ORIGINAL ARTICLE

Differences on the Cranial Width between Sexes in Indonesian Adult Sample Population

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ABSTRACT

Introduction: Morphometric analyses of the cranium have been widely applied to estimate age at death, ancestry, skull variation, geographical relationships, and gender differences in forensic science and anthropology. These metrics provide crucial information for plastic surgery, and craniofacial surgery as well as forensic application. Although sex-related differences in cranial dimensions have been reported, data specific to the Indonesian population remain limited. **Method:** Cranial width was measured on antero-posterior/AP plain skull x-ray of 24 Indonesian males and 24 females (19-69 years) using MicroDicom 2024.2. Statistical analysis was performed using an independent t-test with a significance level of $p<0.05$. Intra- and inter-observer analyses were conducted prior to the main analysis. **Results:** The μ±SD of both parameters from the intra- and inter-observer measurements did not differ significantly. The mean ± SD of euryon-euryon in adult males vs. females are 162.7±9.43 mm and 157.0±7.86 mm. There is a significant difference in cranial width between males and females ($p=0.002$). **Conclusion:** Cranial width differs significantly between Indonesian males and females. Within the limitations of this study, cranial width measured from plain skull radiographs may serve as a supportive anthropometric parameter for sex estimation. Future studies with larger and more diverse populations are recommended to strengthen these findings.
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Keywords: Radiography, Adult, Cephalometry, Human and medicine, Sex difference

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INTRODUCTION

Anthropometric studies refer to the scientific approach of measuring and analyzing human body dimensions, including skeletal and craniofacial structures. Within this field, craniofacial anthropometry focuses on head and facial measurements obtained from radiological images, cadaveric specimens, and living subjects. These measurements play an essential role in clinical assessment, forensic identification, and anthropological research. In 2012, Nur et al. demonstrated that frontal skull radiographs are highly useful in surgical treatment planning, as they provide valuable information regarding cranial width and asymmetry. Their study incorporated 14 commonly used linear measurement variables and identified 23 standardized cranial landmarks for radiographic assessment, highlighting the reliability of frontal radiographs in craniometric analysis (1,2,3).

Craniometric measurements have increasingly been applied in reconstructive surgery, anthropology, opthalmology, and forensic science. Consequently, anthropometric research has become an important component of both healthcare and societal applications (2,4). Radiographic analysis, in particular, has been recognized as a reliable source of information for evaluating sexual dimorphism in forensic contexts. A recent systematic review by Zaidun et al. (2024) reported that radiometric analysis of the human rib cage can effectively distinguish sex-related differences, including variations in rib cage size, costal arch depth, and the superior–inferior and anteroposterior dimensions of specific ribs.

In the craniofacial region, Sofwanhadi (2001) conducted a cephalometric study involving 30 young adults from Javanese, Batak, and Chinese ethnic groups. The study, which examined living subjects, found that males exhibited significantly greater cranial widths than females across all three ethnic groups. Furthermore, sex-related differences were observed in multiple additional cephalometric parameters, including maximum head length, maximum head breadth, frontotemporal breadth, bi-gonial breadth, facial height, nasal dimensions, mouth width, intercanthal and outer canthal widths, as well as ear length and breadth (5,6).

However, the radiograph cephalometry study has yet been widely reported based on the sample population of Indonesian people. Therefore, this study aims to investigate sex-related differences in cranial width, measured as the *euryon-euryon* linear distance on AP skull radiographs in males vs. females. Thereby, at least in part, contributing the population-specific data for sex determination in forensic and anthropometry fields based on skull radiographs (7,8,9).

MATERIALS AND METHODS

Study Approval and Ethical Considerations
This study received ethical approval with 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 ethical committee. Confidentiality was strictly maintained, and data were used solely for research purposes.

Study Design
To evaluate cranial width (euryon-euryon distance) in the adult Indonesian population, a cross-sectional study design was used. Secondary data from antero-posterior skull radiographs that satisfied particular inclusion and exclusion criteria served as the basis for data gathering. The dates of the radiograph used in this study were taken between 2020 and 2024 (2).

