Malaysian Journal of Medicine and Health Sciences (eISSN 2636-9346)

ORIGINAL ARTICLE

Mastoidal Width Between Adult Indonesian Males vs. Females Based on the Radiograph Cephalometry

Rizky Alvian Adi Kurniawan[1,3], Viskasari Pintoko Kalanjati[2], Abdurachman[2], Choy Ker Woon[4,5]

[1] Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
[2] Department of Anatomy, Histology and Pharmacology, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
[3] Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jawa Timur, Surabaya, Indonesia
[4] Institute of Pathology, Laboratory and Forensic Medicine (I-PPerForM), Universiti Teknologi MARA, Sungai Buloh Campus, 47000 Sungai Buloh, Selangor, Malaysia
[5] Department of Anatomy, Faculty of Medicine, Universiti Teknologi MARA (UiTM), Sungai Buloh Campus, Jalan Hospital, 47000 Sungai Buloh, Malaysia

ABSTRACT

Introduction: Comprehensive studies investigating sex-related differences in mastoid width among Indonesian adults remain limited. Mastoid width, defined as the distance between the two mastoid processes, provides a valuable morphological parameter for sex determination in forensic anthropology. This study aimed to compare the mastoid width between adult males and females (18-69 years), thereby contributing to the identification of secondary sexual characteristics in human skulls. **Method:** A total of 50 anterior–posterior skull radiographs from patients of Mongoloid race in Surabaya, Indonesia, were analyzed. Mastoid width was measured between the lowest points of the left and right of mastoid process using MicroDicom software (2024.2). Subjects with congenital cranial abnormalities, tumors, or major head trauma were excluded. Statistical analysis was performed using an independent t-test (SPSS 24.0), with a significance level of < 0.05. **Results:** Intra- and interobserver assessment revealed no significant differences, indicating a high level of measurement consistency and reliability between repeated observations and different examiners. The mean mastoid width in males (n= 25) was 124.97 ±7.9mm, while in females (n= 25) was 115.85 ±6.6mm (p = 0.000). **Conclusion:** The average mastoid width in males is significantly greater than in females, demonstrating clear sexual dimorphism in the craniometric characteristics of the Indonesian population based on radiographic analysis
Malaysian Journal of Medicine and Health Sciences (2026) 22(SUPP6): 55-60. doi:10.47836/mjmhs.22.s6.9

Keywords: Cephalometry, Adult Indonesian population, Radiography, Human and medicine, Sex characteristic.

Corresponding Author:
Viskasari P. Kalanjati, PhD
Email: viskasari-p-k@fk.unair.ac.id
Tel: +6231-5020251

INTRODUCTION

Skull morphometry is considered the second most reliable predictor of sex determination after the pelvis. Without enough pelvic bones, the skull and mandible become critical variables for sex confirmation (1). Numerous cranial metric parameters have been investigated for age and sex determination, including maximum cranial length and breadth, bizygomatic distance, foramen magnum dimensions, and paranasal sinuses measurements (2,3).

Among these, the mastoid bone has been widely reported as one of the parameters for determining sex. The mastoid bone is rather resistant to trauma due to its compact structure and anatomical position (2). Located posterior to the earlobe, the mastoid forms part of the temporal bone (4). Previous studies have demonstrated that mastoid dimensions in adult males are significantly larger compared to in females. Female skulls are significantly more paedomorphic than the males. After puberty, females skulls become more apparent as the male skull develops adult traits (5). Growth is defined as an increase in the size and number of cells and intercellular tissue, implying an increase in physical size and bodily structure on a partial or total basis (6). Mastoid development begins with the petrous portion of the temporal bone, which ossifies endochondrally, while other parts ossify between eight week to the third month post-conception (4,7,8). The mastoid process, extending from the basolateral area of the skull behind the external acoustic meatus, represent a key morphological feature of the temporal bone. Similar to other craniofacial bones, mastoid growth is influenced by sex (9).

