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Evaluation of Sexual Dimorphism and Age Determination Through Bimastoid Breadth Measurement Using Digital Computed Tomography Images in the Iranian Population

تقييم الفرق بين الجنسين وتحديد العمر بواسطة قياس عرض الخشاء للعظم الصدغي باستخدام صور التصوير المقطعي الرقمي المحوسب للمجتمع الإيراني

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Abstract

Individual identification is a critical focus of forensic research, aiming to achieve heightened accuracy in the identification process. Particularly in cases involving fragmented and damaged skeletal remains, sex determination plays a pivotal role. It is imperative to establish the precision of cadaver bones in such scenarios. This research aimed to evaluate sex-based differences and assess age using bimastoid width measured through digital computed tomography images. The study included a total of 153 adults (77 males and 76 females) aged between 15 and 50. Bimastoid breadth measurements were obtained from CT scan images of the skull base, revealing that bimastoid distance is larger in males compared to females. The study observed significant differences in bimastoid breadth between men and women, with an average mastoid width of 132.371 in men and 121.724 in women. The findings indicate that the measurement of bimastoid breadth does not significantly change with increasing age. However, substantial differences were found between men and women in bimastoid breadth measurements, which can be utilized to determine sex in forensic investigations.

Keywords: Forensic sciences, Sexual dimorphism, Age determination, Bimastoid breadth measurement, Digital computed tomography.

المستخلص

يعتبر تحديد الهوية الفردية محورًا مهمًا في المجال الجنائي؛ حيث يهدف إلى تحقيق أعلى درجات الدقة في عملية تحديد الهوية. ويؤدي تحديد الجنس دورًا محوريًا خاصة في الحالات التي تشمل البقايا الهيكلية المجزأة والمتضررة. ومن الضروري تحديد دقة استخدام عظام الجثث في مثل هذه الحالات. وتهدف هذه الدراسة إلى تقييم الاختلافات الجنسية وتقدير العمر باستخدام عرض الخشاء المُقاس من خلال صور التصوير المقطعي المحوسب الرقمي. وشملت الدراسة ما مجموعه 153 شخصًا بالغًا (77 ذكرًا و76 أنثى) تتراوح أعمارهم بين 15 و50 عامًا. وتم الحصول على قياسات عرض الخشاء من صور التصوير المقطعي لقاعدة الجمجمة، والتي كشفت أن مسافة الخشاء أكبر لدى الذكور مقارنة بالإناث. ووجدت الدراسة اختلافات كبيرة في عرض الخشاء بين الرجال والنساء؛ حيث يبلغ متوسط عرض الخشاء 132.371 للرجال و121.724 للنساء. وتشير النتائج إلى أن قياس عرض الخشاء لا يتغير بشكل ملحوظ مع التقدم في العمر. ومع ذلك، تم العثور على اختلافات جوهرية بين الرجال والنساء في قياسات عرض الخشاء يمكن الاستفادة منها لتحديد الجنس في التحقيقات الجنائية.

الكلمات المفتاحية: علوم الأدلة الجنائية، ازدواج الشكل الجنسي، تحديد العمر، قياس عرض الخشاء، التصوير المقطعي الرقمي المحوسب.

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1. Introduction

Identifying the gender and age of individuals poses a significant challenge in the fields of forensic science and anthropology on a global scale. In forensic investigations, the ability to anonymously identify individuals is crucial, particularly in cases such as plane crashes, mass graves, fires, and similar events where the body is extensively damaged, making traditional physical examination methods ineffective for victim identification. Skeletal remains discovered in archaeological studies are sometimes incomplete. Then there's immigration, one of the most important challenges in the world today due to war and poor living conditions in some countries. In the destination country, the personal details of the immigrants are not registered, and therefore, new age identification methods are needed to determine a person's age [1-7].

