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ORIGINAL ARTICLE

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Sex estimation using angular measurements of nasion, sella, and glabella on lateral cephalogram among Indonesian adults in Yogyakarta

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Abstract

Background Sex estimation gives the probability that someone is classified as a male or a female. Lateral cephalogram analysis can be used for sex estimation due to the resistance and dimorphism of the skull. Glabella has been known to have dimorphic characteristic in male and female, while nasion and sella have been widely used as a standard point in many craniometric measurements. This study aimed to develop an equation using nasion–sella–glabella (NSG), sella–glabella–nasion (SGN), and glabella–nasion–sella (GNS) angles on lateral cephalograms for sex estimation among Indonesian adults in Yogyakarta, Indonesia.

Results A total of 138 adults (aged 20–40 years) digital lateral cephalograms were taken from the dental records at Universitas Gadjah Mada Dental Hospital (108 used to form the equation of sex estimation; 30 used to test the equation), and the parameters were measured with EzDent-i Vatech. An independent *t*-test was used to analyze the differences in the angles between male and female adults. The equation for sex estimation was determined using discriminant function analysis. The average measurements of the NSG angles in male and female adults were 9.64° ± 1.36° and 11.21° ± 1.57°, respectively, the SGN angles were 54.65° ± 4.19° and 60.83° ± 4.13°, respectively, whereas the GNS angles were 118.33° ± 4.61° and 109.84° ± 5.19°, respectively. The independent *t*-test revealed a significant difference ($p < 0.05$) between male and female adults. Discriminant function analysis yielded an equation for sex estimation using the NSG, SGN, and GNS angles with an accuracy of up to 75.9%, with the accuracy of sex estimation based on the testing sample being 70%.

Conclusion Based on the findings of this study, male Indonesian adults have a smaller NSG and SGN angles but a bigger GNS angle than female adults. Related to the accuracy, the study's findings indicate that the discriminant function of NSG, SGN, and GNS angles for sex estimation should not be generalized in wider population. More cephalogram parameters must be investigated in future studies on sex estimation.

Keywords Sex estimation, Radiograph, Lateral cephalogram, Angular measurement, Discriminant function

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Background

Sex is a biological identity that classifies a human as a male or a female, despite other biological variation related to alteration of sex-chromosome patterns in sparse cases. In the forensic field, sex identification is important to narrow down the searching and matching stage, notably when finding incomplete human remains (Brogdon 2011; White and Pharoah 2014). Besides the pelvis as the most dimorphic structure for sex estimation, the skull has been also widely used in the identification process (Qaq et al. 2019; Mello-Gentil and Souza-Mello 2021). The skull shows sexual dimorphism mostly because of the difference in skeletal growth between male and female populations and the mastication force that took place during the process (Ibrahim et al. 2017; Sprowl 2013).

Several methods can be used for sex estimation. Radiographic methods are one of the most widely used because of their noninvasive characteristics toward human remains (Viner 2018). Among radiographic techniques used to the human skull, lateral cephalograms were proven to give high accuracy of up to 100% in sex estimation (Qaq et al. 2019). Lateral cephalograms provide an image of the craniofacial area from the lateral aspect to show anatomical landmarks of the bone, teeth, and soft tissues in the head and neck, morphological structure difference, and intracranial details simultaneously (White and Pharoah 2014; Yazdanian et al. 2022). In particular, lateral cephalograms are used in dentistry to evaluate the dentofacial relationship before, during, and after orthodontic treatment (Phulari 2013).

A lateral cephalogram shows the anatomical landmarks that can be measured in the form of lines, angles, or areas (White and Pharoah 2014). The accuracy of cephalometric measurements in sex estimation ranges from 68 to 100% (Capitaneanu et al. 2017). Cephalometric measurements followed by statistical analysis are chosen over direct cranial measurements because of possible misidentification if uncommon cranial morphologies are present (Qaq et al. 2019; Sprowl 2013). The discriminant function analysis is one of the chosen statistical analyses for sex estimation. The principle of the analysis is classifying an unidentified individual into a group that gives greater probability (Klales et al. 2020). This method is widely used in sex estimation because it is reliable and reproducible (Wankhede et al. 2015).

