Rom J Leg Med [26] 56-61 [2018]
DOI: 10.4323/rjlm.2018.56

Estimation of age and sex from bimastoid breadth with 3D computed tomography

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Abstract: One of the main steps of identification process defining the individual in forensic medicine practice is age and sex determination. The aim of this study is to investigate the possibility of age and sex determination through bimastoid breadth measurement in cases where the cranium can be reached. In the study, the bimastoid breadth measurements were evaluated for 300 male and 300 female cases in 20-50 age group whose cranial computed tomography images were taken. First, length measurement was made in coronal plane on three-dimensional reconstructed computed tomography images. Then, through the measurement of the same length in the axial plane and in two-dimensional coronal plane, the verification was made for the values obtained before. These measurements made were also verified with the same three-staged verification by radiodiagnostic specialist.

After determining exact measurement value, data was evaluated for the determination of sex differences. A statistically significant difference was detected for both sexes among the age groups in the study. Accuracy rates obtained by single discrimination analysis for the measured values were detected as 82.7% in females and 80% in males. A significant change was not detected in mastoid dimension with the advancing age on the examined population.

As a result, while the morphometric measurements of bimastoid breadth provide a high ratio of dimorphism for sex determination in the modern Turkish population, there is no significant dimorphism for age determination. The obtained data demonstrates the importance of modern radiological methods and anthropometric studies in presenting anthropological data for age and sex determination.

Key Words: identification, age estimation, sex estimation, mastoid, 3D computed tomography.

INTRODUCTION

Two of the most important parameters for identification both in forensic and archaeological cases are age and sex determination. In forensic practice, there are conditions in which the body unity is harmed and the victims cannot be recognized and identification is not possible through physical characteristics in mass deaths such as natural disasters and plane crashes or examination of remains in mass graves. Hemogenetic or odontological methods are primarily used in such conditions [1-6]. But in accordance with the conditions and the state of the material, molecular genetic methods cannot be studied or a regular dental record is not available for the individuals who are wanted to be identified. In addition, due to the war in Syria and the Middle East, intensive refugee immigration to Europe has been experienced in recent years. Due to the fact that these persons are not registered with the databases in the judicial systems, the importance of alternative identification methods has increased in recent years [7]. In similar conditions where primary identification methods cannot be used, practical

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and cost-efficient anthropometric methods with high accuracy rate are applied. In conditions where the bodies of the individuals were damaged extensively and the unity of the bodies was harmed, identification is aimed through using present body and bone pieces.

Identification studies made by using radio diagnostic imaging for body and skeletal remains and metric measurement methods for osseous structures constitute one of the most interesting new methods in this field [8-14]. Osteometric measurements made with radiological methods has many advantages such as not requiring the cleaning of the bones, not being a bone-destructuring operation and being more practical and applicable than many other identification methods [11, 15].

Cranium is the most convenient body part for age and sex determination through morphological and anthropometric methods after pelvis. The change caused by the involvement of muscle mass increased by puberty in cranial bones in males and the preservation of juvenile characteristics in females cause the high sexual dimorphism of the cranium [16-18].

In researches about determination of age and sex through cranial metric measurements, many parameters were studied such as; cranium maximum length or width, biorbital width, interorbital distance, bizygomatic breadth, nasion-prosthion height, nose width or height, mastoid height, dimensions of mastoid process, bimastoid breadth, foramen magnum maximum length or width and maxillary sinus or frontal sinus measurements [19-28]. The important point here is being able to make analysis on present bones even in conditions where body unity is damaged. Mastoid bone is also rather suitable for age and sex determination studies as it mostly stands even the body decomposition since it is rather resistant to traumas with its anatomic position and compact structure [29].

The aim of this study was to present the usability of bimastoid breadth value obtained by 3D reconstructed cranial CT image for age and sex determination.