Population and Sample
The research was conducted on 48 antero-posterior plain skull radiographs of patients who underwent AP skull imaging recorded in the Radiology Department at Airlangga University Hospital and Husada Utama Hospital in Surabaya, East Java, Indonesia (males, n=24; females, n=24). This sample size is comparable to other radiographic cephalometry studies and is considered sufficient to detect a statistically significant sex-based difference in cranial width. Each plain skull radiograph was oriented through adjustment with the Frankfort horizontal plane position. The inclusion criteria included high quality plain skull radiograph of adults aged 19-69 years, no previous trauma in the skull region, and conventional skull plain radiograph. As for the exclusion criteria are undocumented plain skull radiograph, patients with deformity and/or previous skull trauma, radiograph taken not in Frankfort plane position (1,2).

Data Collection and Processing
Initially, 74 medical records containing anteroposterior (AP) plain skull radiographs were identified from the target patient population. Following a screening process based on the predefined exclusion criteria, 48 radiographs met the inclusion criteria and were included in the analysis. All eligible radiographs were imported into MicroDicom software without major editing. No manual image modifications were performed; only the default display settings of MicroDicom were used. Specifically, no adjustments to brightness, contrast, cropping, sharpening, or image enhancement were applied. This approach ensured that all measurements were obtained from unmodified images, thereby preserving the integrity, reproducibility, and accuracy of the cephalometric assessment.

Intra- and inter-observer reliability analyses were conducted using 20% of the total sample size (10). All radiographs met the minimum image quality requirements, with a resolution of at least 300 dots per inch (dpi) and a JPEG (.jpeg) file format (2).

The parameter measured in this study was cranial width, defined as the linear distance between the left *euryon* (eurL) and the right *euryon* (eurR). The left *euryon* was identified as the most lateral point on the cranium parallel to the superior aspect of the orbits on the left side, while the right *euryon* was defined as the corresponding most lateral point on the right side (Figure 1). For the assessment of parameter (n = 48), the skull photo was categorized according to sex in a blind manner (females n = 24, males n = 24). Measurements were first performed in duplicate by one researcher to

Figure 1: The MicroDicom software displayed the cranial width (eurL-eurR) as a yellow line. An illustration of cranial width is shown by the yellow line, which is the linear distance determined using MicroDICOM software. This picture illustrates the process by which cranial width is calculated. Sources: Adapted from (1).

assess intra-observer reliability, followed by a single measurement by the first and the second observer to assess inter-observer reliability. The mean and standard deviation (μ ± SD) for each measurement were then calculated for statistical analysis (1,8).

Data Analysis

All statistical analyses were performed using Microsoft Excel, Microsoft Corporation (2018) (11) and the Statistical Package for the Social Sciences (SPSS 24.0) software package (13). Level of significance was considered when $p < 0.05$ was considered statistically significant. Levene's homogeneity test and Shapiro-Wilk normality test were conducted prior to an independent t-test or Mann-Whitney test to analyze significant differences in cranial width between males (n = 24) and females (n = 24). The analysis of the inter- and intra-observer data were also analyzed using independent t-test or Mann-Whitney test (n = 10) (12).

RESULTS

In this study, intra- and inter-observer analyses were conducted to minimize potential observational bias (14). As presented in Table I, the first observer performed measurements twice for intra-observer reliability, and these results were subsequently compared with measurements obtained by a second observer for inter-observer reliability. The intra-observer analysis demonstrated no statistically significant differences in either the male group (p = 0.101) or the female group (p = 0.105). Similarly, the inter-observer analysis revealed no significant differences between observers for males (p = 0.134; n = 5) or females (p = 0.147; n = 5), indicating good measurement reliability.

As shown in Table II, the μ ± SD of cranial width measured was greater in males (162.7 ± 9.43 mm; n = 24) than in females (157.0 ± 7.86 mm; n = 24). From the statistical analysis, it was shown a significant difference in cranial width between males and females (p = 0.002), as illustrated in Figure 2.