To date, multiple methods have been suggested to distinguish the age of individuals. DNA testing is perhaps the most precise way to determine a person's gender and age. But due to the high cost and time required to perform this mode of testing, it isn't always possible for everyone. On the other hand, sometimes due to the high level of corruption of the organ and finding only a small part of the body, it is very difficult to distinguish age and sex, even though DNA testing[8, 9]. One of the most common ways to find out a person's age and gender is using bones. The most suitable bone for determining sex after the pelvis is the skull. It should be noted that a single parameter on skull bone is not enough to determine accurate age and sex, and several factors must be considered together to get the desired result [10-12].

There are some differences between skulls of men and women. These differences are more commonly used for sex determination by Forensic specialists, archaeologists, and anthropologists. In general, females have a lighter skull, thinner bones, and less-defined muscle attachment compared to males. Researchers also use foramen magnum, bizygomatic width, intraorbital distance, paranasal sinus dimension, etc [7, 13, 14].

The mastoid process, just behind the external ear, serves as an attachment site of several muscles located in the head. It contains mastoid air cells that enclose air-filled spaces. The mastoid process is usually stronger in males. In anthropology, it has been proven that due to genetic and environmental factors, there are many differences in bone structure between different populations. Researchers find it crucial to examine such variations in different populations [15-19].

This study aimed to determine the age and gender of individuals on the basis of the distance between one's mastoid processes measured by CT scan images and collect appropriate data to improve the accuracy of the same.

2. Method

This study analyzes the bimastoid breadth of individuals who visited hospital for a brain CT scan (Velayat and Shahid Rajaie Hospital Archives). The sample size included 153 people, 77 men and 76 ladies, ranging from 20 to 50 years old.

The sample size of 153 was determined based on statistical considerations and the need to achieve a sufficient level of statistical power to detect. Meaningful differences and associations relevant to the purpose of the study a power analysis was conducted prior to the study to determine the sample size required to achieve the desired level of statistical power. This analysis took into account the expected effect size, the variability of the measurements, and the desired level of confidence in the study results. The calculated sample size for comparing the bimastoid distance based on studies conducted for

the mean and standard deviation of male and female genders, 110±21 and 101±19 respectively, at a confidence level of 95% and a test power of 80%, yields a minimum of 74 samples estimated for each gender. In this study, a total of 153 samples were collected, comprising 76 female and 77 male samples, covering the required minimum sample size.

The participants were separated into six age bunches which were 5 years apart in age, each group of about 20 individuals as follows:Group 1 = 15-20, Group 2 = 20-25, Group 3 = 25-30, Group 4 = 30-35, Group 5 = 35-40, Group 6 = 40-45, Group 7 = 45-50.

In order to enhance the credibility of the study, efforts were made to balance the numbers of male and female participants in each age group to the best extent possible. Patient data, including age and gender, was obtained from hospital records and handled confidentially. Ethical guidelines outlined by the Ministry of Health were strictly adhered to. The use of 3D imaging technology enabled non-invasive and highly accurate measurement of bimastoid breadth. Whole information extracted from Shahid Rajaee and Velayat archives. Hospitals of Qazvin University of Medical Sciences, Qazvin, Iran

2.1. Criteria for exclusion:

Individuals with a prior history of cranial surgery, cranial trauma, cranial pathologies, significant head and facial trauma, and cranial deformities were not included in the study. Bimastoid breadth:

Coronal images have been reconstructed using axial images. The apical point of the mastoid process was evaluated in both axial and coronal pictures and obtained data were recorded in millimeters. The distance between the two mastoid processes is evaluated in both axial and coronal pictures so that the measurement is completely accurate, Fig. 1, BandC.

2.2. Collecting and analyzing the data:

Measurements in millimeters were recorded and entered into the SPSS statistical software, where they were categorized into different sex and age groups. The mean and standard deviation of the data were calculated, and a t-test was conducted to compare the measurements obtained from both genders.