MATERIAL AND METHODS

Cranial CT images of a total of 600 people including 300 males and 300 females between the ages of 20 and 50 taken in Dokuz Eylül University Faculty of Medicine Radiodiagnostic Department for different indications between 2012 and 2015 were examined in the study. There were 50 females and 50 males in every group in the sampling separated into six groups with a difference of 5 years in each. To prevent the non-proportional concentration between the age ranges and the related low reliability, it was tried to examine the images of an equal number of males and females from all ages.

All demographically information such as age and sex were obtained from legal hospital records for the individuals evaluated. Not to affect measurement standard and analysis results, cases that had cranial pathology, cranial surgery or any acute or chronic diseases to cause osseous lesion were not included in the study.

All cranial CT images evaluated were obtained from a high-resolution computed tomography device with 120-140 kVp and 162-183 mA technical specifications and slices thickness between 0.67-1 mm. In three-dimensional images obtained through reconstruction, the breadth was measured between the end points of "mastoid process" section of both mastoid bones in the rear face of the cranium in coronal plane and the value found was millimetric recorded (Fig. 1). For the measurement reliability, this value detected was verified with the measurement of the same 3 dimensional reconstructed cranium image in axial plane from below (Fig. 2) and its measurement made in coronal plane in 2 dimensional imaging (Fig. 3) .

The obtained measurement values were evaluated with “Statistical Package for the Social Science (SPSS) for Windows 21.0” package program. Independent student's t-test was used to defined the significance of the metric difference among sexes ($p<0.05$). Discriminant function analysis was made for being able to determine

Figure 1. Bimastoid breadth measurement from the rear in coronal plane in 3 dimensional imaging.

Figure 2. Bimastoid breadth measurement from the below in axial plane in 3 dimensional imaging.

Figure 3. Bimastoid breadth measurement in coronal plane in 2 dimensional imaging.

sex and sectioning point was determined in the table obtained and discriminant function formula was formed. Accuracy rate values were also detected for the obtained measurements in order to be able to make a percentage classification. For age determination analyses, One-way ANOVA test was applied to the values obtained from both sexes and the significance was evaluated among age groups.

RESULTS

Mean age of the population in the study was detected as 35.49±8.64 for the whole population; as 35.43±8.61 for male cases and as 35.56±8.68 for the female cases.

According to the F-ratio value obtained in the statistical significance evaluation of the difference between sexes, a significant difference was detected among sexes. In bimastoid breadth measurements according to sex, it was detected that, mean measurement values in males were higher than mean measurement values in females. Mean bimastoid breadth was detected as 108.53±4.38 mm in males and 100.82±4.19 mm in females (Table 1).

Data for the discriminant function analysis of the measurement used and canonical discriminant coefficient values are available in Table 2. Wilks' lambda value shows the percentage coefficient presented by the variable. Unstandardized coefficient and sectioning point values for bimastoid breadth are available below the table. Sectioning point can be detected by taking the average of centroid. In this method, discriminant score obtained by calculations can classify the individual; as male if the score is higher than the sectioning point and as female if it is lower [30].

Discriminant function score can be found with $Y_{(sex)}$=a+b1x1+b2x2+…bnxn formula. X presents; measurement, a presents; constant coefficient and b presents; the coefficient of the related measurement.

For example if we use the measurement taken from no. 22 individual;

$Y_{(sex)}$ = -24.410+(0.233*110.60) = 1.340

In this situation, the individual is determined as a male, as the score is higher than sectioning point value. Accuracy rates and cross validated rates used for the classification of the obtained measurement values are shown in Table 3. Accuracy rates for females are observed to be very slightly higher than males. According to this result, correct sex determination was 82.7% in females and 80% in males.

Sex distribution of each group, including 50 males and 50 females separated into age groups with a difference of 5 years, evaluated by One-way ANOVA analysis. When the average of the measurements is considered, a significant difference is not observed among sexes. A statistically significant difference was not detected according to the One-way ANOVA test findings made according to the age groups for both sexes (p>0.05) (Table 4). In multi-comparison analyses among age groups, a statistically significant difference was not observed in any comparison (Table 5).

