นิพนธ์ต้นฉบับ . Original Article

การระบุเพศจากกระดูกขากรรไกรล่างในประชากรไทยภาคตะวันออกเฉียงเหนือ: เปรียบเทียบระหว่างการวัดกระดูกโดยตรงแบบดั้งเดิมและจากภาพถ่ายทางรังสีทางการแพทย์

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Sex Determination from the Mandible of the Northeastern Thai Population: Compared between Conventional and Radiographic Measurements

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บทคัดย่อ

หลักการและวัตถุประสงค์: นักนิติมานุษยวิทยาสามารถระบุเพศของบุคคลจากโครงกระดูกได้โดยใช้กระดูกขากรรไกรล่างซึ่งเป็นวิธีการหนึ่งในการระบุเพศจากโครงกระดูก เนื่องจากกระดูกขากรรไกรล่างเป็นกระดูกที่แข็งแรงทนทานและยากต่อการเสื่อมสลาย อีกทั้งกระดูกสามารถบอกได้ถึงอายุ และเพศได้ ดังนั้นผู้วิจัยจึงเลือกกระดูกขากรรไกรล่างมาใช้ในการระบุเพศในการศึกษาครั้งนี้ วัตถุประสงค์การศึกษาครั้งนี้เพื่อเปรียบเทียบลักษณะกระดูกขากรรไกรล่างในประชากรไทยจากกระดูกแห้งด้วยการวัดระหว่างเพศชายและหญิง พร้อมทั้งเปรียบเทียบความแม่นยำจากการระบุเพศจากภาพถ่ายทางรังสีด้วย

วิธีการศึกษา: กระดูกขากรรไกรล่างแห้ง ในการวัดทั้งหมด 100 ชิ้น เพศชาย 50 ชิ้น และหญิง 50 ชิ้น โดยทำการวัดทั้งหมด 10 ตำแหน่ง และนำภาพถ่ายรังสีทั้ง 100 ชิ้น มาวิเคราะห์ 4 ตำแหน่ง

ผลการศึกษา: จากการศึกษาพบว่าการวัดกระดูกแห้งขากรรไกรล่างมีค่าเฉลี่ยในเพศชายมากกว่าหญิงอย่างมีนัยสำคัญ และพบว่าสมการที่ใช้ในการจำแนกเพศมีความแม่นยำสูงสุดเท่ากับร้อยละ 76.1 และจากการวัดจากรังสีทางการแพทย์พบว่าสมการที่ใช้ในการจำแนกเพศมีความแม่นยำเท่ากับร้อยละ 70.0

สรุป: วิธีการวัดกระดูกแห้งและการวัดจากภาพถ่ายรังสีของกระดูกขากรรไกรล่างสามารถนำไปใช้ในการประเมินเพศและสามารถใช้ทดแทนกันได้เนื่องจากมีค่าความแม่นยำและค่าเฉลี่ยในตำแหน่งวัดใกล้เคียงกันในทั้งสองวิธี

คำสำคัญ: กระดูกขากรรไกรล่าง, การระบุเพศ, ภาพถ่ายทางรังสี

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Abstract

Background and Objective: Forensic anthropologists can determine the gender of an individual from skeletal remains by using the mandible as an alternative method of identifying the skeleton's sex. The mandible is quite durable and not easily deteriorate, making it a reliable tool for gender and age determination.

Methods: Dried mandibles were selected for analysis. A manual conventional measurement was used to compare the characteristics of the mandible in the Northeastern population of Thailand distinguishing between males and females. Furthermore, the researchers compared the ability of computed tomography (CT) images to determine sex with conventional manual measurements. A total of 100 dry mandibles were used for this study, with 50 belonging to males and 50 to females. 10 variables were measured by using conventional method and there were 100 CT scan images analyzed in relation to four variables.

Result: The mean values of mandibular measurements were greater in males, when compared to females. According to dried bone analysis, the equation for sex determination was the most accurate at approximately 76.1%, and radiographic image was the highest accuracy of approximately 70.0%.

Conclusion: The results of this study showed that when it comes to be determined for the sex of individuals using the mandible, both methods are interchangeable because a similar level of accuracy and the mean values of measurements can be found in two methods

Keywords: mandible, sex determination, radiographic images

Introduction

Human identification is necessary for official investigators to establish the identity of the deceased. However, many crime scenes only contain skeletal remains, making identification difficult. In these circumstances, forensic anthropology knowledge is crucial since it can provide the information that might be contained in skeletal remains, including gender, race, height or age at the time of death, and the details regarding the physical appearance of the deceased. An individual's bones could contain a wide variety of information that could be useful in a variety of situations. Skeletal investigations are very useful in determining a person's gender, which is one of the most important outcomes. During the investigation or examination of bones, it may be necessary to examine several bones together in order to determine the gender of the bones. For example, the morphology of the pelvis and skull may be used to determine the gender.[1,2] An example of this is the size of the mastoid process, which is just one of the many parts of the skull that can provide information about a person's gender based on the shape of the skull[3], a ridge on the external occipital protuberance[4], an individual's forehead shape[5-7], as well as the appearance of the orbit or the eye socket.[7,8] In addition, the hip bones or pelvis can be used to indicate the sex of a person as well.[9-11] In order to evaluate the bones that were exhibited for sex assessment as examples, examiners need considerable expertise. The reason for this is that some bone areas require qualitative examination. A large bone ridge or process, for instance, is more likely to be present in men than in women, e.g. a prominent bone ridge or process. A number of other bones have also been included in previous studies in order to identify the genders of the skeleton, including the sternum[12], femur[13], calcaneus[14] and lumbar vertebrae.[15,16] Numerous studies have been conducted on diverse populations over the years. As there was a shortage of data regarding this part of the Thai population (Northeast), the mandible was chosen for the purpose of assessing sex. Among the many characteristics that make the mandible unique from other bones are its large size, its durability, and its resistance to decay, which make it different from any other bone. Additionally, mandibles are commonly found at crime scenes as pieces of bone that can also be used to aid in the identification of the sex and age of a particular skeleton, depending on the quality of the bone found at the scene. Because of the unique characteristics of this bone, it is considered one of the most suitable for the identification of humans, due to its distinctive morphology.[17] There are conditions that must be complied with selection of the mandible in this study, such as the absence of any lesions or deformity.