The glabella has dimorphic characteristics between males and females (Berg 2017; Nikita and Michopoulou 2017), and the nasion is commonly used as a standard point in cranial measurements (Iscan and Steyn 2013). Meanwhile, the sella is located inside the cranial base so that it has a resistance against common traumas and can be detected with minimal radiographic imaging (Brogdon 2011). The angular measurement was chosen over the linear or areal because those two measurements might depend on the magnification scale from the X-ray devices. In addition, in the Canadian and American population, the sex estimation equation that included the NSG and GNS angles has been proven to give an accuracy of > 80% (Qaq et al. 2019). However, the use of the SGN angle as a parameter in sex estimation has not been observed yet.

In Indonesia, cephalometric characteristics had been observed as a manifestation of population mixing following migrations (Sofwanhadi and Abe 2001). However, no studies have discovered a method for sex estimation in Indonesia, especially the one that used cephalogram analysis combined with statistical analysis. In the forensic field, the specific population reference is needed for sex estimation (Berg 2017). Thus, this study aimed to develop a sex estimation method using both NSG, SGN, and GNS angles and discriminant function analysis in lateral cephalograms for the Indonesian population.

Methods

Study design and ethical aspects

This cross-sectional study used digital lateral cephalograms that were collected retrospectively from the dental records at our university dental hospital. Ethical clearance was obtained from the Ethics Committee of the Faculty of Dentistry and Prof. Soedomo Dental Hospital Universitas Gadjah Mada (ref. no. 0123/KE/FKG-UGM/EC/2022). To ensure participant confidentiality, radiograph authorization was limited.

Sample characteristics

A total of 108 digital lateral cephalograms (54 male adults, 54 female adults) were selected based on the following inclusion criteria: lateral cephalograms from patients aged 20–40 years and all permanent teeth had erupted (excluding the third molar). The exclusion criteria were as follows: lateral cephalogram with (1) loss of any tooth (including retained root); (2) any lesion detected in the sella turcica, forehead, frontal sinus, nose, and upper face area; (3) any trauma or deformity detected in the cranial base and upper face; and (4) history of orthodontic treatments. Radiographs were traced and measured using EzDent-i Vatech software (Gyeonggi-do, South Korea). Additional samples with amount of 30 lateral cephalograms were also included, out of previous samples in this study, to evaluate the accuracy of sex estimation using equation derived from discriminant function analysis.

Variable measurements

The following are the positions of the nasion, sella, and glabella: the nasion is located on the most concave point at the intersection of the frontonasal suture and the internasal suture, the sella is located at the center of the hypophysial fossa in the sella turcica, and the glabella is located on the most convex point of the frontal area. The NSG, SGN, and GNS angles were calculated by drawing lines from those three points. Once the angle is formed, the angle value will automatically appear. Figure 1 demonstrates the positions of the nasion, sella, and glabella points as well as the NSG, SGN, and GNS angle measurements.

Statistical analysis

The intra-observer and inter-observer reliability tests were used to assess the consistency of point determination by the observers and angle measurements conducted using the software. Two weeks after the first measurement, the same observer performed intra-observer measurements on 30% of the total samples (34 radiographs), while another observer performed inter-observer measurements on 10% of the total samples (12 radiographs). The result was analyzed using the intraclass correlation coefficient method type 2.1: two-way random for consistency. Data were subjected to normality and homogeneity tests. Since the normality (Kolmogorov–Smirnov test) and homogeneity (Levene's test) tests showed that data were normally distributed, an independent *t*-test was used to compare the angles of male and female adults. The sex estimation equation was created using discriminant function analysis. The form of the equation would be as follows:

$$Di = a + b_1X_1 + b_2X_2 + \cdots + b_pX_p$$

A cutting score for the classification limit was determined from the average of the group centroids value:

$$Z_{ce} = \frac{Z_A + Z_B}{2}$$

with Z_{ce} = *cutting score*, Z_A = *centroid* of group A, and Z_B = *centroid* of group B. Confidence interval was set to 95% for all of the statistical analysis.

Results

The results of the intraclass correlation coefficient test to determine the intra-observer and inter-observer reliabilities are shown in Table 1.

