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Biological Identification of Skulls in Indonesian and Thai Populations: Ancestry Estimation, Sex Determination, Stature Estimation, and Age Estimation

Identificación Biológica de Cráneos en Poblaciones de Indonesia y Tailandia: Estimación de Ascendencia, Determinación del Sexo, Estimación de Estatura y Estimación de Edad

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SUMMARY: This review article will present an overview of biological profiles in forensic utilities. The biological profile of the skull in the existing literature can help to identify humans, especially if the condition of the victim found is a result of mutilation or a bomb explosion. When it comes to the precision of identifying skeletal remains, the human skull is frequently cited as being first in the estimation of age and ancestry and second in terms of sex and stature. It can be an alternative to assessing the following biological parameters: sex, age, stature, and ancestry. The implementation of biological profiles in the identification process is very important considering that some cases require the assistance of forensic anthropology. This review article shows the importance of the value of skulls. The method that can be applied is craniometry which can be used to determine sex, age, stature, and estimated ancestry. Different results will occur depending on the completeness of the skull. Therefore, estimation formulas have different accurate results. Discriminant function analysis has been performed on various measurement sets and its discriminant power has been validated by many researchers. Geometric morphometric analysis has become the main tool for shape analysis and many attempts have been made to use it in analyzing skulls. Several methods supported by technology have also been developed. It is hoped that the review article will show significant differences in results between studies in Thailand and Indonesia, even though they are in the same racial group.

KEY WORDS: Biological profile estimation; Sex determination: Age estimation; Stature estimation; Ancestry.

INTRODUCTION

The most important thing in identification is the level of accuracy. A high accuracy value can speed up the identification process. The use of the correct method supports this process quickly, especially when the condition of the victim found is a result of mutilation or a bomb explosion. Special conditions with an incomplete body are a challenge to the identification process; this study intends to obtain an identification method quickly, precisely, and accurately.

The biological profile can help process identification from the evaluation of four criteria: age at death, sex, stature, and ancestry. The human skull is often said to be first in estimation of age and ancestry, and second of sex and stature in terms of the accuracy of identification from skeletal remains(Kasikam *et al*., 2021). The characteristics of the human population are more visible in the physical size of individuals because the size of the average male is larger than the average female (Gustafsson *et al*., 2007).

The segment of the skull found was able to show the individual's profile. Ancestry can be seen from the exocranial, craniometrics, and orbital shapes, as each hereditary group has a different shape and size (Artaria, 2008; Hefner, 2016; Woo *et al*., 2018; Musilová *et al*., 2019;

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Kongkasuriyachai *et al*., 2020; Marini *et al*., 2020; Kongkasuriyachai *et al*., 2022), while sex can be seen from the craniometrics, including the mandible (Sangvichien *et al*., 2007; Rooppakhun *et al*., 2009; Guyomarc & Bruzek, 2011; Aurizanti *et al*., 2017; Patterson & Tallman, 2019; Marini *et al*., 2020; Ramamoorthy *et al*., 2020). Some sections will be very different for males and females. Age estimation can be done through suture closure, endocranial, exocranial, and lambdoid suture (Jangjetriew *et al*., 2007; Nasution, 2010; Chandra *et al*., 2015; Ruengdit *et al*., 2017, 2020), though some experts use third molars if the mandible is found (Verochana *et al*., 2016). Stature is estimated using craniometrics. The parts measured include the cranial and mandibular, as well as certain points of the Basion-Nasion-Nasal Bone, Head Length-Head Breadth, G-op, Ba-N and Ma-SN (Giurazza *et al*., 2012; González-Colmenares *et al*., 2016; Prasad *et al*., 2019).

The biological profile is part of the identification process carried out by forensic anthropologists. This is necessary for parts of decomposed remains or skeletons. The biological profile consists of estimates of sex, age, ancestry, and stature. It is very important to accurately determine the sex, as this cuts down the possibilities of searching through missing person reports in half. However, through accurate estimation of ancestry, sex determination can indicate specific populations. When the estimated ages and statures are added, the search for probabilities narrows even further. If these estimates are wrong, unidentified human remains may never be identified. Conversely, a correct estimate speeds up the identification process.

The components of this biological profile are estimates based on metric or nonmetric methods (visual observation and recording of categorical data). While age is inherently nonmetric, stature is inherently metric. Estimates of sex and ancestry can take a metric or nonmetric approach.

The development of the identification process is based on scientific profile biology. Indonesia and Thailand are mongoloids. The parameters for determining individual profiles in both populations have the same standard size through mongoloid similarity. This article will discuss how the development of methods used to identify individuals through biological profile parameters in Indonesian and Thai populations.