Sex dimorphism cephalometry based on the Indonesian population has been the subject of limited published research. Previous studies have primarily focused on dry skulls or living individuals. Sofwanhadi (2016) reported cephalometry measurements in thirty young adults, revealing that men from Javanese, Batak, and Chinese ethnic groups had wider bizygomatic widths compared to women. At least one of these three ethnic groups differed in other cephalometry, such as maximal head length, maximal head breadth, frontotemporal breadth, bigonial breadth, morphological facial height, nasal height, nasal breadth, maximal mouth breadth, intercanthal breadth, outerchantal breadth, physiognomic ear length, and physiognomic ear breadth (10). Radiographic imaging has been recognized as a valuable tool for examining sexual dimorphism. Furthermore, it is cost-effective, easily available, and reliable for medical diagnostics, treatment planning, and applications in forensic anthropology (11). According to by Choy et al. (2024), radiometry of the human ribcage can identify gender differences with significant variation observed in rib cage size, costal arc depth, and the superior-inferior and anterior-posterior rib dimensions. However, the mastoid distance has yet to be reported in such study (12).

In this study, the researchers examined mastoid width cephalometry using radiographs of adult males and females from Surabaya, East Java, Indonesia, to evaluate whether the findings demonstrate sexual dimorphism, as reported in other studies conducted on dry skulls or the living participants.

MATERIALS AND METHODS

Study Approval and Ethical Considerations

This research obtained ethical approval under registration numbers 082/KEP/2024 and 25/KEP-RSHU/VIII/2024 from the ethical committee of Universitas Airlangga Hospital, Surabaya, Indonesia and Husada Utama Hospital, Surabaya, Indonesia. Confidentiality was upheld rigorously, with data being used exclusively for research purposes.

Study Design

This study employed a cross-sectional design to assess mastoid width (MW) in the adult Indonesian population (13). The secondary data were obtained from antero-posterior (AP) skull radiographs that fulfilled the established inclusion and exclusion criteria. All radiographs were derived from patients' medical records and had been acquired for clinical purposes. The images were stored in the radiology database in Digital Imaging and Communications in Medicine (DICOM) format. The radiographs included in this study were collected between 2020 and 2024).

Population and Sample

The study population comprised of adult Indonesian men and women who had undergone AP skull radiography between 2020 and 2024 in two hospitals at Surabaya, East Java, Indonesia. A total of 50 subjects were purposively selected based on predefined inclusion and exclusion criteria, consisting of 25 males and 25 females. The inclusion criteria required high-quality radiograph of adults aged 18-69 years, with no history of cranial abnormalities or conditions impacting skull structure, and with documented consent to participate. Exclusion criteria included individuals cranial bone malignancies, congenital cranial deformities, or other conditions that could influence MW measurement, as well as those with unclear or incomplete radiographic images (13,14).

Data Collection and Processing

A total of 74 medical records containing AP plain skull radiographs were initially reviewed. Following inclusion and exclusion criteria, 50 radiographs were retained for analysis. The images were processed using the MicroDicom software (2024.2) without major editing, and intra- and interobserver reliability was assessed using 20% of sample (15). All radiographs were standardized as JPEG files with a minimum resolution of 300 dots per inch (DPI).

Mastoidal width was measured as the linear distance between the right and the left mastoid points (MaR and MaL), representing the lowest anatomical point of the mastoid process on both sides. A horizontal line was drawn across these two landmarks to obtain the maximum transverse distance of the mastoid region. (Figure 1) (13). The skull photo was blindly classified by sex for the parameter assessment (n=50). Measurements were performed twice by one observer and once by another researcher, with the mean μ±SD of the three measurements of each sample and subsequently analyzed (12)