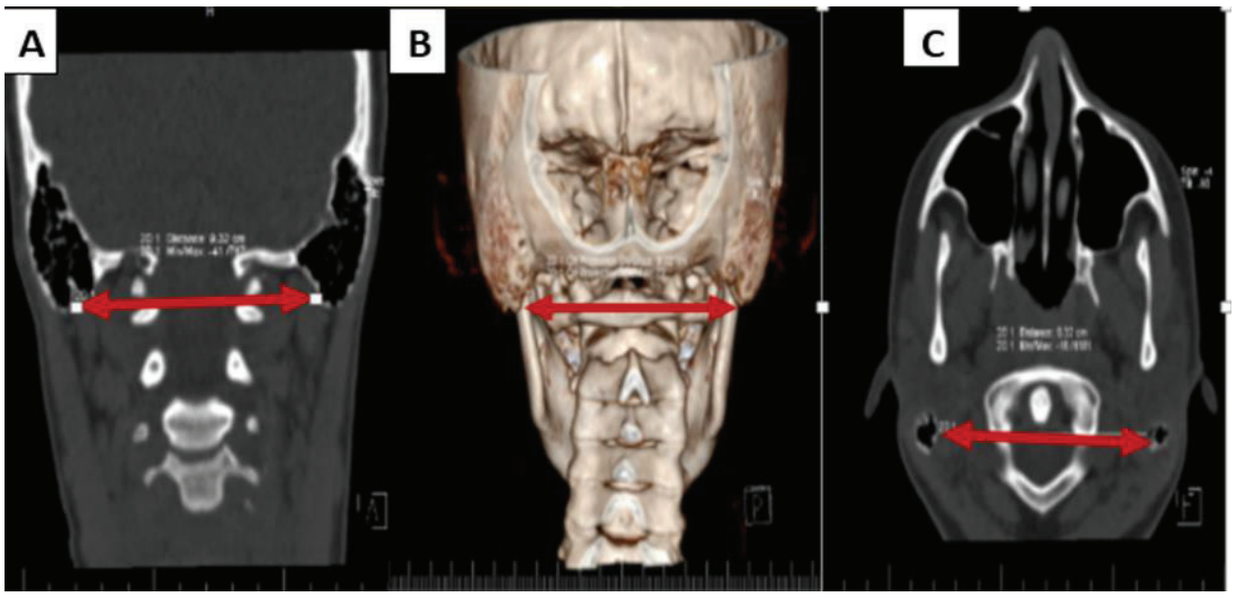

Figure 1- *Measurement of the bimastoid breadth, which is coronal in figure A , three-dimensional VRT images in figure B, and transvers section in figure C.*

Furthermore, the Pearson correlation coefficient was used to assess the correlation between the results across different age groups and genders. Statistical significance was determined with a threshold set at values equal to or below 0.05, while higher values were considered to be not statistically significant.

3. Result

The samples chosen for this study were from individuals aged 15 to 50, with an average age of 30 years. They were randomly selected from patients at Velayat and Shahid Rajaie Hospital in Qazvin, Iran. In total, 153 samples were measured, comprising 76 men and 74 women.

Descriptive statistics including mean and standard deviation and maximum and minimum bimastoid breadth are shown in Table 1.

According to the data obtained from the bimastoid breadth, significant differences were found between men and women. The average bimastoid breadth is 132.371 in men and 121.724 in women.

To evaluate the accuracy of CT imaging, first a formula derived from diacritic function analysis showed that the accuracy of gender estimation was 89/3%:

$$Gender = -2/004 \times Distance\ bimastoid$$

Then the samples were divided into 6 groups using age distribution. Almost every group has more than 20 samples. Data was evaluated using the One-way ANOVA analysis. Considering the average bimastoid breadth, we observed considerable differences within the genders. As shown in Table 2, the distance between the mastoid processes in men (132.371 mm) is greater than in women (121.724 mm).

Additionally, the maximum and minimum distance between the mastoid process were 151.5 mm and 111.0 mm, respectively.

By studying the breadth of the bimastoid process in different groups and its relation to age, we found an interesting difference between one of the groups and the others, Fig. 2. According to Table 3, with the increase in the age of the samples from group 1 (15 to 20 years) to group 2 (20 to 25 years), the average bimastoid breadth increased significantly, although with increasing age in other groups [3, 4, 5], there was no meaningful correlation between the ages of individuals and their bimastoid breadth.