Qualitative vs quantitative methodology

Forensic anthropologists have a role to perform in the death investigation process, especially in the identification of skeletal remains. The analysis that needs to be done relates to biological characteristics such as sex, age, stature, and ancestry of the skeleton. The time of death, the likelihood of trauma, or the pathology that led to death can often be judged by the skeletal remains (Traithepchanapai *et al*., 2016).

The methods used in forensic anthropology are split into qualitative and quantitative. Qualitative methods are used in histological and radiographic summaries. Qualitative assessments also include skeletal investigation from histologic and radiographic evidence (Rattanachet, 2022). Existing life history records can show how individuals live their lives. For example, someone who has experienced a traffic accident and received trauma during his life is recorded through his health condition and can be seen from the results of x-rays when fractures in his body. Quantitative methods are more objective. Morphometric assessment is a quantitative approach to biological profiling (Rattanachet, 2022). Morphometrics also extends to histology and radiographs. When osteometry measurements are included, we are able to show variation in the population. For example, in the height and width of the nose (nasal index) there are significant differences between the Mongoloid, Negroid, and Caucasoid races. The method can also be applied to sex determination.

To reduce errors, new approaches modify methods to achieve high levels of accuracy. The development of science in supporting identification is very influential. Standard methods with consistency and ensuring classification between ancestry groups are the purposes of this article. Both qualitative and quantitative methods can be applied in biological profiling, especially if more in-depth research uses quantitative methods. Correlation and regression will make for a good analysis and is able to show the significance of the research.

The implications of using fragmented bone in forensic anthropology

The 2004 Indian Ocean tsunami disaster that occurred made us realize that forensic anthropologists were needed to handle cases of identification with a large number of victims (Traithepchanapai *et al*., 2016). Numerous victims and the need for individual identification require an appropriate method. The time taken for the identification process is directly proportional to the decomposition of the victim's body. Thus, the slower the process, the more difficult it is to identify victims.

The second Bali bombing in 2002 in Indonesia resulted in 202 deaths and 209 injuries (Laranono, 2006). Many victims were found with incomplete body parts. The problem was that the victims came from various regions across the country. This case shows the importance of implementing forensic anthropology in assisting the identification process. The analysis that needs to be done is related to biological characteristics such as sex, age, stature, and ancestry of the skeleton.

Ancestry estimation from the skull

Ancestry refers to the geographic area of origin. Estimation of ancestry from human skeletal remains is possible due to geographically patterned human variation. Human populations differ due to evolutionary processes such as natural selection, genetic drift, mutation, and gene flow, which collectively shape genotypic and phenotypic variation, including skeletal variation. This makes ancestry possible based on observations and measurements of skeletal variation (Christensen *et al*., 2019). Forensic anthropology involves the study of morphoscopic traits and skeletal measurements that correspond to geographically patterned genetic variation (Christensen *et al*., 2019). Ancestry estimation of skeletonized remains by forensic anthropologists is conducted through comparative means and a lack of population-specific data results in possible misclassifications (Herrera & Tallman, 2019).

Estimation of ancestry is a necessary step in the identification of bone remains. The biological profile was successfully tested on 208 individuals from two recent European populations using exocranial meshes. The original classifier was based on geometric morphometric analyses (CPD-DCA, PCA, and SVM) and was able to assess the sex of individuals belonging to one French population with an accuracy exceeding 90 % (Musilová *et al*., 2019).

Ancestry from Population American Black, White, and Optimized Summed Scored Attributes (OSSA) uses the character states of six morphoscopic traits. The traits assessed in the OSSA method include the Anterior Nasal Spine (ANS), Inferior Nasal Aperture (INA), Interorbital Breadth (IOB), Nasal Aperture Width (NAW), Nasal Bone Structure (NBS), and Post-Bregmatic Depression (PBD). Each character's state is scored on the basis of shape, its presence or absence, and degree of expression (Christensen *et al*., 2019). The American Black and American White samples comprise of 20th-century individuals from the William M. Bass Donated Skeletal Collection housed at the University of Tennessee, Department of Anthropology, Knoxville, TN. The Asian sample comprises of modern individuals from Japan, Thailand, and North America. These datasets are supplemented with additional samples from the National Museum of Natural History, including a Japanese sample from the Tokyo prefecture donated by Tokyo Imperial University to the Smithsonian Institution and Chinese crania obtained by Hrdlička come from a cannery cemetery in Karluk, Alaska. This sample is representative of the ancestry groups. Canonical discriminant analysis performed on the transformed values of the principal coordinates (CAP) applies a principal coordinate analysis using any one of the several distance measures. The application of statistical classification methods and biodistance analysis using cranial morphoscopic data has been explored here. These results demonstrate that cranial morphoscopic traits can be used to successfully assess ancestry and can provide estimated error rates (Hefner, 2016).

