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Original article

Length of cranial base and total face height in cephalograms for sex estimation in Indonesia

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ABSTRACT

Background: *Sex estimation is the first step in identifying bodies following disasters or accidents. Craniometric analysis of lateral cephalograms can be used in the process. Among the measurements that can be used are the length of cranial base, determined by Basion–Nasion (Ba-N) length, and the total face height, determined by the Nasion–Menton (N-M) length, which can highlight significant differences between men and women.* ***Purpose:*** *This study aimed to determine the differences in length of cranial base and total face height measurements between men and women and to demonstrate how these two measurements can be used for sex estimation in the Indonesian population.* ***Methods:*** *This cross-sectional study employed a patient database from the dental hospital of Universitas Gadjah Mada. The study sample consisted of 116 cephalograms taken of 58 men and 58 women aged 20–40 years. The linear measurements were taken using EzDent-I Vatech software.* ***Results:*** *The mean cranial base length measurements in the men and women groups were 103.83 ± 4.37 and 96.01 ± 3.80 mm, respectively, whereas the total face height measurements were 121.03 ± 7.26 and 111.23 ± 5.09 mm, respectively. The Mann–Whitney U-Test revealed a significant difference ($p < 0.05$) between the groups. Logistic regression showed that the two measurements can be used to form an equation for sex estimation with an accuracy of 88.8%.* ***Conclusion:*** *Length of cranial base (Ba-N) and total face height (N-M) measurements from lateral cephalograms can accurately be used for sex estimation. Further research among specific populations is required to develop accurate methods for sex estimation employing morphometric examination on radiographs.*

Keywords: *cephalometry; forensic anthropology; radiography; skull base*
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INTRODUCTION

Natural and man-made disasters, as well as accidents, can lead to individual fatalities.[1] Indonesia is geographically situated between the intersection of tectonic plates and the ring of fire, a line of active volcanoes. This location makes Indonesia vulnerable to natural disasters.[2]

Forensic odontology, including skull radiography, has become a primary identifier during disaster victim identification.[3] Extraoral radiographs display oral and maxillofacial anatomical landmarks, facilitating morphometric measurements to support the identification process, especially in determining victims' sex. Linear and angular measurements for sex estimation can be performed using cephalograms[4,5] and panoramic[6] radiographs, in addition to being directly measured in the mandible and cranial regions.[7,8] Sex identification is important because it guides the identification of a person's age, specific population, and stature.[9] The human skeleton has sexually dimorphic characteristics, and several types of bones can therefore be used for sex estimation. In addition to the pelvis, the skull has been shown to be a highly accurate means for sex estimation.[10]

Radiography, including lateral cephalograms, is a noninvasive practice that can be performed on either living individuals or corpses to obtain antemortem and postmortem data.[11] Dental radiography is a highly reliable method for identifying corpses, providing images of teeth, jaws, and surrounding tissues, which are the body parts most resistant to decomposition and fragmentation during

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a disaster. Consequently, a dental radiograph can serve as an individual's primary identifier.[9,12]

The lateral cephalogram is a skull radiography technique widely used in dentistry. Images can show bone, teeth, and soft tissue that allow for craniofacial measurements to be taken.[13] In the forensic field, sex estimation using lateral cephalograms has an accuracy of 80%–100% across various populations.[4,14] Sex estimation in lateral cephalograms can be completed using craniometric points. Craniometric points on anatomical landmarks of cephalograms are measured as lines, angles, or areas. Among the measurements, the length of cranial base, as measured by the Basion–Nasion (Ba-N) length, and total face height, using measurements of Nasion–Menton (N-M) length, can identify significant differences between men and women.[14–16] To the best of our knowledge, the application of lateral cephalograms for sex estimation has not been previously conducted within the Indonesian population. This study aims to determine the differences in the length of cranial base (Ba-N) and total face height (N-M) between men and women and to identify a sex estimation method using these parameters for the Indonesian population.

