SEX ESTIMATION USING DIRECT GONIAL ANGLE MEASUREMENT IN 16-24 YEARS OLD INDONESIAN POPULATION

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ABSTRACT

INTRODUCTION: Sex determination has an important role in post-mortem (PM) profile reconstruction, which enables to reduce the possibility of identification. Gonial angle (GA) of mandible is a reliable sex parameter through skeletal examination. However, given frequent limited resources in forensic setting, direct GA measurement approach on deceased’s body is more practicable.

OBJECTIVES: This study aims to evaluate GA discriminative ability in sex estimation by using direct measurement method in 16-24 years old Indonesian population.

MATERIAL AND METHODS: One hundred individuals (M = 43, F = 57) between 16-24 years old from Jepara District, Central Java, Indonesia, were selected for the measurement of both left (LGA) and right (RGA) gonial angle using a goniometer. Inter-and intra-observer reliability were 0.906 and 0.936, respectively, after one month using intra-class correlation coefficients (ICC). Measured LGA and RGA from males and females were compared using Mann-Whitney U-test, and Pearson’s correlation between LGA and RGA were calculated. Binary logistic regression and ROC curve models were applied to analyze GA capability in sex discrimination.

RESULTS: There was no significant difference between LGA and RGA measurements, and a high correlation was detected ($r = 0.73$). Both LGA and RGA had significant value to predict sex. AUC value of LGA was 0.615 ($p = 0.048; 95\% CI: 0.51-0.73$) and RGA was 0.637 ($p = 0.015; 95\% CI: 0.53-0.74$).

CONCLUSIONS: The proposed direct examination method of GA to predict sex shows a low discriminating performance on both LGA and RGA variables.

KEY WORDS: sex determination analysis, mandible, gonial angle, forensic anthropology, forensic dentistry.

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INTRODUCTION

Determination of individual sex is the foremost step of a post-mortem (PM) identification process [1]. It enables forensic experts to identify an individual using a sex-specific examination, and helps to reduce the search from a missing person [2]. The process of obtaining sex information on unidentified bodies utilizes multiple sexually dimorphic features in human anatomical structure.
Mandible is known as the strongest bone in the cranial area, and has multiple sexually dimorphic parameters, such as corpus growth [3], ramus [4], and gonial angle (GA) [5]. However, these parameters are usually acquired from radiographic or skeletal examination [6]. In some cases, PM radiograph or dental autopsy is not feasible due to ethics [7], law [8], or limited resources (e.g., limited radiograph equipment, electrical sources, mortuary, or human resources) in mass disasters [9]. Hence, a direct non-invasive examination process is needed. The importance of sex identification also plays a role in determining an individual age, especially in juveniles age group between 16 to 24 years old, where there is a significant third molar growth difference between males and females [10]. By acquiring individual sex, dental age estimation can be done accurately.

Among different parameters in the mandible, GA is the only parameter, which can be measured through a different approach, which is a direct examination with goniometer [11]. Therefore, obtaining sex information through GA measurement could resolve the need for radiographic examination [4, 12].

**OBJECTIVES**

This study aimed to assess the GA discriminative ability for sex estimation using a direct measurement method.

**MATERIAL AND METHODS**

The sample comprised of 100 individuals from Jepara District, Central Java, Indonesia, including 43 males (20.19 ± 1.88 years old) and 57 females (19.56 ± 2.16 years old), with age ranged between 16-24 years old. Purposive sampling method was used based on inclusion and exclusion criteria. Selected individuals met the following inclusion criterion: seven permanent teeth present in mandible from the first incisor to second molar without history of tooth extraction; and exclusion criteria: medical history of skeletal development disorders, severe occlusal wear, or orthodontic treatment detected. All collected data were anonymized, and participants were required to sign informed consent. Participants aged below 18 years old were represented by their parents/guardians, and followed by approval from the participant. Ethical clearance was obtained from Universitas Diponegoro Health Research Ethics Committee, number: 225/EC/KEPK/FK-UNDIP/IX/2020.

GA was measured for both left (LGA) and right (RGA) gonial angle using a goniometer. Consistency in the measurement was standardized with four reference points, which were placed on the inferior mandibular corpus and posterior mandibular ramus (Figure 1). Reference points were placed in supraglenoid, gonion, mid mandibular angle, and inferior border of the mandible below foramen mental. One examiner performed all the measurements, followed by a second measurement by the first and second examiner to verify the inter- and intra-observer reliability after one month from 10% of randomly selected participants using intra-class correlation coefficient (ICC). All data were collated using Excel, version 360 (Microsoft, Redmond, USA), and statistical analysis was completed using R, version 4.0.3.

Measured LGA and RGA from males and females were compared using Mann-Whitney U-test, and Pearson’s correlation between LGA and RGA was calculated. From each significant ($p < 0.05$) measurement parameter, binary logistic regression models were made. Area under curve (AUC) with 95% confidence interval (CI) of receiver operating characteristic (ROC) curves and Brier score were calculated to understand how well the binary logistic regression model distinguishes between the two sexes. Both AUC and Brier score value of 1 represented a perfect accuracy, and 0 showed complete inaccuracy.

**RESULTS**

The mean ICC values showed reproducibility of the measurement method, with 0.906 and 0.936, respectively for inter- and intra-rater agreements. Overall, the measurement of LGA and RGA in both sexes showed that male was higher than female. Furthermore, there was no significant difference between LGA and RGA measurements ($p > 0.05$, Table 1).

Both LGA and RGA parameters had a significant value in sex ($p < 0.05$). Pearson’s correlation coefficient reported a high linear relationship between LGA and
RGA ($r = 0.73$). Binary logistic regression model was derived separately with both predictors’ variables. Binary logistic model and the performance of each predictor variable are presented in Table 2.