Research in Indonesia was conducted to determine whether the samples could be significantly differentiated from each other from a set of cephalometric data. The comparison of groups could be used in forensics for the determination of ethnic identity and/or sex (Artaria, 2008). The variables analyzed in the Cephalometric were maximum head length (g-op), maximum head breadth (eu-eu), minimum frontal breadth (ft-ft), maximum bizygomatic breadth (zy-zy), bigonial breadth (go-go), maximum physiognomic nasal breadth (al-al), nasal length (n-sn) and morphological height of face (n-gn). Correct classification could be done in 17.7 %- 83.4 % of males, and 18.4 %-86.2 % of females within each group (Artaria, 2008).

Craniometrics for ancestry estimation has a different formula, depending on whether or not a complete skull is used. Research in Thailand showed that the first formula was for a complete skull, with a predicted and correct classification accuracy of 89.3 % and tested accuracy of 91.2 %. The second formula, limited to the cranium, gave an 84.3 % predicted and correct classification accuracy and a tested accuracy of 85.3 %. The third formula for a male skull gave a predicted and correct classification accuracy of 92.0 % and a tested accuracy of 85.3 %. The fourth formula, for a female skull, produced an 89.8 % predicted and correct classification accuracy and a tested accuracy of 88.2 % (Kongkasuriyachai *et al*., 2020).

The probability of ancestry is very important when starting identification. Several previous studies have shown that using the same method with different sample conditions can produce different accuracy values. If the determination of offspring is not estimated properly, errors will likely occur in the next estimation (sex, age, stature).

Research conducted in Indonesian and Thai populations shows that several variables can be used to differentiate ancestry, for example through the cephalometric method maximum head length (g-op), maximum head breadth (eu-eu), minimum frontal breadth (ft-ft), maximum bizygomatic breadth (zy-zy), bigonial breadth (go-go), maximum physiognomic nasal breadth (al-al), nasal length (n-sn) and morphological height of face (n-gn).

Sex determination from the skull

Sex is the biological characterization of sexually reproducing species. Determination of sex from the skull and documented skeletal collections represent major populations (Caple *et al*., 2018). The female skulls are much more pedomorphic than the males. After the onset of puberty, the differences between the male and female skull become clearer as the male skull develops adult characteristics (Krishan *et al*., 2016). Sex determination is more problematic when the body is skeletonized compared to other times. If the aims of sex determination differ in paleoanthropological studies and police investigations, both fields are confronted with the same biological and methodological limits and require a high level of reliability. However, the reliability and accuracy of sex assessment from skeletal remains are dependent on the anatomical region available (Bruzek & Murail, 2006).

The main problem that forensic anthropologists have to face in identification is the specificity of population identification methods (Sangvichien *et al*., 2008; Manoonpol & Plakornkul, 2012; Rattanasalee *et al*., 2014; Sakaew *et al*., 2016; Alias *et al*., 2018; Kilmer & Garvin, 2020), especially in the case of sex determination based on skull measurements. It is generally understood that this Fordisc® computes Discriminant Functions (DF) specific to the population being counted (Guyomarc & Bruzek, 2011). Population affinity is known to be a hugely important variable when estimating sex because the manifestation of sexually dimorphic traits, body size, or social and behavioral habits differs across populations (Musilová *et al*., 2019).

Sex determination methods based on craniometrics have resulted in Portugal, France, the U.S.A, and Thailand using Logistic Regression over Linear Discriminant Analysis and Support Vector machines. Although the Portuguese, French, and American samples share a similar sexual dimorphism, the Thai sample was unsuccessful, due to a lower degree of dimorphism (Bruzek, 2014). The reliability of sex determination using Fordisc1 3.0 with 12 cranial measurements shows in globally poor reliabilities, varying between 52.2 % and 77.8 % using different options and subsamples. This data supports the rejection of Fordisc1 3.0 use in a European forensic context. A forensic tool based on discriminant function analysis is probably more applicable in the United States, where most cases can be compared to the Forensic Data Bank. Not surprisingly, the discriminant functions specific to a sample offer the best results (from 74.47 % to 86 % for the Thai and French sub-samples respectively) but are still below the 95 % threshold that is preferred when using an identification method (Guyomarc & Bruzek, 2011).