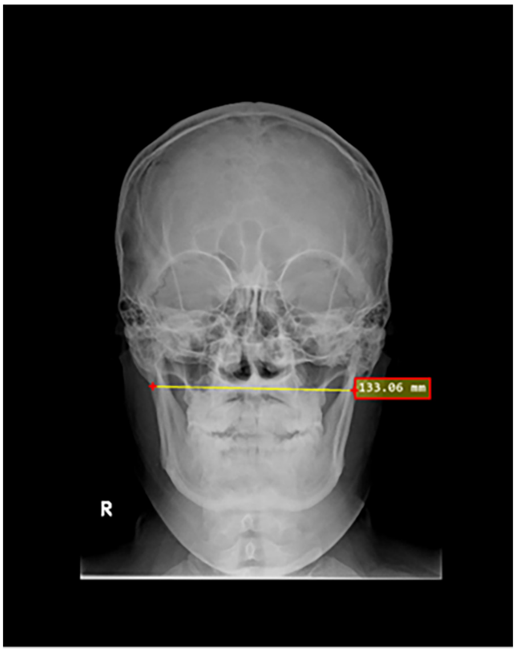

Figure 1: The figure shows the linear measurement from the lowest point of the mastoid process on the right side to left side on the MicroDicom software (yellow line). The yellow line indicates the linear distance measured with MicroDICOM software, demonstrating matoid widht evaluation. This picture shows the methods utilized for MW. Sources: Adapted from (9).

Data Analysis

The data were processed using Microsoft Excel 2021 (16). Statistical analysis was performed with SPPS version 24.0, applying an independent t-test to determine the level of significance, which was set at $p < 0.05$ (17). Prior to the t-test, the Shapiro-Wilk normality test and the Levene's homogeneity test were applied. The results confirmed that the data were normally distributed and exhibited homogeneous variances. Therefore, the use of independent t-test was deemed appropriate. Inferential statistics were also employed to evaluate intra and inter-observer reliability.

RESULTS

To minimize potential observational bias, intra- and interobserver analyses were conducted (12). These analyses were conducted by the first observer twice as indicated in Table I (intra-observer analysis), and compared with the analysis of the second observer (interobserver analysis). The intraobserver analyses revealed no significant differences both in males (p= 0.32) and females (p= 0.13) groups. Similarly, interobserver measurements revealed no significant differences (men p= 0.978, women p= 0.931).

The subsequent analysis was performed on the total sample numbers (n= 50). Normality testing (p= 0.282) and homogeneity testing (p= 0.370) confirmed that the data were parametric. As shown in Table II, the mean ±SD mastoid width in males was significantly larger than females (124.97 ±7.9mm vs. 115.85 ±6.6mm). Independent t-test analysis demonstrated a highly significant difference between sexes (p= 0.000) (Figure 2).

The findings indicated that males exhibited a markedly greater mastoid distance than females, with a mean difference of 9.12 mm (95% CI: 4.98–13.26 mm), thereby confirming strong sexual dimorphism in the mastoid area.

Table II. Comparison of the bimastoidal width between men and women.

Group	Matoidal Width (μ±SDmm)	P between (independent-t test)
Male (n=25)	124.97 ±7.9	0.000
Female (n=25)	115.85±6.6	

Footnotes

1. Mean ± SD is the average measurement and standard deviation for each group, illustrating variation around the mean. Table II shows that men have a substantially greater mean bimastoidal width than women(124.97±7.9mmvs.115.85±6.6mm).
2. Significant difference: The statistic alanalysis revealed a significant difference in bimastoidal width between men and women (p = 0.000). This demonstrates a statistically significant difference between the two groups, confirming that the observed difference is unlikely to be due to random chance.

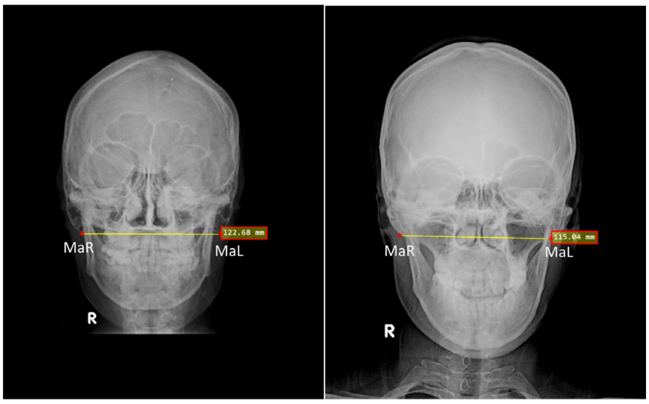

Figure 2: Man and women represent plain skulls for the measured mastoidal width parameter Man (left side) can be seen to be significantly larger than women (right side) (MicroDicom, Linear measurement is indicated by a yellow line). The photos depict a linear measurement from the mastoid process on the right to the left side, revealing a longer mastoid width in the male subject compared to the female exhibited in MicroDICOM Software (yellow line). Sources: Adapted from (13)

DISCUSSION

This current study demonstrated that the cephalometric assessment of mastoid width using plain skull radiographs can be reliably performed with MicroDicom software (15), and showed a relatively comparable measurements between observers and intraobserver. This indicates that the measurement method used was both valid and reliable (18).