Table 1- *Different distribution of age on both genders.*

Age group	Frequency
15-19	20 (13.1)
20-24	22 (14.4)
25-29	21 (13.7)
30-34	23 (15.0)
35-39	23 (15.0)
40-44	20 (13.1)
45-50	24 (15.7)
Total	153

3.1. Prediction of gender with bimastoeid process distance

For predicting gender with bimastoeid process distance, used the ROC curve, Fig. 3. The bimastoeid process distance cutoffs required for prediction of Male/Female were 126.1mm (sensitivity=82.1, specificity=70.1), 125.4 mm (sensitivity=61.04, specificity=65.58) and 128.25mm (sensitivity=68.3, specificity=76.1) respectively, both have high predictive value; In line with the clinical results obtained for different bimastoid process distances, the AUCs were 0.81.0 ($p<0.001$), Table 4.

Table 2- *Analysis of bimastoid breadth (mm) in Iranian population (men and women) and t-test for significance between averages.*

Gender	N	Mean ± SD	Range	P
Female	76	121.7 ± 4.5	111.0 – 130.5	<0.001
Male	77	132.4 ± 4.8	124.3 – 151.5	

Table 3- *Analysis of bimastoid breadth in both genders by age distribution.*

Age group	N	Mean	95% Confidence Interval for Mean	Range
15-19	20	125.7 ± 6.1	122.8 - 128.5	111 - 139.2
20-24	22	127.7 ± 7.8	124.2 - 131.1	114.6 - 141
25-29	21	127.3 ± 7.2	124 - 130.6	117.5 - 151.5
30-34	23	127.2 ± 6.1	124.6 - 129.8	120.1 - 140.1
35-39	23	127 ± 6.6	124.2 - 129.9	111.8 - 135.7
40-44	20	127.5 ± 7.6	124 - 131.1	112.8 - 144
45-50	24	127.3 ± 8.6	123.4 - 131.3	111.6 - 139.8
Total	153	127.1 ± 7.1	126 - 128.3	111 - 151.5

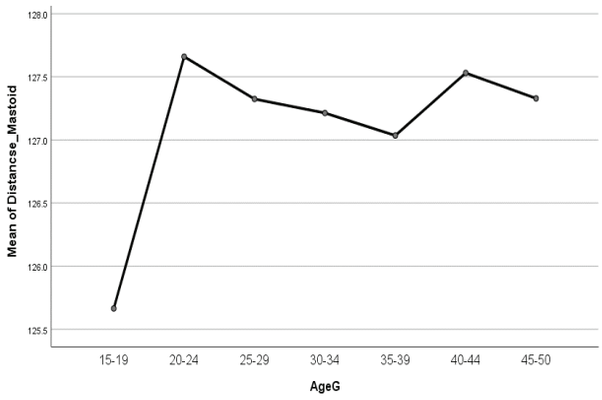

Figure 2- *Studying bimastoeid breadth in different age groups*

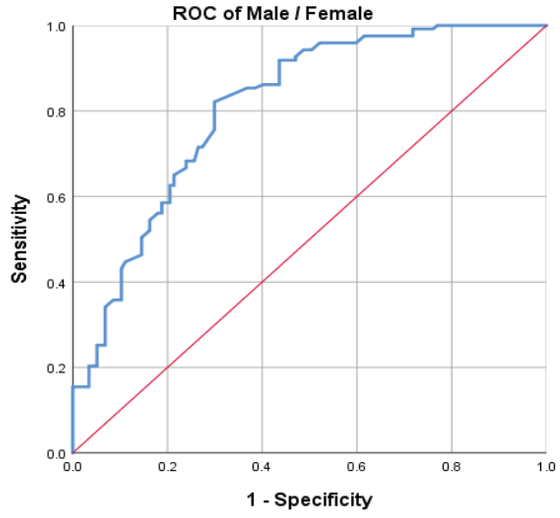

Figure 3- *ROC curves analysis for sex determination by bimastoeid breadth*

4. Discussion

Currently, there are various methods available for determining age, each with its own unique characteristics. Macroscopic age determination methods are more frequently used due to their cost-effectiveness and speed compared to molecular or microscopic methods [20]. From a forensic science perspective, determining age is particularly challenging when dealing with deformed or traumatized skulls. The mastoid process may be of particular importance due to its ability to remain intact in situations where the rest of the cranium is at risk of injury. This characteristic makes it a valuable anatomical feature for forensic analysis and age determination in cases where the skull may be damaged or deformed [21].