The best practical equation for sex determination with six measurements (maximum cranial length, bizygomatic breadth, biauricular breadth, nasal height, biorbital breadth, and right mastoid length) was derived from a stepwise discriminant method. This equation with 90.6 % accuracy (91.1 % in males and 90.0 % in females) can provide valuable application utilizing sex determination from the skull in the Thai population (Aljarrah *et al*., 2022). The cranium and mandible can be used to determine sex with the Jorgensenûs craniometry among Thais via a multiple logistic regression model on M5 (Nasion-basion length), M8 (Maximum breadth), M40 (Facial height), and M45 (Bizygomatic breadth) (Sangvichien *et al*., 2007). The research was shown to determine sex more accurately with a multiple logistic regression model based on 4 skull measurements (mm) i.e., nasion-basion length (M5), maximum breadth of the cranium (M8), facial length (M40), and bizygomatic breadth of the face (M45) (Sangvichien *et al*., 2007).

In Saudi Arabia, the foramen magnum has shown that using CT scan images to evaluate foramen magnum (FM) and occipital condyles measurements morphometrically for sex determination by using discriminant function analysis and to note visually the variation in shape has resulted in 472 CT scans (236 males and 236 females; age range, 18—72 years) that was estimated with eight dimensions of the FM and occipital condyle. The most common shape of FM was hexagonal, while the tetragonal shape was the least common type. The coefficient of reliability (R) was high, ranging between 0.89 and 0.99. All eight measurements (the FM length and width, FM index, FM area, and the width and length of right and left occipital condyles) were significantly greater in males than females. Univariate discriminant function showed an accuracy rate varying from 61 % to 66.6 % based on FM or occipital condyles measurements. The multivariate analysis of FM and occipital condyle measurements increased the overall accuracy rate of sex determination to 71.6 % (Aljarrah *et al*., 2022).

Research in Indonesia has significant differences in the craniofacial linear measurements of men and women in lateral cephalometric radiographs. The subjects consisted of 50 males and 50 females who met the inclusion criteria. In this study, Technical Error Measurement (TEM) was done to test inter-observer reliability and intra-observer reliability. The measurement results for all 10 of these craniofacial parameters were greater in males than in females(Aurizanti *et al*., 2017). Another research in Indonesia was done on the indigenous people of the Sub-Dayak Kenyah tribe who live in Pejalin Village, Tanjung Palas Districts, Bulungan Regency, in the North Kalimantan Province. The measurement of the nasal height (from nasion (n) to subnasale (sn)) and nasal breadth (maximum breadth from ala left to right) was recorded. The result was mean and SD of the nasal height in males was 51.33 ± 3.92 mm, whereas females showed 49.34 ± 3.97 mm (Marini *et al*., 2020).

Age estimation from the skull

Age estimation is an important element in the identification of individuals when human skeletal remains are found. This is important for constructing biological profiles in the process of identifying individual forensic cases or for establishing profiles of past population deaths (Yuniarti *et al*., 2013). However, it is argued that the reliability of the estimate is too dependent on the demographic profile of the Western reference samples from which the methods are generally developed. The rate of bone remodeling and degeneration is known to differ between European, African, and Asian populations. Age estimation of unidentified adult human remains relies on standards that have used reference populations of known age, sex, and ancestry to correlate various signs of skeletal degeneration and remodeling to different life stages and their associated chronological age ranges. The most accurate age estimations will always be achieved using standards developed on a reference sample that is the same as the study population, as skeletal growth and degeneration are non-uniform across time and regions due to complex relationships with genetics, environment, socioeconomics, and behavioral influences (Pedersen & Domett, 2022).

Cranial sutures have long been used as indicators for age estimation because they vary in their timing of closure with age (Kampan *et al*., 2014). Cranial sutures are the coronal, sagittal and lambdoid sutures on the ectocranial surface. Research has shown that the time of cranial suture closure is one of the indicators of age at death, but its progression varies greatly. Using composite scores helps to diminish this variation. Information on suture closure is useful when other criteria are not available or when being used in conjunction with other attributes. Endocranial sutures start closing before ectocranial sutures. Furthermore, endocranial closure is more related to age than the other and no difference between sexes can be found. Using the closure of each suture separately to determine the age at death may not be appropriate, while using the sum of suture scores reduces variations (Jangjetriew *et al*., 2007). Other research has shown that the accuracy percentage was higher in males than females. Accuracy in estimating age was considerably higher in the group of 50+ years than in the younger individual groups, especially in males when the accuracy of prediction approached 100 %. Most of the cases were labeled with more advanced phases than actual age phases for males. In contrast, females were mostly estimated into lower age phases than their true phases (Ruengdit *et al*., 2017).