Table 1. Descriptive statistic of bimastoid breadth (mm) in male and female Turkish population and t-test of significance between means

						T-test for Equality of Means	
	n	**Mean**	**Min**	**Max**	**Std. D.**	**t**	**df**
Male	300	108.5	98.6	122.1	4.38	22.023	598.0*
Female	300	100.8	87.8	114.8	4.19	22.023	596.8*

* p = 0.00.

Table 2. Discriminant function analysis and canonical discriminant function coefficients for bimastoid breadth of Turkish males and females

	Wilks' λ	**df**	**F-ratio***
Bimastoid diameter	0.552	598	484.99
* p=0.00			
	Standardized Coefficient	**Unstandardized Coefficient**	**Centroid**
Bimastoid diameter	1.000	0.233	M=0.899
			F= -0.899
Sectioning point (Constant)			-24.410
			0.000

Table 3. Prediction accuracy of sexual identification in the bimastoid breadth

			Predicted Group Membership		
			Male	**Female**	**Total**
Original[a]		**Male**	240	60	300
		Female	52	248	300
	%	**Male**	80.0	20.0	100.0
		Female	17.3	82.7	100.0
Cross-validated[b]		**Male**	240	60	300
		Female	52	248	300
	%	**Male**	80.0	20.0	100.0
		Female	17.3	82.7	100.0

[a] 81.3% of original grouped cases correctly classified. [b] 81.3% of cross-validated grouped cases correctly classified.

Table 4. Analysis of bimastoid breadth by age distribution in both sexes

		Male				Female			
Age range	**n**	**Mean (mm)**	**Std. Deviation**	**Min. (mm)**	**Max. (mm)**	**Mean (mm)**	**Std. Deviation**	**Min. (mm)**	**Max. (mm)**
21 - 25	50	109.68	4.58	100.40	118.70	100.48	3.67	93.40	109.90
26 - 30	50	108.22	4.66	98.60	117.80	100.62	4.08	93.50	114.30
31 - 35	50	109.05	4.32	99.60	119.20	101.52	3.98	92.20	108.30
36 - 40	50	108.61	3.84	101.40	118.10	100.74	4.19	94.10	114.80
41 - 45	50	107.55	4.45	99.60	118.50	101.29	4.44	91.30	112.50
46- 50	50	108.09	4.30	99.30	122.10	100.28	4.77	87.80	110.10
Total	300	108.53	4.38	98.60	122.10	100.82	4.19	87.80	114.80

Table 5. Significance of bimastoid breadth by intergroups and intragroups according to age

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Male	**Between Groups**	142.69	5	28.54	1.50	0.19
	Within Groups	5601.87	294	19.05		
	Total	5744.55	299			
Female	**Between Groups**	57.79	5	11.56	0.65	0.659
	Within Groups	5194.78	294	17.67		
	Total	5252.57	299			

DISCUSSION

In addition to being used for age and sex determination by metric methods, craniums obtained from skeletal remains can also present a chance to make osteometric measurements depending on statistical basics through radiological imaging methods (such as two-way head graphy, lateral cephalometric graphy, multi-slice CT, 2 and 3 dimensional reconstructed CT, MR) (10, 14). Morphometric analyses of the researchers based on these imaging methods constitute an opportunity to form extensive social databases. Thin slice opportunity, fast evaluation advantage, 3 dimensional evaluation opportunity and gradually decreasing imaging costs are prominent advantages [31]. In researches made on postmortem period; the elimination of maceration-related ethical concerns, fast evaluation advantage and the wide research database formed against the difficulty in reaching bone collections are defined as the main advantages (8-13).