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

Group	Intra-observer 1 (μ±SD mm)	Intra-observer 2 (μ±SD mm)	Intra-observer (μ±SD mm)	Inter-observer 2 (μ±SD mm)	P between (Independent t-test)
Male (n=10)	164.0 ±9.47	164.6 ±9.39	164.3 ±9.68	164.4 ±9.55	0.100
Female (n=10)	158.7 ±5.52	158.1 ±5.66	158.4 ±5.58	159.0 ±4.69	
p between	0.101		0.105		

Footnotes:
1. The intra-observer analysis, involving two separate observations, revealed no statistically significant differences in the measurements of the cranial width (p = 0.101). Similarly, the mean of intra-observer analysis of measurements also indicated no statistically significant differences with inter-observer of the cranial width (p = 0.105).
2. The intra- and inter-observer reliability was assessed using an independent t-test with a sample size of 20, revealing no significant difference between males and females (p = 0.100).

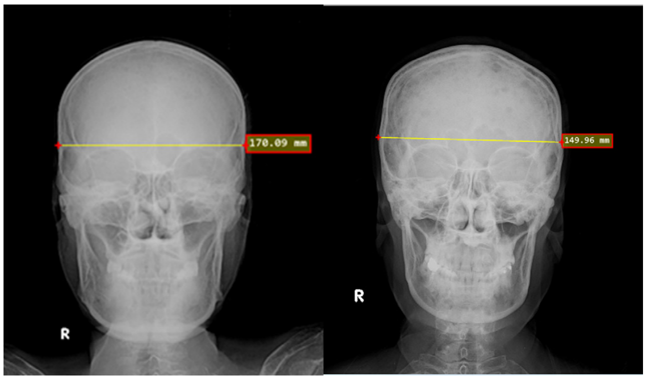

Figure 2: Men and women's representative plain skulls for the measured cranial width parameter. *Euryon* to *euryon* distance is more prevalent in men (left side) than in women (right side). (A yellow line in MicroDicom represents linear measurement). Sources: Adapted from (1).

Table II: Comparison of cranial width between male vs. female.

Group	Intra-observer 1 (μ±SD, mm)	Intra-observer 2 (μ±SD, mm)	Intra-observer mean (μ±SD, mm)	Inter-observer 2 (μ±SD, mm)	Intra-and inter-observer mean (μ±SD, mm)	Intra-observer p-value	p between (Independent t-test)
Male (n=24)	162.7±9.34	162.7±9.61	162.7±9.43	162.6±9.55	162.7±9.48	0.030	0.002
Female (n=24)	157.2±7.89	156.8±7.85	157.0±7.86	157.5±7.63	157.0±7.87	0.032	
p between	0.110		0.30				

Footnotes:
1. Intra- and interobserver reliability was assessed using an independent t-test with a sample size of 48
2. There were no statistically significant differences in intra-observer measurements (p =0.110)
3. The mean of intra-observer and inter-observer analysis also indicated no statistically significant differences (p= 0.30).
4. Intra- and inter-observer reliability was assessed using Independent T-Test, which revealed a significant difference between males and females (p = 0.002), with μ±SD, mm mean values of 162.7±9.48 mm for males and 157.0±7.87 mm for females.

DISCUSSION

Our findings demonstrate a statistically significant sex-based difference in cranial width, with males exhibiting larger euryon–euryon distances than females. This result aligns with the study by Ibrahim et al. (2020), who reported larger cranial width in Malaysian males compared to females using post-mortem computed tomography of 87 radiographs. In our study, cephalometry utilizing plain skull x-rays could be performed with MicroDicom software (10) and measurements between observers and intra-observer were found to be reasonably comparable (7,8). Osirix 3-D Volume Rendering was used to evaluate about 22 cranial characteristics. The findings showed that all measurements were significantly higher in males than in females, with the exception of the orbital height of the left eye as assessed by an independent-t test. The interorbital width parameter had the smallest difference, and the cranial width had the largest, ranging from 1.13 mm to 15.06 mm (7).

Comparable trends were also noted by Sofwanhadi (2000) in Indonesian living subjects, further supporting our population-specific findings. According to a study by Sofwanhadi (2000), which used a sliding caliper straight and Martin's curve to measure samples from three races in the young adult of Indonesian population (n=260); the cranial width is one of the parameters that showed significant difference between males and females. It is also found that there was a significant difference between the cranial width or head breadth of men and women in Bataks (158.2±7.21mm and 151.6±5.7mm), in Chinese (159.2±7.56mm and 153.3±5.1mm), and in Javanese (157.5±5.92mm and 150.1±6mm) (5).