Studies on age estimation methods using cranial suture closure were validated on publication. Famous methods used were Acsadi and Nemeskeri (1970), with suture location on Endocranial vault and Ectocranial vault, Meindl and Lovejoy (1985) on Ectocranial vault and Lateral-anterior, Perizonius (1984) on the Young system and Old system, Masset (1982) on Endocranial vault and Ectocranial vault, Baker (1984) on Endocranial vault, and Mann (1991) on Maxillary. The relationship between suture closure and age was so erratic in some studies that fluctuating bias, high inaccuracy, and a wide range of estimated ages make cranial sutures appear to be fairly useless in forensic contexts (Ruengdit *et al*., 2020).

Stature estimation from the skull.

Estimating the stature of human skeletal remains has taken long time history in physical anthropology (Gocha *et al*., 2013). It can tell us about health and well-being in the past, as well as highlight growth and development trends at the population level (Gocha *et al*., 2013). Stature estimation represents one of the most important features in biological profiles, meaning anthropometric and medical investigations (Untoro & Putri, 2019). Stature has a biologically proportional correlation with other parts of the human body (Giurazza *et al*., 2012). The skeleton can help estimate the stature of an individual with genetically predetermined and inherent characteristics that can be evaluated (González-Colmenares *et al*., 2016).

A study of stature estimation involving 200 Caucasians from an Italian population with the use of CT scans at a mean age of 64.5 years was conducted. In this sample, mean height was 167cm for males and 156cm for females. The correlation coefficient for height and Basion-Nasion (Ba-N) was 0.53 and for Basion-Nasal Bone was 0.50. The equation based on Ba-N distance generates poorer results of stature estimation; the differences between the estimated statures and the measured values are greater than 10 cm in 25 % of all cases and the difference ranges from -4 cm to +4 cm in 55 % of cases. Similar results are obtained using the equation based on the Ba-N distance (Giurazza *et al*., 2012).

Research from the bone collection of the contemporary Colombian population owned by the National Institute of Legal Medicine with 54 male and 16 female samples resulted in measurements of N-M ($p < 0.001$) and G-Op, Ba-N, Ma-SN ($p < 0.05$), which correlate with accurate stature for males. The correlation between these measurements with stature for females was not significant (González-Colmenares *et al*., 2016).

To prove estimated stature from Head Length (HL) and Head Breadth (HB), a study comprised of a total of 300 (187F and 113M) young and healthy students in age range 18-25 years in Medical College, Indore, Madhya Pradesh, India was done. The mean height in males was 171.33±6.89 cm and that in females was 157.34±5.31 cm. The mean HL and HB in males were 18.19±0.81 cm, 13.48±0.79 cm and in females it was 17.05± 0.66 cm, 12.81±0.67 cm. Pearson's correlation coefficient was significant for HL and HB in female subjects and HL in male subjects, whereas it was not significant for HB in male subjects (Prasad *et al*., 2019).

Craniometrics for stature estimation in the Thai Population has shown that all cranial and mandibular measurements are significant with Pearson correlation. Their correlation coefficient (r) values range from 0.16 to 0.60. The standard error of estimation (SEE) value ranges from 6.22 – 7.32 cm. The accuracy of the formula is 68 % for males and 60 % for females, with an error prediction of +/- 0 to 5 cm.

Somatometry of the skull can be used to estimate stature. 124 Japanese cadavers, comprising 77 males and 47 females, show that somatometry of the skull was performed on diameter (distance between glabella and external protuberance) and circumference (length around the skull through two points: the glabella and the external protuberance). The correlation coefficient of stature for various parameters of the skull ranged from 0.32 to 0.53. If subjects aged seventy or more were excluded, these values were from 0.38 to 0.60. The regression equations for the estimation of stature from the skull were obtained. Their S.E.E. were 6.96 cm in males, 6.59 cm in females and 7.95 cm in both sexes. If subjects aged seventy or more were excluded, these values became 6.80, 5.50, and 7.08 cm, respectively (Chiba & Terazawa, 1998).

Clearly, future work is needed to determine the nature and extent of biological variation in stature and body proportions (Gocha *et al*., 2013).

DISCUSSION

In the identification process, the first thing that is always done is DNA and fingerprint analysis. When meeting a victim who cannot be identified in either of these ways, another appropriate identification method is needed to identify the individual.

Table I shows several studies regarding the biological profile of the skull. Details from several studies show that in terms of ancestry parameters, each population group has different and very prominent criteria. The significance continues in the determination of sex. According to craniometry, the results indicated that the dimensions of a male skull were larger than that of a female (Rooppakhun *et al*., 2009). Lateral skull and cranial outlines with size information retained can be estimated as ancestry and sex. Classification accuracy dropped slightly when mandibular measurements were removed from the analysis (86–90 % with five skull measurements versus 83–86 % without the mandible) (Caple *et al*., 2018).