The aim of this study is to determine age and sex from bimastoid breadth measurements using cranial CT images. It was analysed; whether the mastoid bone is free from the maturation and possible changes occurring with the advancing age. In result; a significant difference was not detected among age groups. When the population of our study is considered, a significant difference doesn't occur in mastoid bone dimension with the advancing age.

In literature, it is stated that mastoid area generally completes its maturization before puberty, its pneumatization increases and it is one of the most slowly growing areas of the body in postpubertal period [32]. Indeed, this maturation period of the mastoid area completed in early ages; prevents the usability of bimastoid breadth measurement for age determination as detected in our study, too.

In literature it is stated that, mastoid process dimension is larger as the male cranium is bigger than the females and owing to activity of spleniuscapitis, longissimus capitis and sternocleidomastoid muscles is stronger [33]. As a reflection of this data, it was again observed in our study that bimastoid breadth measurement obtained from male cases was higher than the females. According to our findings, mean bimastoid breadth was detected as 108.5±4.3 mm in males and as 100.8±4.1 in females.

In the calculations made after determining sectioning points of measured values and applying discriminant function analysis, sex determination with a ratio of 80.0% could be made in males and 82.7% in females. In a study made by Marinescu M. *et al.* on adults in Romania, accuracy rate for bimastoid breadth was detected as 73% and the measurements were defined as significant difference [34]. In the study made by Jain D. *et al.* on Indian adults, accuracy rate for bimastoid breadth was detected as 75% and its usability in sex determination was defined as relatively high degree [24].

Different parameters apart from bimastoid breadth measurement can be used for sex determination from cranium. In a study by Steyn M. and İşcan M.Y. evaluating 12 cranial parameters of 44 Caucasian males and 47 females from South Africa, the accuracy rate for the bizygomatic breadth detected as the most dimorphic parameter was found 80% [19]. Kranioti E. *et al.* obtained an accuracy rate of 81.9% for the bizygomatic width in the research evaluating 16 cranial parameters on 90 males and 88 females in bizygomatic breadth in Crete detected as the parameter with the highest distinction rate [20]. In the study evaluating 5 cranial parameters on 164 males and 140 females made in USA by Walker P.L., an accuracy rate of 82.6% was obtained for glabella which is the most dimorphic parameter [35]. In the study evaluating 5 cranial parameters on 205 males and 108 females made in Japan by Sakaue K. and Adachi N., an accuracy rate of 80.5% was obtained for supra-orbital ridge measurement which is the most dimorphic parameter [36]. When high accuracy rate obtained in our study (80.0% in males and 82.7% in females) is considered, this shows that bimastoid breadth measurement can be used for sex determination in Turkish population.

CONCLUSION

Population studies constitute one of the basic reference points of identification studies based on anthropometric measurements. Depending on many factors such as the geographical characteristics of the area people live in, genetic factors, nutrition habits, diseases and socio-cultural levels, inter-population or intra-population age and sex differences can be observed. Thus, especially in forensic cases; data for the population of the individual should be used as much as possible in biological profile studies [37].

In this study, the possibility of age and sex determination from cranial bimastoid breadth measurement in Turkish population was evaluated. According to the results obtained, it was concluded that; there is no significant change occurs in mastoid bone dimension with the advancing age. When obtained accuracy rates with high reliability are considered; it is supported that, the analysis method with 3D reconstructed CT images is convenient for sex determination. Starting from here, it is concluded that this method can be used especially in conditions where primary identification methods cannot be used and in conditions requiring preliminary inspection.

Conflict of interest. The authors declare that there is no conflict of interest.

Acknowledgement. This research was made with the consent of Dokuz Eylül University Faculty of Medicine Directorate of Non-Invasive Clinical Researches Ethics Board dated 16.03.2015 with no 243.

The results of this research were presented verbally in the 13th Forensic Sciences Congress (National congress) organized in Turkey.