According to the result (Table 1), the ICC values for the three angles in the intra-observer measurements were above 0.9. The ICC values in the inter-observer measurements were above 0.9 for both the SGN and GNS angles while above 0.75 for the NSG angle. All measurements were statistically significant ($p < 0.05$).

The mean NSG, SGN, and GNS angles for both male and female adults were calculated. Referring to Table 2, the Kolmogorov–Smirnov test reveals that all variables in this study have a normal distribution ($p > 0.05$), as well as Levene test that shows a normal homogeneity among variables ($p > 0.05$).

Data were further subjected to the independent *t*-test for the comparison of means, and the results are shown in Fig. 2. Accordingly, the mean difference for angular measurements in both groups was statistically significant, where male adults have lower NSG and SGN angles but have higher GNS angles than female adults.

The significant differences in NSG, SGN, and GNS angles among the groups could be explained generally by the different positions of the glabella in male and female adults. The glabella of a male adult is more prominent and located more anterior than that of female adults (Berg 2017; Nikita and Michopoulou 2017). When assuming that the nasion and sella in male and female adults are in the same position, the difference between the NSG, SGN, and GNS angles could be seen not only directly but also through the mathematical logic presented in Figs. 3, 4, and 5.

The NSG, SGN, and GNS angles were further subjected to discriminant function analysis because of their significant difference between the male and female groups. The results of the discriminant analysis and equation for sex estimation using NSG, SGN, and GNS angles are presented in Table 3.

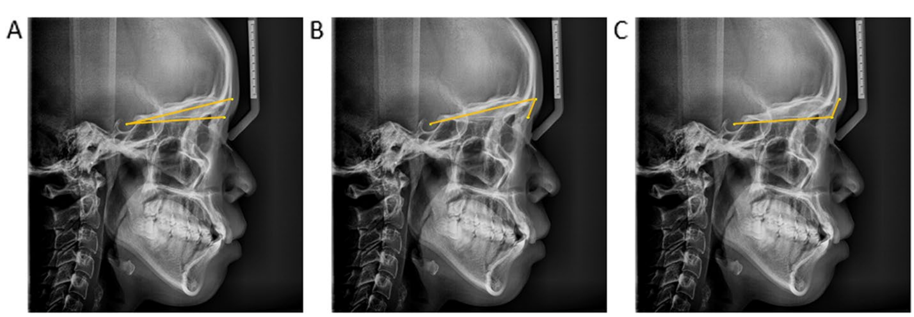

Fig. 1 Angular measurements on lateral cephalogram. **A** The NSG angle was formed by the line starting from the nasion to the sella and terminating at the glabella. **B** The SGN angle was formed by the line starting from the sella to the glabella and terminating at the nasion. **C** The GNS angle was formed by the line from the glabella to the nasion and terminating at the sella

Table 1 Reliability test

Intraclass correlation coefficient (average measures)				
Variables	**Intra-observer**	**Sig**	**Inter-observer**	**Sig**
NSG angle	0.931	0.000	0.769	0.011
SGN angle	0.975	0.000	0.972	0.000
GNS angle	0.977	0.000	0.954	0.000

Table 2 Normality and homogeneity test

Variables	**Kolmogorov–Smirnov test (sig)**[a]		**Levene test (sig)**[b]
NSG angle	Male	0.200	0.471
	Female	0.200	
SGN angle	Male	0.200	0.945
	Female	0.162	
GNS angle	Male	0.200	0.333
	Female	0.200	

[a] Test for normality. [b]Test for homogeneity of variances, based on means

The cutting score was determined at 0, based on the group centroids values (Table 4).

The interpretation was made based on the group centroids; for all discriminant values below 0 (negative), the estimated model would predict a male, whereas for all discriminant values above 0 (positive), the model would predict a female.

Among the samples used in forming the equation ($n = 108$), the model could correctly estimate the sex of 82 samples, indicating an overall accuracy of 75.9% (Table 5).

A validation test was conducted on amount of 30 lateral cephalograms as testing sample. The accuracy of sex estimation using SNG, SGN, and GNS on testing sample is shown in Table 6.