The cranial index became a popular measure in racial studies to categorize human groups in the late nineteenth century. Variation of the cranial shape is known to be associated with specific ancestral groups, although there is still controversy surrounding the cranial index. In the study of the modern Thai population, the brachycranic type had a frequency of 42.7 %, followed by the mesocranic (27.03 %) and hyperbrachycranic types (25.59 %). The rarest type observed in this study was the dolichocranic type (4.32 %). The cranial index of Thai females in the current study was significantly different from that of modern Korean females. For Thais, central Thais, Northeastern Thais and Korean samples, there is no significant difference (Woo *et al*., 2018).

The orbital shape is one of the most ambiguous features for morphological study in ancestry estimation. Recent research used digital image analysis to obtain more objective results. Samples from Thai and Japanese skulls had the formula for predicted and cross-validated accuracy of 80.7 % and a tested accuracy of 86.8 %. This methodology potentially increases the utility of orbital shapes for ancestry estimation (Kongkasuriyachai *et al*., 2022).

Research in Indonesia using cephalometrics showed group comparison results that can be used in forensics, including the classification of determining the correct sex (Artaria, 2008; Marini *et al*., 2020). Of all individuals, 84 % of females and 86 % of males were classified accurately (Artaria, 2008). Craniofacial linear measurements include face height (N-ANS), total facial height (N-Me), frontal sinus height (FsHt), mandibular ramus height (Ar-Go), lower face height (ANS-Me), mandibular body length (Me-Go), mastoid width (MaWd), mastoid height (MaHt), the depth of the face (Ba-ANS), and the length of the craniofacial base (Ba-N) (Aurizanti *et al*., 2017). Lateral cephalometric radiography showed that the linear measurements of 10 cephalometric parameters were higher in males than females, so it can be used to determine sex (Aurizanti *et al*., 2017).

Table I. Summary of findings for biological identification using skulls.

Author	Variable Sample	Biological Parameter	Populations	Methods	Accuracy
Musilová *et al*., 2019	Exocranial	Ancestry	European (French)	Geometric Morphometric	90 %
Hefner, 2016	Cranial	Ancestry	The American Black and white, Asian (Japan, Thailand, Chinese, North America)	Cranial Morphoscopic	-
Kongkasuriyachai, 2020	Orbital Shape	Ancestry	Thailand and Japanese	Morphometric	86.8 %
Kongkasuriyachai *et al*. 2022	Cranial	Ancestry	Thailand and Japanese	Craniometric	91.2 %
Woo *et al*., 2018	Cranial	Ancestry	Thailand and Korea	Cranial Index	-
Artaria, 2010	Cranial	Ancestry, Sex	Indonesia	Cephalometric	84-86 %
Marini *et al*., 2020	Nasal	Ancestry, Sex	Indonesia	Nasal Index	-
Guyomarc & Bruzek, 2011	Cranial	Sex	Thailand and French	Craniometric	74-86 %
Piyawinitwong *et al*., 2007	Cranial and Mandible	Sex	Thailand	Craniometric	88.8 %
Ramamoorthy *et al*., 2020	Cranial	Sex	Thailand	Craniometry RadiAnt DICOM	70-81.4 %
Rooppakhun *et al*., 2009	Cranial	Sex	Thailand	3D CT Craniometric	92.3 %
Tallman *et al*., 2019	Cranial	Sex	Native America and Thailand	Craniometric	74-94.4 %
Aurizanti *et al*., 2017	Cranial	Sex	Indonesia	Craniofacial (Cephalometric Radiograph)	-
Jangjetriew *et al*., 2007	Endocranial Closure	Age	Thailand	Suture Closure	-
Ruengdit *et al*., 2017	Suture Closure	Age	Thailand	Suture Closure	-
Ruengdit *et al*., 2020	Suture Closure	Age	Thailand	Suture Closure	-
Chandra *et al*., 2015	Lambdoid Closure	Age	India	Suture Closure (panoramic radiograph)	-
Nasution, 2010	Lambdoid, Endocranial, and Ectocranial Closure	Age	Indonesia	Suture Closure	-
Verochana *et al*., 2016	Third Molar	Age	Thailand	Chronological Age	75 %
Inchai *et al*., 2016	Cranial and Mandible	Stature	Thai;and	Craniometric	68 %
Giurazza *et al*., 2012	Basion-Nasion-Nasal Bone	Stature	Caucasian	Craniometric	-
Prasad *et al*., 2019	Head Length (HL) and Head Breadth (HB)	Stature	India	Craniometric	-
González-Colmenares *et al*., 2016	G-Op, Ba-N, Ma-SN	Stature	Colombian	Craniometric	-
Chiba & Terazawa, 1998	Glabella, and External Protuberance	Stature	Japanese	Craniometric	-