MATERIALS AND METHODS

Ethical approval for the study was obtained from the Ethics Committee Faculty of Dentistry and the Dental Hospital of Universitas Gadjah Mada (reference number: 0123/KE/FKG-UGM/EC/2022). A total of 116 samples were collected from dental records from 2019–2022 at the Dental Hospital of Universitas Gadjah Mada. Patient data were kept confidential and will not be used outside of this research. The inclusion criteria were lateral cephalograms from patients aged 20–40 years, whose permanent teeth had all erupted (excluding the third molar), which clearly showed the patients' cranial base. The exclusion criteria were as follows: lateral cephalograms with lesions, trauma, and anomalies in the frontonasal suture, foramen magnum, and mandibular symphysis; a history of orthodontic and or orthognathic treatment; and edentulous condition. The cephalogram of each subject was obtained using the Vatech Pax-I® machine (Vatech, Gyeonggi-do, South Korea), and Ba-N and N-M measurements were performed using the EzDent-i Vatech software (Vatech, Gyeonggi-do, South Korea), as shown in Figure 1. The Ba, or the Basion point, was located at the lowest point of the foramen magnum, and the N, or the Nasion point, was located at the intersection between the frontonasal suture and the internasal suture in the most concave area. Meanwhile, the M, or the Menton point, was located at the lowest point of the mandibular symphysis area. Measuring the length of cranial base involves drawing a line between the Basion and Nasion points, referred to as the Ba-N line, while measuring the total face height involves drawing a line between the Nasion and Menton points, known as the N-M line.

The length of cranial base and total facial height were measured by two observers (NAR and AHN). Together with an oral radiologist from the research team who had five years of experience, the two observers underwent a calibration process prior to performing measurements. To determine the Ba, N, and M points on a cephalogram, they additionally consulted and calibrated with an orthodontist. The intraclass correlation coefficient test was used to conduct intra- and interobserver tests. After a two-week interval, the intraobserver test was conducted on 36 samples, comprising radiographs from 18 men and 18 women participants. Following this, an interobserver test involving six men and six women radiograph samples was conducted.

Normality and homogeneity tests (Kolmogorov–Smirnov and Levene's tests, respectively) showed that the data were not normally distributed. Therefore, the

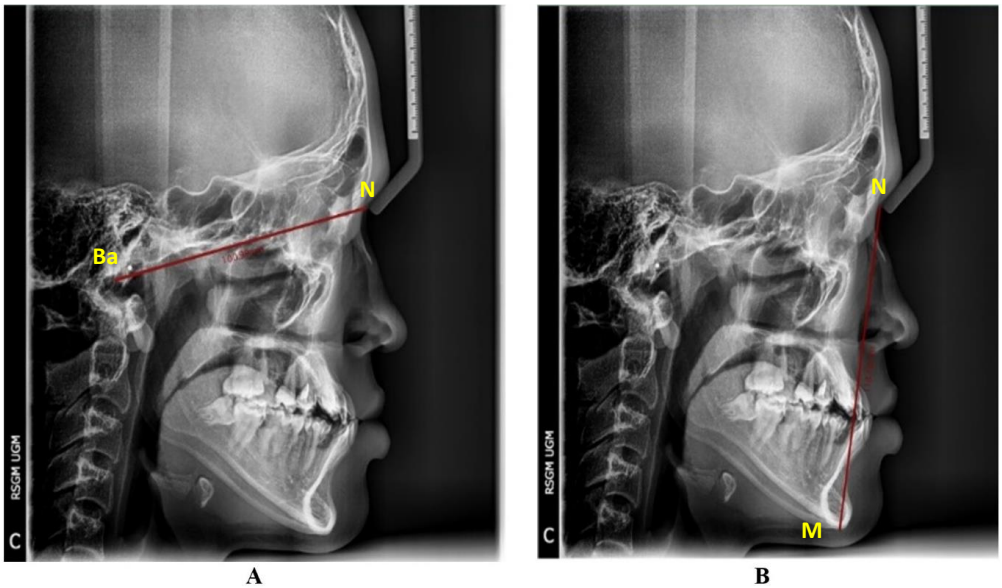

Figure 1. Tracing the (A) length of cranial base (Ba-N) and (B) total face height (N-M) on a lateral cephalogram.

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Mann–Whitney U-Test method was used to compare measurements. Logistic regression analysis was used to determine the mathematical equation for sex estimation.