Among the testing samples ($n = 30$), the model could correctly estimate the sex of 21 samples, indicating an overall percentage of 70%.

Discussion

Sex estimation becomes the first identification step preceding another identity such as age, specific population, and stature, considering that those identities will follow the sex pattern (Mello-Gentil and Souza-Mello 2021).

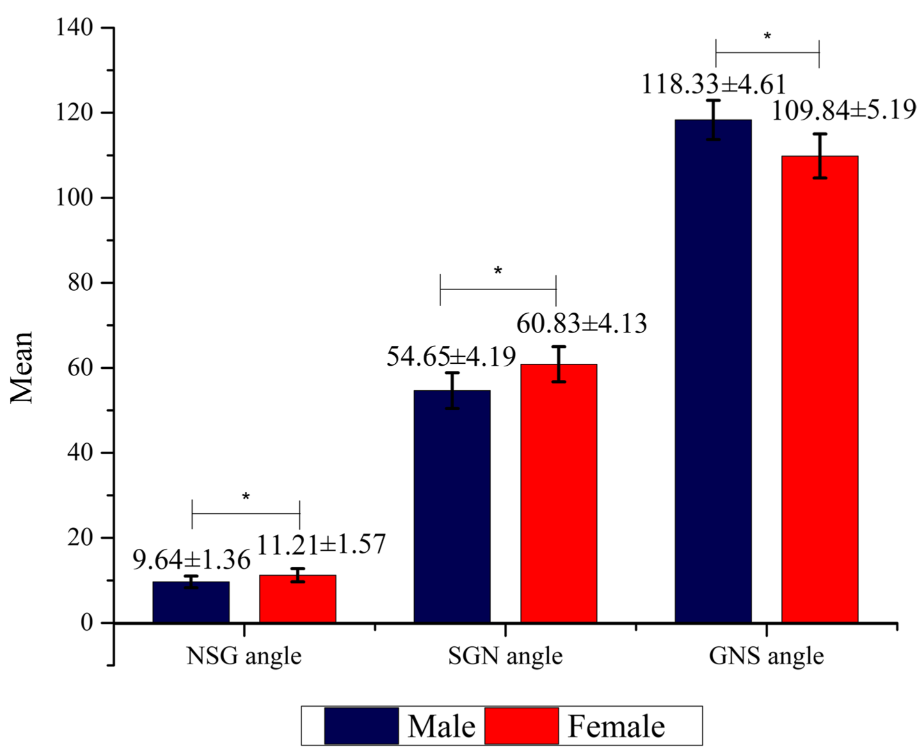

Fig. 2 Mean comparison of NSG, SGN, and GNS angles. Mean comparison of NSG, SGN, and GNS angles between male and female adults shown in means ± standard deviation (*$p < 0.05$ based on the independent *t*-test)

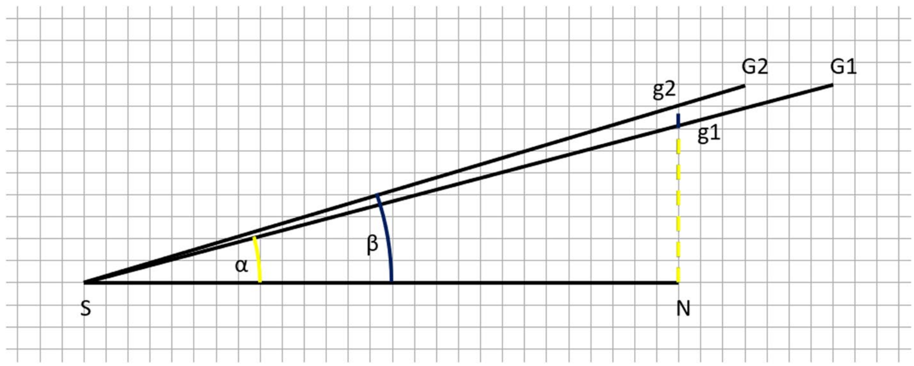

Fig. 3 Schematic illustration of the NSG angle. $NSG_1 = \alpha =$ male NSG angle; $NSG_2 = \beta =$ female NSG angle