Although several studies have been performed on skulls, mostly to evaluate sex and ancestry, not many studies have been performed to estimate stature. In many cases, when only the cephalofacial region is available, it is very difficult to identify the body. In these situations, stature prediction from cephalofacial marks is helpful in forensic studies even if it is controversial and has contrasting opinions (Giurazza *et al*., 2012). Such research should take into account a variety of different factors, including ethnic admixture, ecogeographic adaptations, and different life and population histories (Gocha *et al*., 2013).

Using metric analysis, more than 85 percent of osteometric parameters in males were significantly higher than in females in Ongkana & Sudwan (2009). Therefore, they could be used to distinguish the gender of Thai mandibles. Further investigation of the correlation between sex and either metric parameters or morphology should be conducted to obtain a specific standard for the Thai population (Ongkana & Sudwan, 2009). Study of the metric differences in sexual dimorphism between pre-contact Native Americans and modern Thai individuals would establish population-specific discriminant function equations to assist in sex. For the Thai populace, classification accuracies show that males have 88.2 % accuracy for the cranium and a 90 % accuracy for the mandible. This differs from females, which have 94.4 % for the cranium and 74 % for the mandible. It was shown that female mandibles were not correctly classified because linear regression classification equations were under 80 % (Patterson & Tallman, 2019).

For decades, cranial suture closure was one of the most commonly used methods of age estimation. However, it is often viewed with caution as its reliability is debated (Ruengdit *et al*., 2017). On the other hand, age estimation based on the obliteration of the sutures is considered to be an applicable endocranial measurement (Jangjetriew *et al*., 2007; Nasution, 2010; Ruengdit *et al*., 2017). Suture closure begins with the endocranial and extends outward to the ectocranial. The timing of suture closure is uncertain, but the endocranial is more reliable because the ectocranial closes slower and not to completion. Therefore, endocranial closure is more related to age estimation (Nasution, 2010). Other studies proved that the lambdoid suture was very effective and will be a practical tool for age assessment in mortals through modified reverse panoramic radiographs (ectocranial). Moreover, results show that significant difference was observed between the age group and suture closure. A correlation coefficient of 0.570 was obtained and was interpreted as good correlation between the age and suture closure status with a P value of <0.001 (Chandra *et al*., 2015).

Stature estimation using craniometrics has an accuracy value of 68 % in ¡¡¡An aforementioned study of the Italian population, where mean height was 167cm for males and 156cm for females, the correlation coefficient for height and Basion-Nasion was 0.53. The Basion-Nasal Bone measured 0.50. The equation based on Ba-N distance generates poorer results of stature estimation (Giurazza *et al*., 2012). In Prasad *et al*. (2019), the value of the correlation coefficient was significant for Head Length (HL) and Head Breadth (HB) in female subjects, but HL and HB in male subjects did not prove significant in male subjects.

The review article showed that the radiograph method was accurate. Research in Indonesia showed a significant difference in craniofacial linear measurements. The sample of 50 males and 50 females were divided into two age groups: 20–24 years and 25–40 years. Lateral cephalometric radiography showed that the linear measurements of 10 cephalometric parameters were higher in males than females, so it can be used to determine sex (Aurizanti *et al*., 2017). Using logistic regression analysis, 3D CT craniometry can be used to determine sex among Thais. According to craniometrics, results indicated that the dimensions of a male skull were larger than that of a female. 4 of 21 cranial measurements displayed insignificant ($p < 0.05$) sexual dimorphism (maximum frontal breadth, anterior interorbital breadth, nasal breadth, and palatal length) (Rooppakhun *et al*., 2009). Overall accuracy was 92.3 %. The accuracy of males and females respectively were 92.85 %, and 91.42 % (using the cut-off point for $P = 0.5$). This explanation can be seen through the nasion-basion length (NA-BA), maxillary breadth (ZMl -ZMr), upper facial height (NA-PR) and palatal length (OR-STA) as the best variable to study.

