the other studies [8, 11, 12, 13, 17, 22, 23, 26, 37, 38, 42, 45] and the functions/measurements stated here are sufficient for sex classification of unknown samples. So, sternum may be a valuable adjunct for sexing the sternums of Chandigarh region of North India with maximum accuracy levels varying from 90% to 85% from multivariate DFA and LRA of sternal measurements, respectively. In the Singh’s studies, DFA was found to have a sex bias in favor of the male individuals whereas it was found biased toward the females in LRA. This can be caused by the difference in the sample size of the two sexes. The sex biases were bigger for the univariate functions than the multivariate ones, which was close to the results yielded with the earlier studies [11, 22]. Since, the statistical standards

and/or techniques with unacceptably bigger sex biases have limited forensic importance^[23], multivariate analyses with least sex biases are suggested for reliable success rate of sex determination.

High number of antro-morphometric studies conducted on different people may yield valuable data. CT scan is a useful application to analyze bone morphometry of living individuals. And if pelvic bones or the skull is somehow highly damaged forensic experts and anthropologists may use sternum bone for sex determination of the deceased in their studies.

Reference

- Ekizoğlu O, Hocaoğlu E, İnci E, Bilgili MG, Solmaz D, Erdil I. *et al.* Sex estimation from sternal measurements using multidetector computed tomography. *Medicine*. 2014; 93(27):1-5.
- Krogman WM, İşcan MY. *The Human Skeleton in Forensic Medicine*. 2 nd edn. Springfield, IL: Charles C. Thomas Publishing, 1986.
- Byers SN. *Introduction to Forensic Anthropology: A textbook* Boston: Allyn and Bacon 2002.
- Bass WM. *Human Osteology. A Laboratory and Field Manual* 5 th edn. Columbia: Missouri Archaeological Society, 2005.
- Spradley MK, Jantz RL. Sex estimation in forensic anthropology: skull versus postcranial elements. *J Forensic Sci*. 2011; 56:289-296.
- Haglund WD, Song MH. *Advances in Forensic Taphonomy: Method, Theory and Archaeological Perspective* New York: CRC Press, 2002.
- Phenice TW. A newly developed visual method of sexing the Os pubis. *Am J Phys Anthropol*. 1969; 30:297-301.
- Bongiovanni R, Spradley MK. Estimating sex of the human skeleton based on metrics of the sternum. *Forensic Sci Int*. 2012; 219:2901-2907.
- Wenzel J, cited by Ashley GT. A comparison of human and anthropoid mesosterna. *Am Phys Anthropol*. 1956; 14:449-465.
- Hyrtil J. Cited by Dwight T. The sternum as an index of sex, height and age. *J Anat Physiol*. 1881; 15:327-330.
- Macaluso PJ Jr. The efficacy of sternal measurements for sex estimation in South African blacks. *Forensic Sci Int*. 2010; 202:111e1-111e7.
- Hunnargi SA, Menezes RG, Kanchan T. Sexual dimorphism of the human sternum in a Maharashtrian population of India: a morphometric analysis. *Leg Med*. 2008; 10:6-10.
- Mukhopadhyay PP. Determination of sex from adult sternum by discriminant function analysis on autopsy sample of Indian Bengali populations a new approach. *J Indian Acad Forensic Med*. 2010; 34:321-324.
- Singh J, Pathag RK, Singh D. Morphometric sex determination from various sternal widths of Northwest Indian sternums collected from autopsy cadavers: a comparison of sexing methods. *Egypt J Forensic Sci* 2012 doi: 10.1016 / j.ejfs, 2011; 12:002.
- Singh J, Pathag RK. Morphometric sexual dimorphism of human sternum in a North Indian autopsy sample: sexing efficacy of different statistical techniques and a comparison with other sexing methods. *Forensic Sci Int*. 2013; 228:174e1-174e10.
- Menezes RG, Kanchan T, Kumar GP. Stature estimation from the length of the sternum in South Indian males: a preliminary study. *J Forensic Leg Med*. 2009; 16:441-443.
- Dahiphale VP, Baheete BH, Kamkhetkar SG. Sexing the human sternum in Marathwada region. *J Anat Soc India*. 2002; 51:162-167.
- Fernandez ED, Saez AS, Moro JI. Anthropological determination of sex by studying the sternum. *Rev Esc de Med Leg*. 2007; 6:27-42.
- Marinho L, Almeida D, Santos A, Cardoso HFV. Is the length of the sternum reliable for estimating adult stature? A pilot study using fresh sterna and a test of two methods using dry sterna. *J Forensic Sci*. 2012; 220:292e1-292e4.
- Macaluso PJ jr, Lucena J. Estimation of sex from sternal dimensions derived from chest plate radiographs in contemporary spaniards. *Int J Legal Med*. 2013; 128:389-395.
- Torwalt CRMM, Hoppa RD. A test of sex determination from measurements of chest radiographs. *J Forensic Sci*. 2005; 50:785-790.
- Ramadan SU, Türkmen N, Dolgun NA. Sex determination from measurements of the sternum and fourth rib using multislice computed tomography of the chest. *Forensic Sci Int*. 2010; 197:120e1-120e5.
- Franklin D, Flavel A, Kulukas A. Estimation of sex from sternal measurements in a Western Australian population. *Forensic Sci Int*. 2012; 217:230e1-230e5.
- Franklin D, Cardini A, Flavel A, Kulukas A. The application of traditional and geometric morphometric analyses for forensic quantification of sexual dimorphism: preliminary investigations in a Western Australian population. *Int J Legal Med*. 2012; 126:549-558.
- Osunwoke EA, Gwunireama IU, Orish CN. A study of sexual dimorphism of the human sternum in the Southern Nigerian population. *J Appl Biosci*. 2010; 26:1636-1639.
- Jit I, Jhingan V, Kulkarni M. Sexing the human sternum. *Am j Phys Anthropol*. 1980; 53:217-224.
- Bowles GS. *The people of Asia*, Weidenfield and Nicolson, London, 1977.
- Sutherland L, Suchey J. Use of the ventral arc in pubic sex determination. *J Forensic Sci*. 1991; 36:501-511.
- Ekizoğlu O, İnce E, Hocaoğlu E. The use of maksillary sinus dimensions in gender determination: a thin slice multidetector computed tomography assisted morphometric study. *J Craniofac Surg*. 2014; 25:957-960.
- Cameriere R, Ferrante I, Mirtella D. Frontal sinuses for identification: quality of classifications, possible error and potential corrections. *J Forensic Sci*. 2005; 50:1-4.
- Emirzeoğlu M, Şahin B, Bilgiç S. Volumetric evaluation of the paranasal sinuses in normal subjects using computer tomography images: a stereological study. *Auris Nasus Larynx*. 2007; 34:191-195.
- Fernandes CL. Forensic ethnic identification of crania. The role of the maksillary sinus – a new approach. *Am J Forensic Med Pathol*. 2004; 25:302-313.
- Deshmukh AG, Deversh DB. Comparison of cranial sex determination by univariate and multivariate analysis. *J Anat Soc India*. 2006; 55:1.
- Morgan O. *Management of dead bodies after disasters: A field manual for first responder* Washington. DC:

- PAHO, 2006.
35. Sidler M, Jackowski C, Dirnhofer R. Use of multislice computed tomography in disaster victim identification – advantages and limitations. *Forensic Sci Int.* 2007; 169:118-128.
 36. The Royal College of Radiologists. Investing in the clinical radiology workforce–The quality and efficiency case, 2012.
 37. Accessed date: April 11, 2014. [https://www.ror.ac.uk/does/radiology/pdf/RCR – CRW workforce – june 2012. Pdf](https://www.ror.ac.uk/does/radiology/pdf/RCR-CRW_workforce-june2012.Pdf)
 38. Mc Cormick WF, Stewart JH, Langford LA. Sex determination from chest plate roentgenograms. *Am J Phys Anthropol.* 1985; 68:173-195.
 39. Torwalt CRRM, Hoppa RD. A test of sex determination from chest plate radiographs. *J Forensic Sci.* 2005; 50:785-790.
 40. Ashley GT. Typing of the human sternum: the influence of age and sex on its measurements. *J Forensic Med.* 1956; 3:27-43.
 41. Rother P, Hunger H, Liebert U, Seidermann D. Sex differences in the human sternum. *Gegenbaurs Morphol. Jahrb.* 1975; 121:29-37.
 42. Selthofer R, Nicolic V, Mrcela T, Radic R, Leksan I, Rudez I. *et al.* Morphometric analysis of the sternum. *Coll Anthropol.* 2006; 30:43-47.
 43. Atal DK, Murari A, Rani Y, Naik SK. Sex differentiation from sternum: a postmortem metric study. *Int J Med Toxicol Leg Med.* 2008; 11:53-58.
 44. Atal DK, Murari A, Naik SK. Sex differentiation from sternal width. *J Ind Acad Forensic Med.* 2009; 30:198-201.
 45. Hunnargi SA, Menezes RG, Kanchan T, Lobo SW, Binu VS, Uysal S. *et al.* Sternal index: is it a reliable indicator of sex in the Maharashtra population of India? *J Forensic Leg Med.* 2009; 16:56-58.
 46. Mahajan A, Batra APS, Khurana BS, Sharma SS. Sex determination of human sterna in North Indians. *J Punjab Acad Forensic Med Toxicol.* 2009; 9:12-15.
 47. Sun YX, Zhao GC, Yang W. Age estimation on the female sternum by quantification theory I and stepwise regression analysis. *Forensic Sci Int.* 1995; 74:57-62.
 48. Dibennardo R, Taylor JV. Multiple discriminant function analysis of sex and race in the postcranial skeleton. *Am J Phys Forensic Med.* 2010; 32:321-324.
 49. Garpert R, Black S, Last J. Sex determination from occipital condyle: discriminant function analysis in a eighteenth and nineteenth century British sample. *Am Phys Anthropol.* 2009; 138:384-394.