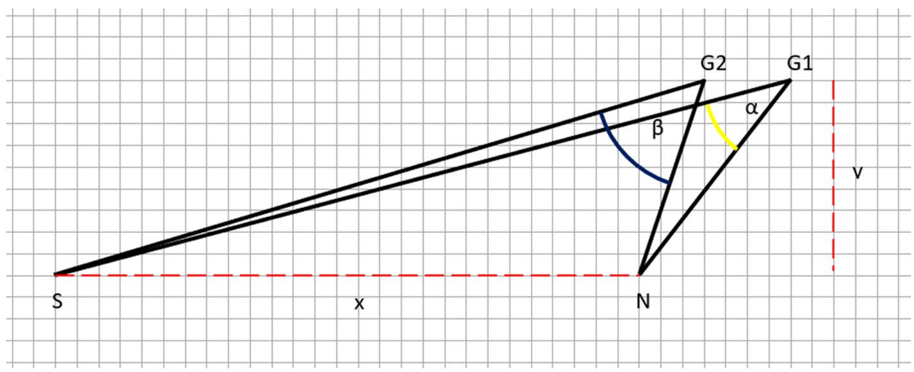

Fig. 4 Schematic illustration of the SGN angle. $SG_1N = \alpha =$ male SGN angle; $SG_2N = \beta =$ female SGN angle

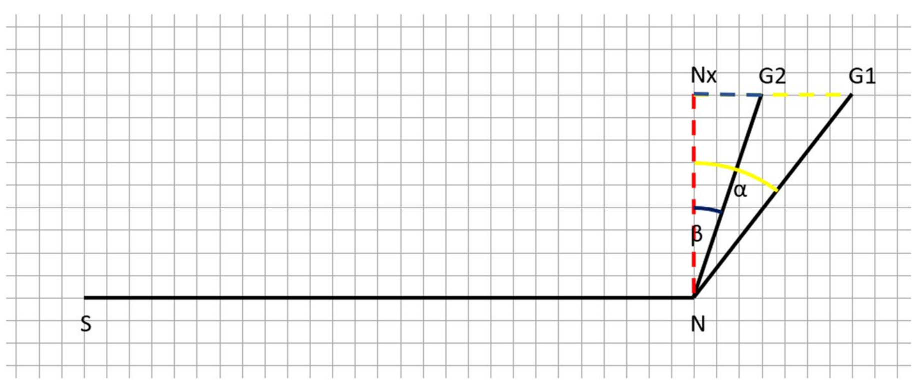

Fig. 5 Schematic illustration of the GNS angle. $G_1NS = \alpha + NxNS =$ male GNS angle; $G_2NS = \beta + NxNS =$ female GNS angle

Table 3 Canonical discriminant function coefficients

	Function 1
NSG angle	0.235
SGN angle	0.097
GNS angle	−0.096
Constant	2.873

$D = 2.873 + 0.235$ (NSG angle) $+ 0.097$ (SGN angle) $- 0.096$ (GNS angle)

Sexual dimorphism occurs in the human skull resulting from the difference in skeletal development and the mastication force involved in the process. Females have less skeletal development because of increased adipose tissue deposition and decreased bone remodeling during the pubertal stage. Meanwhile, males have more skeletal development because of the longer pubertal stage and testosterone production, which supports bone apposition (Sprowl 2013). In this study,

Table 4 Functions at group centroids

	Function 1
Male	−0.891
Female	0.891

Table 5 Classification results of discriminant function analysis

	Predicted group membership	
	n	%
Male	44	81.5
Female	38	70.4
Total	**82**	**75.9**

Table 6 The accuracy of sex estimation using testing sample

		Sex	Predicted group		Total
			Male	Female	
Original	Count	Male	11	4	15
		Female	5	10	15
	%	Male	73.33	26.67	100.0
		Female	33.33	66.67	100.0

individuals aged 20–40 years were chosen because active cranial bone development is stable at the age of 20 years and will stop at the age of 40 years before entering the degenerative stage (Aurizanti et al. 2017).