The research revealed an advanced methodology using data obtained from three-dimensional computed tomography (3D CT) to evaluate the craniometric data of the Thai population. The research showed that Thai males were larger than Thai females with a statistically significant difference, especially in the maximum cranial length, basion-bregma height, nasion-basion length, nasion-bregma length and bizygomatic breadth parameters ($p << 0.001$). In addition, the craniometric data based on Thai skulls of the people in the northeast region was different from the people in the central region. Furthermore, the linear regression equations obtained from the pairwise parameter proved useful to predict the craniometric parameters in forensic medicine (Rooppakhun *et al*., 2010).

When using radiographs, 2D results have a higher level of accuracy compared to 3D. This is because the 3D image is able to penetrate other parts so that the point determined in the measurement often coincides with other parts. This leads to human error.

Table I shows several previous studies that have proven methodology and accurate results, and others that need to be further developed. Craniometrics can be used for sex determination, age, stature, and ancestry estimation. A different result would occur if a complete skull was used. That is why the formula estimation has a different result for accuracy.

Several methods developed by previous researchers have results that need to be developed further. Results with high accuracy from (75 % to 94 %) can be used as a reference in developing the identification process. Research with an accuracy of less than 75 % does not automatically invalidate it. However, some errors from the methodology and/or samples used could be present. A further round of reviews, with initial testing used as a benchmark, could be used in order to achieve a high accuracy value.

Developments in the identification process are also expected to be supported by advancing technology. The results of the research can be used as data for technology development. The more developed the identification process, the easier and faster the determination of individual biological profiles.

CONCLUSION

The implementation of the biological profile during the identification process is very important with several cases that require the aid of forensic anthropology. The significant value of the application of the method in showing the individual's biological profile is very helpful in cases of natural disasters, terrorism, murder, and mutilation, when the victim's condition is incomplete, or only a skeleton remains. As reviewed in this article, the application of biological profile identification through the skull is strongly influenced by ancestry or origin through geographic areas. Each population group has different criteria that can show the characteristics of its ancestry. This follows other biological profile parameters such as sex, age, and stature.

This review article shows the significant value of the skull. The method that can be applied is craniometric, which can be used for sex determination, age, stature, and ancestry estimation. A different result would happen depending on the completeness of the skull. That is why the formula estimation has a different result for accuracy. Discriminant function analysis has been conducted on various sets of measurements and its power of discrimination has been validated by many researchers. Geometric morphometric analysis has become a major tool for shape analysis and many attempts have been made to use it to analyze the skull. The existence of a review article is expected to be able to show significant differences in results between studies in Thailand and Indonesia, even though they are in the same racial group. The analysis of data from unknown skeletons is presented and freely available for use by practitioners of forensic anthropology.

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SARI ANJANI, R. C.; DYAH ARTARIA, M.; SINGSUWAN, P.; ARUNORAT, J. & MAHAKKANUKRAUH, P. Identificación biológica de cráneos en poblaciones de Indonesia y Tailandia: estimación de ascendencia, determinación del sexo, estimación de estatura y estimación de edad. *Int. J. Morphol., 42(1)*:137-146, 2024.

RESUMEN: Este artículo presenta una descripción general de los perfiles biológicos en las utilidades forenses. El perfil biológico del cráneo en la literatura existente puede ayudar a identificar a los humanos, especialmente si la condición en la que se encuentra la víctima es el resultado de una mutilación o la explosión de una bomba. Cuando se trata de la precisión en la identificación de restos óseos, el cráneo humano se cita con frecuencia como el primero en la estimación de edad y ascendencia y el segundo en términos de sexo y estatura. Puede ser una alternativa para evaluar los siguientes parámetros biológicos: sexo, edad, estatura y ascendencia. La implementación de perfiles biológicos en el proceso de identificación es importante considerando que algunos casos requieren la asistencia de la antropología forense. Este artículo de revisión muestra la importancia del valor de las cnezas óseas. El método que se puede aplicar es la craneometría para determinar el sexo, la edad, la estatura y la ascendencia estimada. Se pueden obtener diferentes resultados dependiendo de la integridad del cráneo. Por lo tanto, las fórmulas de estimación tienen resultados precisos diferentes. Se ha realizado un análisis de función discriminante en varios conjuntos de medidas y muchos investigadores han validado su poder discriminante. El análisis a través de la morfometría geométrica se ha convertido en la principal herramienta para el análisis de formas y se ha utilizado frecuentemente en el análisis de cráneos. También se han desarrollado varios métodos apoyados en la tecnología. Se espera que este trabajo muestre diferencias significativas en los resultados entre los estudios realizados en Tailandia e Indonesia, aunque pertenezcan al mismo grupo racial.

PALABRAS CLAVE: Estimación del perfil biológico; Determinación del sexo; Estimación de la edad; Estimación de estatura; Ascendencia.

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