None of the variables has reached an optimal AUC value of 0.75. AUC of LGA and RGA ranged between 0.62 and 0.64, with a lower bound of 95% CI ranged between 0.51 and 0.53%. ROC curve is illustrated in Figure 2. Although the parameters had significant value in sex, the accuracy of parameters’ prediction of individual sex was almost 50-50, or considered poor.

**DISCUSSION**

It is essential to understand the accuracy of direct GA measurement because it upholds the value of acquiring GA information when radiographic images or dental autopsy cannot be done due to law, ethical values, or logistical reason. Sahelangi et al. reported that it is appropriate to comply with ethical, religious, and cultural aspects in a mass disaster identification process; therefore, an invasive autopsy on human remains might be impractical due to these considerations [7]. A goniometer was chosen as a measurement tool in the present research, as Ohtani et al. reported difficulties in accessing a victim’s mouth in Tsunami victims due to law prohibition in incising dead bodies without a permit [8].

The 100 subjects selected in the current study were individuals aged 16-24 years, with an average age of 20.19 ± 1.88 and 19.56 ± 2.16 years old for men and women, respectively. The sample of juveniles were taken based on minimum variability on GA and its’ role in dental age estimation. The variability in GA’s sexual dimorphism is affected by tooth [13], edentulous status [14], and masticatory musculature [15]. Bulut et al. observed no significant difference in GA between sexes, except for old adults (60-80 years old) [16]. Furthermore, acquiring sex information on juveniles could provide additional information for dental age estimation methods, as third molar development differs significantly between sexes [17, 18].

The measurement taken from goniometer implies that males had a greater overall GA than females (Table 1). This result is in line with various research using multiple methods of GA measurement. Upadhyay et al. stated that men presented a larger GA (135 ± 1.16) than women (133 ± 2.57) using skeletal and lateral cephalometric measurements [12]. Similar findings were also found by Kharoshah et al. using computer tomographic scan (M = 122.8 ± 4.3, F = 121.1 ± 3.9), and Sandeepa et al. who applied orthopantomogram (M = 128.89 ± 6.02, F = 124.41 ± 3.18) [19, 20]. However, it must be noted that the acquired GA value differed between measurement methods and populations, as various factors, such as habits, race, ethnic, etc., may affect GA measurements [19]. Further research comparing GA value between radiographical images, cranio-metric, and direct measurements are needed.

Although both variables had significant differences between males and females, the measurement between LGA and RGA was not significantly different (Table 1). A similar finding was found by Bhullar et al. [21], and

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**TABLE 1.** Mean left (LGA) and right (RGA) gonial angle measurement in males and females using Mann-Whitney U-test

<table>
<thead>
<tr>
<th>Parameter</th>
<th>n</th>
<th>Males Mean Standard deviation</th>
<th>Females Mean Standard deviation</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>LGA</td>
<td>100</td>
<td>120.20 3.25</td>
<td>119.40 3.66</td>
<td>0.59</td>
</tr>
<tr>
<td>RGA</td>
<td>100</td>
<td>120.60 2.78</td>
<td>119.20 3.46</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 2.** Binary logistic model and sex discriminating performance of each predictor variable

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Binary logistic model</th>
<th>Significance</th>
<th>Accuracy</th>
<th>AUC (95% CI)</th>
<th>Brier score</th>
</tr>
</thead>
<tbody>
<tr>
<td>LGA</td>
<td>logit(y) = –14.48 + 0.12x</td>
<td>0.048</td>
<td>0.60</td>
<td>0.62 (0.51-0.73%)</td>
<td>0.23</td>
</tr>
<tr>
<td>RGA</td>
<td>logit(y) = –19.63 + 0.16x</td>
<td>0.015</td>
<td>0.61</td>
<td>0.64 (0.53-0.74%)</td>
<td>0.23</td>
</tr>
</tbody>
</table>

AUC – area under curve, CI – confidence interval

**FIGURE 2.** Receiver operating curve and area under curve for each predictor variable

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Gonial angle measurement
- Gonial angle left, AUC = 0.62 (95% CI: 0.51-0.73)
- Gonial angle right, AUC = 0.61 (95% CI: 0.53-0.74)
another approach suggested by Saikiran et al. was to measure LGA only [22]. Furthermore, a high correlation coefficient was found between LGA and RGA, which indicated that both parameters would create multicollinearity if used as an independent variable in logistic regression model. Therefore, we opted to derive a binary logistic regression model from both LGA and RGA separately [23]. The results for the accuracy of the method were considered inadequate, which was shown in low accuracy, AUC, and Brier score. Capitaneanu et al. indicated that for a sex determination method to be usable, AUC value needs to be higher than 0.75 [24]. Furthermore, other study reported varied accuracy using gonial angle. Abu-Taleb et al. obtained an overall accuracy of 79.6% of GA measurement in panoramic radiographs [25]. On the contrary, in Belaldavar et al. study, cephalography achieved an accuracy rate of 56.3% only [26].

The approach of conventional goniometer as a measurement tool in the present research proved that it was not a sufficient tool to discriminate between the two sexes in the terms of sensitivity. However, the results of measurements showed a significantly different value between the two sexes. Therefore, advanced approach using an electro-goniometer with higher reliability and accuracy could be considered to enhance similar methods [27].

CONCLUSIONS

The proposed direct examination method of GA shows a significant difference between males and females in Indonesian population between 16 to 24 years old. However, binary logistic model shows a low sex discriminating performance on both LGA and RGA variables. Future research should consider adding other sexually dimorphic dental parameters, such as a craniol or odontometric evaluation to improve the sex estimation performance on the predictive model.

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CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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