The human skull can be used as skeletal predictor for sex estimation because of its resistance to most trauma. Sex estimation using the human skull can be effectively conducted through lateral cephalograms (Darkwah et al. 2018; Qaq et al. 2019; Yazdanian et al. 2022). Most of the anatomical landmarks in the head and neck from the lateral side could be observed in detail on lateral cephalograms (White and Pharoah 2014; Yazdanian et al. 2022). These radiographs are widely available in dental records and can be used for antemortem data in forensic identification (Yazdanian et al. 2022).

Based on the result in this study (Table 1), the ICC value indicated excellent reliability ($ICC>0.9$) for all angles in the intra-observer measurements. In the inter-observer measurements, the ICC value of the SGN and GNS angles indicated excellent reliability ($ICC>0.9$), while slight difference was found in the ICC value of the NSG angle which showed good reliability ($0.75<\text{ICC}<0.9$) (Koo and Li 2016). This ensured consistency for point determination and angle measurements through the software used in repeated measurements. Digital cephalometry analysis has advantages over conventional measurement methods. Besides the good reliability, digital methods enable multiple analyses, can adjust the contrast and magnification, and are convenient to use during measurements (Alqahtani 2020).

The results of this study (Fig. 2) showed a significant difference in the NSG, SGN, and GNS angles between male and female adults. These could be explained through schematic figures (Figs. 3, 4, and 5). The male's glabella is more prominent and located more anterior than that of the female's (Berg 2017; Nikita and Michopoulou 2017), and it is assumed that the nasion and sella in male and female adults are in the same position, while the glabella is on the same height for the male and female.

The difference in the NSG angle is shown in Fig. 3. When the nasion is projected perpendicularly to the sella–glabella line, the projected line is longer in female adults (N-g2) than in male adults (N-g1). In a triangle, the angle opposite to the larger side is bigger, so that $\angle\alpha$ (opposite to N-g1 line) as male adult's NSG is smaller than $\angle\beta$ (opposite to N-g2 line) as female adult's NSG.

The difference in the SGN angle between male and female adults is illustrated in Fig. 4. The triangle of SG1N and SG2N was assumed to have same area measurements since it shared the same length (x) and height (y). The triangle area could be calculated from $\frac{1}{2}xy\sin\theta$ so it was $\frac{1}{2}\overline{SG1}\overline{NG1}\sin\alpha$ for the SGN1 triangle and $\frac{1}{2}\overline{SG2}\overline{NG2}\sin\beta$ for the SGN2 triangle. The length of $\overline{SG1}$ and $\overline{NG1}$ was bigger than the $\overline{SG2}$ and $\overline{NG2}$, so that $\sin\alpha$ has a smaller value than $\sin\beta$. Therefore, it can be concluded that $\angle\alpha$ (SG1N; SGN in male) was smaller than $\angle\beta$ (SG2N; SGN in female).

The difference in the GNS angle between male and female adults is illustrated in Fig. 5. A projected point was formed perpendicularly for the nasion (Nx) in the same vertical height as the glabella (G1 and G2). The distance from the Nx to G1 (male glabella) is longer than that from the Nx to G2 (female glabella) so that in the principle of a triangle, $\angle\alpha$ (opposite to the Nx–G1 line) is larger than $\angle\beta$ (opposite to the Nx–G2 line). Summed up with the N_XNS angle, which is the same for male and female adults, the G1NS ($\angle\alpha + N_X$NS) as male's GNS is bigger than G2NS ($\angle\beta + N_X$NS) as female's GNS.

The result of this study (Fig. 2) for the NSG angle and GNS angle is similar to those of a previous study conducted on the Canadian and American population (Qaq et al. 2019). However, a slight difference in the tendency of the measurements was found between the results of the present study and the previous study. The NSG and GNS angles in male subjects in the study conducted in Yogyakarta, Indonesia, were higher than those in a previous study conducted on the different population. Meanwhile, the female's NSG and GNS angles in the present study were lower than those in a previous study (Qaq et al. 2019). The population difference was the main factor. The present study focused on the Indonesian population. The term "population" could refer to the similarity in geographic, ethnic, or temporary factors (Franklin et al. 2016). Each population has unique characteristics related to genetic, climate, or socio-economic factors (de Freitas Guimaraes et al. 2020; Techataweewan et al. 2021; Ubelaker and DeGaglia 2017).