Sexual dimorphism in the mastoid process is well-documented and reflects a combination of biological, hormonal and genetic factors. Males typically exhibit

Table I. Intra-observer analysis in men and women from observer, and inter-observer analysis in men and wmen from observer 1 and 2.

Group	Observation 1.1 (μ±SD mm)	Observation 1.2 (μ±SD mm)	p (Shapiro-Wilk test)	p (Levene test)	P between (independent-t test)	Intra-observer mean (μ±SD mm, p)	Observation 2 (μ±SD mm)	P between (independent-t test)
Male (n=10)	126,93 ± 7,5	126,32 ± 7,4	0.687	0.887	0.864	126,62 ± 7,4 (p=0,32)	126,82 ± 7.9	0.978
Female (n=10)	117,53 ± 5,8	117,72 ±5,3	0.687	0,753	0.914	117,62±5,55 (p=0,13)	117,77 ± 7,7	0.931

Footnotes

1. Intra-observer analysis: The first observer conducted the analysis twice, as shown in Table I. The intra-observer results revealed no significant differences between men (p=0.32) and women (p=0.13) groups.
2. Inter-observer analysis: A comparison of results from the first and second observers. Inter-observer measures found no significant differences (men p=0.978, women p=0.931).
3. Total sample numbers: The analysis was done on a total sample size of 50. The data in this sample were found to be parametric, as indicated by the normality test (p=0.282) and homogeneity test (p=0.370).

larger mastoid volumes and broader mastoid widths compared with females (19). The larger size in males is likely attributable to more prolonged post-pubertal bone growth, increased muscle mass, and stronger muscular attachments, such as of the sternocleidomastoid and splenius capitis, which influence bone remodeling and periosteal apposition (20). Furthermore, prenatal and postnatal exposure to sex steroids, particularly testosterone, modulates craniofacial growth patterns, thereby contributing to the establishment of sexual dimorphism in skull features such as the mastoid process. Genetic regulation also plays a role, as sex-specific differences in genes related in bone morphogenesis and the responsiveness to mechanical loading influence skeletal robusticity (21). Taken together, these factors explain a biological rationale for the significantly greater mastoid width in males in this study. Given that the mastoid region is subject both to muscle attachments and nodal growth influences, the sexual dimorphism demonstrated may reflect the integration of hormonal, muscular and genetic influences on cranial skeletal architecture.

In this present study, the mastoid width in adult males was found to be significantly greater than in females, a finding consistent with previous research. Aboelalla et al. (2024) reported similar findings in a sample of 150 Egyptian adults (75 males and 75 females) using Cone Beam Computed Tomography (CBCT), demonstrating statistically significant difference in both mastoid diameter and bizygomatic distance between sexes ($p < 0.001$). Likewise, Okumuş et al. (2021) observed greater mastoid diameters in males compared to females in a Turkish population (n = 200), based on CBCT measurements obtained from sagittal, coronal, and axial views. These attributed this sexual difference to hormonal influences, cranial growth patterns, and variations in muscle attachment sites (2,3,22).

In another study by De Castro et al., (2021), the Brazilian sample included 80 human skulls (34 females and 46 males (18 to 60 years), the mastoid triangle was measured using the opisthion (op), left and right mastoids (ma), and dry skull based on three reference points. They reported significantly higher mean values in males (16), indicating sexual dimorphism in mastoid dimensions (23).

Buran et al. (2018) reported that, in a Turkish population of 600 individuals (300 males and 300 females), mastoid width measured from cranial CT images was significantly greater in males (108.5 ±4.38mm) than in females (100.8 ±4.19mm). Similarly, İnceoğlu et al. (2021) analyzed CBCT scans from an adult European sample (98 males and 149 females) and found that males exhibited wider mastoid distances (105.86 ±4.40mm) compared to females (102.03 ±3.75mm). These findings are consistent with the present study, reinforcing the pattern of sexual dimorphism observed across different populations (14,24).