RESULTS

The reliability test results using intraclass correlation coefficient (ICC) analysis are shown in Table 1. The results demonstrated excellent intra- and interobserver reliability (ICC value > 0.90). Figure 2 shows the mean and standard deviation in Ba-N and N-M measurements of both groups. The men group had a larger length measurement than the women in both parameters. The analysis was continued to determine the equation for sex estimation using logistic regression analysis.

The estimation of the coefficient to be used in the regression equation model is presented in Table 2. All independent variables obtained a p-value of $p<0.05$, indicating that each resulting regression coefficient has a significant effect. Based on the logistic regression results in Table 2, the Ba-N and N-M parameters could be combined to form a mathematical equation for estimating the probability of each person being women, as expressed by Equation (1).

$$\text{Ln } (P/1\text{-}P) = 64.740 - 0.424 \text{ Ba-N} - 0.193 \text{ N-M} \quad (1)$$

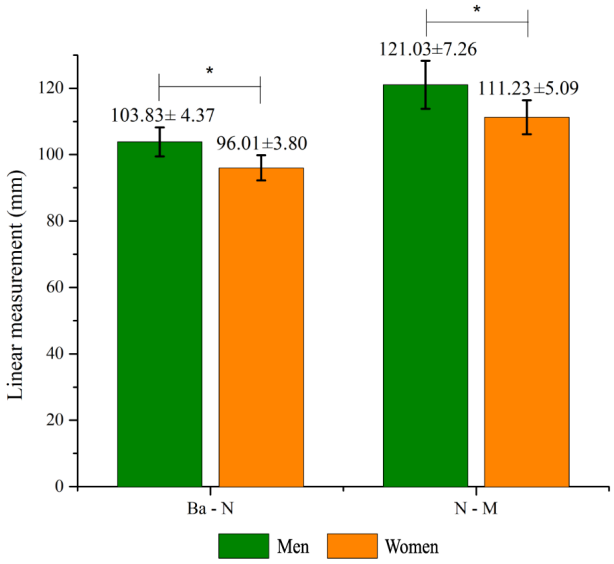

Figure 2. Comparative analysis of the length of cranial base (Ba-N) and total face height (N-M) among men and women. Data are expressed as mean ± standard deviation in mm. *$p < 0.05$ based on the Mann–Whitney U-Test.

Table 1. Intraclass correlation coefficient for average measurements

	n	Intraclass correlation coefficient	F test with true value 0 (Sig.)
Intraobserver	36	0.999	0.000
Interobserver	12	0.993	0.000

Table 2. Variables in Equation 1

	B	S.E.	*P* value
Ba-N	-0.424*	0.100	0.000*
N-M	-0.193*	0.059	0.001*
Constant	64.740*	12.164	0.000*

B: Beta coefficient**;** S.E: Standard error of the estimate

Table 3. Classification result

Observed	Predicted		Percentage of correct prediction
	Men	Women	
Men	52	6	89.7
Women	7	51	87.9
	Overall percentage		88.8

Cutoff value = 0.500

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Equation (1) was applied to all samples for sex estimation. The cutoff value in Equation (1) was 0.50 (50%), which was used to predict sample classification. If the result of the calculation using Equation (1) is <0.50 (<50%), the sample is predicted to be in category 0 (men), whereas if the result of the calculation is >0.50 (>50%), the sample is predicted to be in category 1 (women).[4]

The distribution of data resulting from sex estimation is shown in Table 3, which was subsequently used to determine the accuracy of sex estimation and the probability of each person being women for all samples in this study. According to these data, the linear measurements of Ba-N (length of cranial base) and N-M (total facial height) could classify all study participants as men or women using Equation (1) with an accuracy of up to 88.8%.

DISCUSSION

Lateral cephalograms are one of the most widely used forms of radiography in dentistry and can be used for sex estimation.[5,13,17] The accuracy of sex estimation through the use of lateral cephalograms in this study reached 80%–100%.[4,14] Various cephalometric parameters have been used in sex estimation, and the length of cranial base (Ba-N) and total facial height (N-M) have been proven to have significant accuracy in sex estimation through several previous studies involving diverse populations.[14–16] This study represents the pioneering investigation into the utilization of length of cranial base and total face height measurements on the lateral cephalogram for the purpose of sex estimation in the Indonesian population, with a particular emphasis on the specific area of Yogyakarta. The lateral cephalogram has been studied in pediatric and adolescent populations of Indonesia,[18,19] but no studies have investigated cephalogram measurements for sex estimation in the Indonesian population. A previous study revealed no significant difference in angular measurements on lateral cephalograms between boys and girls aged 8–12 years.[19] However, our study demonstrated that linear measurements of length of cranial base and total face height showed significant differences between groups of men and women aged 20–40 years.