Similarly, Woo et al. (2017) observed significantly greater maximum cranial width in Thai males, reinforcing the presence of sexual dimorphism across Southeast Asian populations. It was reported from a cephalometric study in Thailand population aged 18-104 years using 185 samples of dry skulls consisting of 116 males and 69 females. Measuring cranial index which consist of maximum cranial length and maximum cranial breadth or cranial width using standard anthropometric instruments (spreading calipers with pointed ends) based on Martin's method. The results are 142.38±5.83mm in male and 138.25±5.49mm in females. The cranial measurements under study show that the cranial width of Thai males is larger than those of Thai females with statistical significance ($p<0.01$) (9).

The cranial width parameter evaluated in this study demonstrated clear sexual dimorphism. Prior studies, such as those conducted by Sofwanhadi et al. (2000), Ibrahim et al. (2020) and Woo et al. (2017), have also found significant sexual dimorphism in cranial length across different groups, confirming cranial width as a valid metric for sex differentiation. Compared with these previous studies, our method offers a simpler and more accessible approach as it utilizes plain radiographs rather than CT or direct caliper measurements (7,8,9). Other regional and international studies have reported the same general pattern, although methodologies and measurement landmarks vary; these collectively provide broader context confirming that cranial width is a stable and reproducible parameter for sex differentiation. Such as Lopez et al. (2021) examined 100 Brazilian dry skulls (47 males, 53 females) and measured 51 cranial dimensions across 29 landmarks using direct caliper-based methods. Although several parameters showed higher mean values in males, the difference in maximum cranial breadth between males and females (134.21 ± 7.78 mm vs. 132.84 ± 7.65 mm) was not statistically significant ($p=0.38$) (8). While, Nur et al. (2012) compared conventional frontal radiographs with cone beam CT to evaluate 21 craniofacial parameters in dry skulls (n=30) from a Turkish population aged 19–69 years. In addition to the euryon–euryon measurement, they assessed multiple other dimensions, including maxillary and mandibular widths, intermolar distances, interorbital width, mastoid width, nasal width, and several midfacial and dental landmarks. Their work highlights the broad applicability of radiographic cephalometry for evaluating cranial morphology across different imaging modalities (1).

The endocrine-driven differences, combined with sex-specific genetic growth trajectories; in females WNT4 and DAX1 genes contribute to the ovarian growth hence estrogen production that are modulating the SRY gene to stimulate testis and the growth of Leydig cells that secretes testosterone (24). During puberty, males undergo a substantial increase in testosterone, which stimulates periosteal bone apposition and promotes greater transverse expansion of the cranial vault through enhanced osteoblast activity (23). In contrast, estrogen in females facilitates earlier epiphyseal closure and modulates cranial growth, resulting in relatively narrower lateral cranial dimensions (22,23,24). As these dimorphic patterns stabilize after puberty, cranial width remains a reliable parameter for sex estimation in forensic and anthropometric applications, as shown in our study. The result of this study highlights evidence that cranial width measured from plain AP skull radiographs could determine sex difference thus is a useful anthropometry indicator for forensic identification in Indonesia (7,8,9). It is, however, wise to take into consideration on other bone parameters and databases for more exact decision. As in the current study only one parameter was analyzed; and arguably needs larger sample population from different regions of Indonesia in the future research, to increase the study power and significance. On the other hand, our findings reinforce the value of cranial width as a practical and accessible indicator for sex estimation, particularly in settings where advanced imaging modalities are still limited in small regions. In particular for Indonesia, which predominantly inhabited by Muslims, where exhumation and autopsy are unfavorable methods even for forensic identification (24).

CONCLUSION

In our study, cranial width measurements in adult males of Indonesian sample populations is significantly larger compared to in adult females. This parameter, arguably, can serve as one of the measurements to determine sex, although multiple indicators should be employed to increase the certainty level and to lower potential bias due to different X-ray method and/ or tool among different sample populations.

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