To ensure accurate measurements of cranial dimensions, mastoid width can be measured using a variety of techniques, including digital calipers applied to dry skulls or radiographic software such as CBCT. By analyzing the variations in cranial morphometry between males and females, this parameter plays a crucial role in identifying sex and, to a lesser extent, age estimation. Previous studies have confirmed that mastoid width is dependable in forensic anthropology and aids in the creation of biological profiles for identification in both clinical and research contexts (24,25).

Biological variations in cranial growth, caused by hormonal and genetic variables, are likely responsible for strong association with sex. Accordingly, mastoid breadth can be considered as a reliable indicator for sex determination (26). The mastoid bone is categorized as a pneumatized bone in adult craniums, and its size depends on its growth and ossification processes. In addition, the dimension of other bones, including the occipital bone, may also contribute to variations in mastoid width. Marinescu et al., (2014) reported that some adult populations have a smaller mastoid breadth, which may reflect differences in cranial morphology associated with age and ethnicity (24,25,27).

The relatively small sample size in this study should be considered when interpreting the results. No power analysis was conducted, which may limit the statistical strength of the findings. Moreover, the samples were obtained exclusively from the Surabaya region, and therefore may not fully represent the craniofacial diversity of the wider Indonesian population. The mastoid width was measured from the radiographs, making the procedure relatively easy to perform by any trained examiner. Moreover, the measurement could be carried out remotely, distant from the site of the incident (3). Standards cephalometry values can be established for certain populations with different races, sex, age groups and other socio-demographic characteristics, thereby enhancing the applicability of this parameter. The present findings may serve as the basis of further forensic and other clinical purposes, including orthodontics, forensic identification, and craniofacial reconstructive surgery (9,12,28). Future research with a larger and more diverse samples, combined with advanced three-dimensional imaging techniques such as CT or CBCT, is recommended to validate and expand the results.

CONCLUSION

This study demonstrated that males exhibit significantly larger cranial measurements than females, making mastoid width a useful sign for sex differentiation. In contexts where cranial data are crucial, this parameter provides a practical and reproducible option for sex estimation. Beyond its forensic relevance, this approach also supports individualized healthcare and offers useful applications in the therapeutic and forensic domains.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude for the Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia, and the Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jawa Timur, Surabaya, Indonesia for their invaluable support and assistance throughout this research. This research received no specific funding from public, private, or nonprofit organizations.