References

1. Ge J, Budowle B, Chakraborty R. Choosing relatives for missing person identification by DNA typing. J Forensic Sci. 2011;56 Suppl 1: S23-28.
2. Brenner CH, Weir BS. Issues and strategies in the identification of World Trade Center victims. Theor Popul Biol. 2003;63(3):173-178.
3. Budowle B, Bieber FR, Eisenberg AJ. Forensic aspects of mass disasters: Strategic considerations for DNA based human identification. LegalMed. Leg Med (Tokyo). 2005;7(4):230-243.
4. Prinz M, Carracedo A, Mayr WR, Morling N, Parsons TJ, Sajantila A, Scheithauer R, Schmitter H, Schneider PM; International Society for Forensic Genetics. DNA Commission of the International Society for Forensic Genetics (ISFG): Recommendations regarding the role of forensic genetics for disaster victim identification (DVI). Forensic Sci Int Genet. 2007;1(1):3-12.
5. Pretty IA. Forensic dentistry: 1. Identification of human remains. Dent Update. 2007;34(10):621-622, 624-626, 629-630 passim. Review.
6. Cattaneo C, De Angelis D, Porta D, Grandi M. Personal identification of cadavers and human remains. Forensic Anthropology and Medicine. 2006.
7. Gurses MS, Inanir NT, Soylu E, Gokalp G, Kir E, Fedakar R. Evaluation of the ossification of the medial clavicle according to the Kellinghaus substage system in identifying the 18-year-old age limit in the estimation of forensic age—is it necessary? International Journal of Legal Medicine. 2017; 131(2): 585-592.
8. Ramsthaler F, Kettner M, Gehl A, Verhoff MA. Digital forensic osteology: Morphological sexing of skeletal remains using volüme rendered cranial CT scans. Forensic Sci Int. 2010; 25; 195(1-3):148-152.
9. Verhoff MA, Ramsthaler F, Krahahn J, Deml U, Gille RJ, Grabherr S, Thali MJ, Kreutz K. Digital forensic osteology—possibilities in cooperation with the Virtopsy Project. Forensic Sci Int. 2008; 174: 152–156.
10. Thali MJ, Braun M, Buck U, Aghayev E, Jackowski C, Vock P, Sonnenschein M, Dirnhofer R (2005). VIRTOPSY—scientific documentation, reconstruction and animation in forensic: individual and real 3D data based geo-metric approach including optical body/object surface and radiological CT/MRI scanning. J Forensic Sci. 50: 428–442.