The present study showed excellent reliability for both intraobserver and interobserver measurements (Table 1), showing that the point determination for Basion, Nasion, and Menton lengths were performed correctly. Consequently, reliable findings may be obtained from repeated measurements taken over different time periods and by different observers. The use of standardized and calibrated tools supported this reliability. Linear measurement on extraoral radiographs using the digital method was consistent with those in previous studies.[20,21]

This study showed that the length of cranial base and total face height were higher in men than in women (Figure 2). This result was similar to that of a previous study, which was performed within the Indian and Colombian populations.[14–16] However, the mean values of linear measurements from this study differed from previous studies because the present study was conducted with the Indonesian population in Yogyakarta. In addition, several factors, such as sample size and inclusion–exclusion criteria, could also influence this difference.[4] Growth differences are also influential as neurocranium and viscerocranium development are affected by many internal and external factors, including diet status, genetics, environment, habit, and lifestyle.[22]

Linear measurement of the cranial base is a favorable parameter for sex estimation.[15,16,23] The Ba-N length, known as the length of the cranial or skull base, commonly grows during human development, especially in its early stages. This growth is related to bone deposition in the area of spheno-occipital and spheno-ethmoidal synchondrosis.[24] For spheno-occipital synchondrosis closure, the maximum cranial base elongation in women is achieved earlier than in men. Consequently, the cranial base tends to be longer in men than in women.[24,25] In addition, the early maturation stage in women impact the cranial base length difference between men and women.[23]

The N-M, or total face height, is usually calculated by adding measurements of the vertical growth of the maxillary bones to the total height of the mandibular body.[26] When a person reaches the age of 17, maxillary bone growth continues, and sexual dimorphism increases.[24] Another growth location in mandibular body height shows differences in growth between men and women in the same age range.[26] The difference in vertical growth of the maxillary bone and mandibular body height causes a difference in total face height, with men having a larger total face height than women.

According to the results of this study (Figure 2 and Table 2), the logistic regression analysis yielded an equation for sex estimation with an accuracy of 88.8% (Table 3). Previous studies[14,16] exhibited a high accuracy with the application of a sex estimation equation using Ba-N and N-M parameters. However, these studies used a discriminant function analysis to obtain their equation. Compared with logistic regression analysis, discriminant function analysis requires a multivariate normal distribution and covariance matrix similarity for each sample population. Logistic regression does not require the fulfillment of both assumptions. In sex estimation, discriminant function analysis and logistic regression produce accurate and almost identical predictions.[27]

Sex estimation in this study and in previous studies[14,16] was completed with high accuracy and therefore almost satisfied the statement of a previous study[4] that cephalometric radiographs could estimate sex in several ethnicities or populations with an accuracy of 80%–100%. However, there is a sizable difference in percentage between this study and the previous studies.[14,16] Several factors contributed to this wide range of accuracy, one of which is the difference in the number of samples. In addition to the difference in

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sample size, the parameters used to construct the equations for sex estimation also varied. This study employed only two linear measurements to construct the sex estimation equations. Previous research[16] used 10 linear measurements, while another study[14] used 14. Thus, the length of base and total face height measurements from this study can be used to formulate an equation for sex estimation with an accuracy rate of 88.8%.

This study indicated that the length of the cranial base (Ba-N) and the total face height (N-M) measured from cephalometric radiographs could be used to estimate an individual's sex. Considering the limited size of the sample utilized in this study, it is imperative to conduct a further study with a larger sample size. To enhance the precision of sex estimation, it is also important to perform further studies involving a wider age range. Due to its vast geographical expanse, Indonesia has a wide variety of ethnic groups, all of which possess distinctive characteristics. Given this, it is necessary to investigate additional linear and angular measurements on lateral cephalograms to establish accurate methods for sex estimation in each specific population.

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