The majority of research has focused on the dimensions of individual mastoid processes, but the bimastoid breadth is also a significant indicator for determining sex and age. The mean distance between the two mastoid processes in our study aligns closely with the findings of Ferat Buran et al. [15], but differs from the results of the study by Manoonpol et al. [22]. The accuracy achieved in measuring the distance between the two mastoid processes in

Table 4- *Estimate of AUC in age estimation by bimastoeid breadth.*

Variable	Area	Std. Error	95% Confidence Interval	P-Value
Gender (Male/Female)	0.810	0.028	0.756 to 0.864	<0.001

our study surpasses that of Ferat Buran et al. [15]. The maximum accuracy for age estimation, which was previously reported at 82.7% in other studies [23-25], was exceeded in our study, with an accuracy rate of 89.3%. This suggests that evaluating genders by measuring bimastoid breadth in the Iranian population is a promising approach.

Variations in the bimastoid region distance across different populations may be due to differences in skeletal robustness, unique to each population, as well as differences between genders. Previous studies have indicated that environmental and nutritional factors impact the growth of the skull and face, particularly the zygomatic alongside the mastoid process and occipital ridges [23]. In a study by Jain et al., the accuracy rate of bimastoid breadth was reported at 75% [20].

As is known, the mastoid process usually develops before puberty but its pneumatization gradually increases and after puberty is an area that grows gradually. Because of this feature, it can be used as a good indicator to determine the age of the person after puberty [16].

The wider distance between the mastoid processes in men compared to women can be attributed to the stronger muscles in men. The mastoid process serves as the attachment site for the sternocleidomastoid muscle, the posterior belly of the digastric muscle, the splenic capitis, and the longissimus capitis. With the exception of the digastric muscle, the rest of the muscles pull outward from the mastoid process [21, 22].

Unfortunately, the method of using the mastoid to determine age has not been common in studies. Instead, there have been other parameters including bizygomatic distance used by Steyn M., İscan M.Y. and Kranioti E. et al that showed subsequently 80% and 81.9% accuracy of age estimation [23, 24]. These data show 89.3% accuracy for the bimastoid distance, which is efficient for age estimation.

After analyzing the data, we obtained the accuracy of estimating age 89/3% in men and 84/3% in women. In a study made by Ferat and et al in 2018 on sex determination, the accuracy rate was calculated at 80.0% in men and 82.7% in women [15]. Also in a study by Marinescu M. et al, Jain D. et al, the rate for was detected 73% and 75% respectively [25].

In the present study, the area under the ROC curve (AUC) was determined to be 81. But in the study by Karmer et al. 2018, the value of the area under the curve was found to be between 64.1-67%, indicating that the current model has a higher capability and accuracy in determining the desired feature [18].

5. Conclusion

Population studies are one of the most popular possible explanations for the anthropometric method used in identification studies. Intra-population age and sex variations can be found due to several factors such as geographical features of the region people live in, genetic factors, nutrition patterns, illnesses, and socio-economic levels. As an outcome, notably in Forensics and Archeology, the possibility of determining age and sex in the Iranian population was investigated in this report. According to the observations, there is no significant change in cranial bimastoid breadth measurement with aging. However, we found a significant difference between male and female bimastoid breadth measurements.

Ethical Approval

This research study obtained ethical approval (IR.QUMS.REC.1398.247) from the relevant institutional review board or ethics committee. The ethical considerations and principles were carefully adhered to throughout the study to ensure the protection of human subjects and the integrity of the research.

Conflict of interest

The authors declare no conflicts of interest.

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