Different from the NSG and GNS angles, the SGN angle in male and female has not been observed yet. The result of this study (Fig. 2), however, has shown that measurement of the SGN angle has potency to be used in sex estimation as it showed significant difference between male and female.

Discriminant function analysis has been utilized for sex estimation using various parameters of lateral cephalogram in different populations. A study conducted on the Indian population using 10 linear parameters resulted in a reliability of up to 99% (Patil and Mody 2005). In the Chinese Han population, discriminant function analysis using two parameters of the frontal bone yielded an accuracy of 76.6% (Luo et al. 2018). A study was also conducted in Iran using four parameters, and the sex estimation accuracy based on discriminant function was up to 87.6% (Bagherpour et al. 2020). Meanwhile, a study conducted in Baghdad generated a function of three parameters with an accuracy of 85.8% (Ali and Al-Nakib 2013).

The discriminant function built in the present study (Table 3) yielded an accuracy of 75.9% using three parameters (Tables 5). Meanwhile, the validation test using different samples yielded an accuracy of 70% (Table 6). It was lower than the accuracy reported in previous studies (Ali and Al-Nakib 2013; Bagherpour et al. 2020; Luo et al. 2018; Patil and Mody 2005). It was strongly recommended that the result should not be implemented in the general population widely. A strict condition must be taken when using the equation built in this study.

This study has limitations. Several factors such as genetics, diet, and physical activities as well as time and conditions during radiograph examinations could not be controlled because this study used retrospective data. Genetics, nutrition-related factors, and physical activity have been proven to influence skull development and further affect sexual characteristic manifestations (Krishan et al. 2016; Mello-Gentil and Souza-Mello 2021; Ubelaker and DeGaglia 2017). The conditions of the patients during radiograph examinations were included in this limitation because the standard procedure for the placement of the patients in the X-ray machine might not be applied equally to every patient. However, the radiographic quality assurance has been applied in dental hospital to overcome this issue.

Related to the discriminant function accuracy, every function possesses population-specific traits. The result will depend on the strength of the parameter in affecting sexual dimorphism in a specific population (Krishan et al. 2016). In addition, the study participants were limited to the adult population of age 20–40 years old so that the standard might not be appropriate to children, adolescents, or older populations.

Despite the limitations above, the results of this study will open and initiate a new perspective on sex estimation in the Indonesian population using lateral cephalograms, which are generally available in dental records.

Conclusions

Sex estimation is an important process in human identification. The anatomical landmarks of the human skull show sexual dimorphism, which can be a choice for the process. Lateral cephalogram analysis combined with statistical analysis is a better method for determining sex, despite being population specific. The results of this study conducted in Yogyakarta indicated that an Indonesian male adult has a smaller NSG and SGN angles than a female adult. Conversely, male adults have bigger GNS angles than female adults. The discriminant function of NSG, SGN, and GNS angles for sex estimation only gives an accuracy up to 75.9% so that it should not be generalized in wider population. Further studies are needed to explore more cephalometric parameters in various anatomical cranial landmarks including linear, angular, and areal measurements for sex estimation.

Abbreviations

NSG Nasion–sella–glabella
SGN Sella–glabela–nasion
GNS Glabella–nasion–sella

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Authors' contributions

AHN did the investigation, resources collection, data curation, formal analysis, and project administration, as well as composed the original draft. RW did the conceptualization, supervision, validation, and visualization, as well as managed the reviewing and editing process of manuscript. RRS did the supervision and methodology verification, as well as supported the reviewing and editing process of manuscript. RDY supported the reviewing and editing process of manuscript. All authors have read and approved the manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
Ethical clearance was obtained from the Ethical Commission of the Faculty of Dentistry and Prof. Soedomo Dental Hospital Universitas Gadjah Mada (Ref. No. 0123/KE/FKGUGM/EC/2022). Sample (radiograph) authorization was limited to ensure participant confidentiality.

Consent for publication
Not applicable. Samples were collected retrospectively from an existing database.

Competing interests
The authors declare that they have no competing interests.

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