11. Grabherr S, Cooper C, Ulrich-Bochsler S, Uldin T, Ross S, Oesterhelweg L, Bolliger S, Christe A, Schnyder P, Mangin P, Thali MJ. Estimation of sex and age of "virtual skeletons"—a feasibility study. Eur Radiol. 2008; 19: 419–429.
12. Hatipoglu HG, Ozcan HN, Hatipoglu US, Yuksel E. Age, sex and body mass index in relation to calvarial diploe thickness and craniometric data on MRI. Forensic Sci Int. 2008; 182: 46–51.
13. Turner WD, Brown RE, Kelliher TP, Tu PH, Taister MA, Miller KW. A novel method of automated skull registration for forensic facial approximation. Forensic Sci Int. 2005; 154:149–158.
14. Zollikofer CP, Ponce de Leon MS, Lieberman DE, Guy F, Pilbeam D, Likius A, Mackaye HT, Vignaud P, Brunet M. Virtual cranial reconstruction of Sahelanthropus Tchadensis. Nature. 2005; 434:755–759.
15. Dedouit F, Telmon N, Costagliola R, Otal P, Joffre F, Rouge D. Virtual anthropology and forensic identification: report of one case. Forensic Sci Int. 2007; 173:182–187.
16. Scheuer L. Application of osteology to forensic medicine. Clinical anatomy. Clin Anat. 2002;15(4):297-312. Review.
17. Bruzek J, Murail P. Methodology and reliability of sex determination from the skeleton in forensic anthropology and medicine (pp. 225-242). Humana Press. 2006.
18. White TD, Folkens PA. The human bone manual. Academic Press. 2005.
19. Steyn M, İşcan MY. Sexual dimorphism in the crania and mandibles of South African whites. Forensic science international. 1998.
20. Kranioti EF, İşcan MY, Michalodimitrakis M. Craniometric analysis of the modern Cretan population. Forensic Sci Int. 2008;18;180(2-3):110.e1-5.
21. Robinson MS, Bidmos MA. The skull and humerus in the determination of sex. Reliability of discriminant function equations. Forensic Science International. 2009.
22. Shanthi CH, Lokanadham S. Morphometric Study on Foramen Magnum of Human Skulls. Medicine Science International Medical Journal. 2013.
23. Manoonpol C, Plakornkul V. Sex determination using mastoid process measurement in Thais. Journal of the Medical Association of Thailand. 2012.
24. Jain D, Jasuja OP, Nath S. Sex determination of human crania using mastoid triangle and opisthion–bimastoid triangle. Journal of Forensic and Legal Medicine. 2013.
25. Petaros A, Sholts SB, Slaus M, Bosnar A, Wärmländer SK. Evaluating sexual dimorphism in the human mastoid process. A viewpoint on the methodology, Clinical Anatomy. 2015.
26. Gapert R, Black S, Last J. Sex determination from the foramen magnum: discriminant function analysis in an eighteenth and nineteenth century British sample. International Journal of Legal Medicine, 2009.
27. Uthman AT, Al-Rawi NH, Al-Naaimi AS, Al-Timimi JF. Evaluation of maxillary sinus dimensions in gender determination using helical CT scanning. Journal of Forensic Sciences, 2011.
28. Michel J, Paganelli A, Varoquaux A, Piercecchi-Marti MD, Adalian P, Leonetti G, Dessi P. Determination of Sex: Interest of Frontal Sinus 3D Reconstructions. Journal of Forensic Sciences, 2015.
29. Kanchan T, Gupta A, Krishan Kewal. Estimation of sex from mastoid triangle - A craniometric analysis, Journal of Forensic and Legal Medicine. 2013.
30. Ünlütürk Ö. Metric assessment of ancestry from the vertebrae in South Africans. International Journal of Legal Medicine. 2017; 131(4): 1123-1131.
31. Gurses, MS, Inanir, NT, Gokalp G, Fedakar R, Tobcu E, Ocakoglu G. Evaluation of age estimation in forensic medicine by examination of medial clavicular ossification from thin-slice computed tomography images. International journal of legal medicine. 2016; 130(5): 1343-1352.
32. Yılmaz MT, Yüzbasioglu N, Cicekcibasi AE, Seker M, Sakarya ME. The evaluation of morphometry of the mastoid process using multidetector computed tomography in a living population. The Journal of Craniofacial Surgery. 2015.
33. Saini V, Srivastava R, Rai R, Shamal SN, Singh TB, Tripathi SK. Sex estimation from the mastoid process among North Indians. Journal of Forensic Science. 2012.
34. Marinescu M, Panaitescu V, Rosu M, Maru N, Punga A. Sexual dimorphism of crania in a Romanian population: Discriminant function analysis approach for sex estimation. Rom J Leg Med. 2014; 22(1): 21-26.
35. Walker PL. Sexing skulls using discriminant function analysis of visually assessed traits. American Journal of Physical Anthropology. 2008.
36. Sakaue K, Adachi N. Evaluation of the sexing methods using the cranial traits in the Japanese population. Nihon Hoigaku Zasshi. 2009.
37. Ramadan SU, Gurses MS, Inanir NT, Hacifazlioglu C, Fedakar R, Hizli S. Evaluation of the medial clavicular epiphysis according to the Schmeling and Kellinghaus method in living individuals: A retrospective CT study. Legal Medicine. 2017; 25: 16-22.