REFERENCES

1. Kurniawan A, Sosiawan A, Nurrahman TF, Chusida A, Rizky BN, Widayanti BF, et al. Predicting sex from panoramic radiographs using mandibular morphometric analysis in Surabaya, Indonesia. J Paleodontol. 2023;17(1).doi: not available
2. Okumuş Ö. Determination of age and sex using bimastoid diameter: a cone beam computed tomography study. Odovtos Int J Dent Sci. 2022;388–394.doi:10.15517/IJDS.2022.48365
3. Aboelalla W, Hassan F, El Bahnasy S. Bizygomatic distance and bimastoid diameter as predictors for age and sex determination in an Egyptian sample: a cone-beam computed tomography study. Egypt Dent J. 2024;70(2):1331–1338.doi:10.21608/EDJ.2024.265900.2913
4. Drake RL, Vogl AW, Mitchell AWM. Gray's Basic Anatomy. 5th ed. Elsevier Churchill Livingstone; 2008.
5. Anjani RCS, Artaria MD, Singsuwan P, Arunorat J, Mahakkanukrauh P. Biological identification of skulls in Indonesian and Thai populations: ancestry estimation, sex determination, stature estimation, and age estimation. Int J Morphol. 2024;42(1):137–146. doi:10.4067/S0717-95022024000100137
6. Akbar IK, Purwanto B, Setijono H. Comparison of antropometry and physical abilities between trained and untrained individuals in second growth phase. Folia Med Indones. 2020;55(4):280–284. doi:10.20473/fmi.v55i4.17323
7. Jin SW, Sim KB, Kim SD. Development and growth of the normal cranial vault: an embryologic review. J Korean Neurosurg Soc. 2016;59(3):192–196. doi:10.3340/jkns.2016.59.3.192
8. Sadler TW. Langman's Medical Embryology. 12th ed. Lippincott Williams & Wilkins; 2012.
9. Ominde BS, Igabari JN, Ikubor JE. Morphometric study of the mastoid process and its role in sex differentiation: a Nigerian computed tomography study. J Forensic Sci Med. 2024;10(1):1–10. doi:10.4103/jfsm.jfsm_7_23
10. Sofwanhadi R. Cephalometric patterns on Javanese, Bataks and Chinese students in Jakarta. Makara J Health Res. 2001;5(2):39–44. doi:10.7454/mjhr.v5i2.5592
11. Kurniawan A, Athalia SA, Prakoeswa BFWR, et al. Cephalometric radiograph-based approach for sex determination using maxillary sinus index in Surabaya, Indonesia. Eur J Anat. 2023;27:663–668. doi:10.52083/DHPM3206
12. Zaidun NH, Alias A, Chung E, Lin NW, Sakaran R, Iwani ND, et al. Anthropometric measurements analysis for sex determination in human ribs: a systematic review. Malays J Med Health Sci. 2024;20(2). doi:10.47836/mjmhs.20.2.36
13. Nur M, Kayipmaz S, Bayram M, Celikoglu M, Kilkis D, Sezgin OS. Conventional frontal radiographs compared with frontal radiographs obtained from cone beam computed tomography. Angle Orthod. 2012;82(4):579–584. doi:10.2319/080311-488.1
14. İnceoğlu A, Bahşi İ, Orhan M, Yalçın ED, İnceoğlu F. The radiological evaluation of the mastoid process and its implications for surgical approaches. Cureus. 2021;13:e16101. doi:10.7759/cureus.16101
15. MicroDicom. MicroDicom DICOM Viewer.
16. Microsoft Corporation. Microsoft Excel. Version 2021.
17. IBM Corp. IBM SPSS Statistics for Windows, Version 24.0. 2016.
18. Zamora N, Llamas JM, Cibrian R, Gandia J, Paredes V. A study on the reproducibility of cephalometric landmarks when undertaking a three-dimensional cephalometric analysis. Med Oral Patol Oral Cir Bucal. 2012;e678–e688. doi:10.4317/medoral.17721
19. Petaros A, Sholts SB, Čavka M, laus M, W∆rml∆nder SKTS. Sexual dimorphism in mastoid process volumes measured from 3D models of dry crania from medieval Croatia. HOMO. 2021;72(2):113–127. doi:10.1127/homo/2021/1243
20. Toneva D, Nikolova S, Tasheva-Terzieva E, Zlatareva D, Lazarov N. A geometric morphometric study on sexual dimorphism in viscerocranium. Biology. 2022;11(9):1333. doi:10.3390/biology11091333
21. Cappella A, Bertoglio B, Di Maso M, Mazzarelli D, Affatato L, Stacchiotti A, et al. Sexual dimorphism of cranial morphological traits in an Italian sample: a population-specific logistic regression model for predicting sex. Biology. 2022;11(8):1202. doi:10.3390/biology11081202
22. Litsas G. Growth hormone and craniofacial tissues: an update. Open Dent J. 2015;9:1–8. doi:10.2174/1874210601509010001
23. De Castro SRPP, Haddad J, Freire AR, Neto OBDO, Prado FB, Rossi AC, et al. Mastoid and opisthion-bimastoid triangles for sex determination in a Brazilian sample. Int J Morphol. 2021;39(4):1068–1073.
24. Buran F, Can IO, Ekizoglu O, Balci A, Guleryuz H. Estimation of age and sex from bimastoid breadth with 3D computed tomography. Rom J Leg Med. 2018;26:56–61. doi:10.4323/rjlm.2018.56

25. Manivanan A. Osteometric assessment of the mastoids for gender determination: a retrospective CBCT study. 2019;2(3).
26. Nagaoka T, Shizushima A, Sawada J, Tomo S, Hoshino K, Sato H, et al. Sex determination using mastoid process measurements: standards for Japanese human skeletons of the medieval and early modern periods. Anthropol Sci. 2008;116(2):105–113. doi:10.1537/ase.070605
27. 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. doi:10.4323/rjlm.2014.21