Moreover, many studies have been conducted in the past involving the use of medical radiographs to identify sex in a variety of occasions, various methods have been employed in these studies to aid the identification of gender.[18-20] A number of factors, such as whether the corpse is decaying or if fragments of the burned body can be found, may contribute to the difficulty in determining the condition of the body.[21,22] In view of the fact that it is difficult to determine a person's gender based on their external appearance, it has alternative choice to determine a person's sex from their bone. As a result, radiography plays a useful role in identifying the gender when it comes to these situations. Due to the fact that medical radiography is considered a useful alternative option that can be used in the analysis of sex identification, this is an interesting alternative option. Thus, an objective of the present study aim to compare the assessment of sex based on conventional manual measurements of dry bones in Thailand's Northeastern region with that based on imaging data generated by mandibular radiography.

Materials and Methods

In this study, the dried mandible used for the experiment were from the Unit of Human Bone Warehouse for Research (UHBWR), Department of Anatomy, Faculty of Medicine, Khon Kaen University. This study was approved by the Center for Ethics in Human Research, Khon Kaen University (HE661238). Total 100 dried mandibles were measured, of which 50 were from females and 50 were from males, for the purposes of this study. The age range of the participants who had donated their bodies for research was between 20 to 80 years old and a total of 100 subjects were analyzed using CT scan images obtained from the CT scans, of which 50 were females

and 50 were males from the Department of Radiology, Srinakarind Hospital, Faculty of Medicine, Khon Kaen University. As part of our experiment, digital Vernier calipers were used to measure the distance between the two dry mandible points into 10 different variables (Figure 1) as follows:

M1: Chin height (id-ng), the distance from the infradentale (id) to the gnathion (gn).

M2: Height of the mandibular body (HMB), the distance from the alveolar process to the lower edge of the mandible perpendicularly.

M3: Breadth of the mandibular body (BMB), the distance from the widest point of the mental foramen perpendicular to the long axis of the mandibular body.

M4: Bigonal width (go-go), the distance between the right and left of the gonion (go).

M5: Bicondylar breadth (cdl-cdl), the distance between the highest point of the two condylar processes.

M6: Minimum ramus breadth (MIRB) The minimum distance of the ramus.

M7: Maximum ramus breadth (MARB) The widest distance of the ramus, measured from the anterior point of the ramus to the posterior point on the mandibular condyle.

M8: Maximum ramus height (MARH) measures the distance from the highest point of the mandibular condyle to the gonion (go) region.

M9: Mandibular length (ML) The distance of the side of the chin at the midpoint to the posterior edge of the mandibular angle.

M10: Bicoronoid breadth (cln-cln), distance between the highest point of the two coronoid processes.

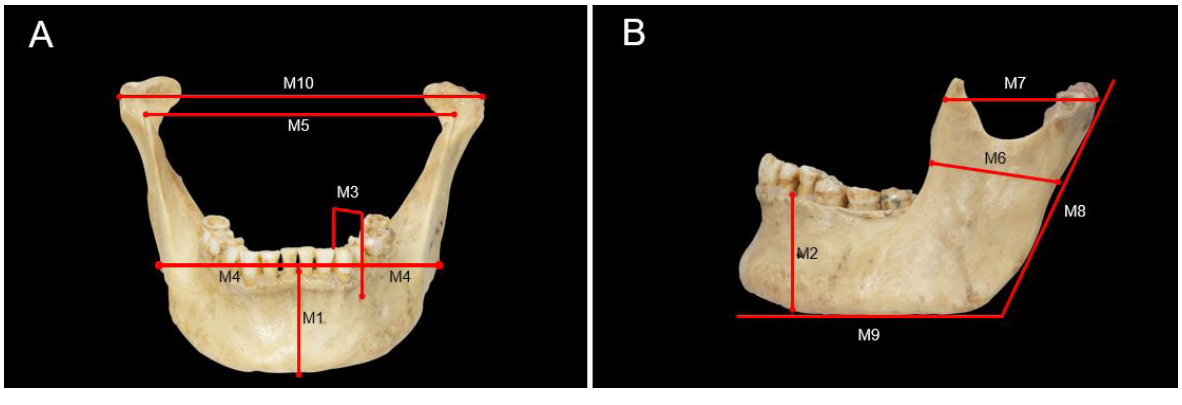

Figure 1 The M1-M10 measurement point on mandible; A: the measurement point at anterior view of mandible B: the measurement point at lateral view of mandible.

According to the research, during the measurement process using medical radiographs (CT scan), the researchers measured the following variables in relation to the medical radiographs which show in Figure 2 and consist of M4: Bigonal width (go-go), M5: Bicondylar breadth (cdl-cdl), M6: Minimum ramus breadth (MIRB), M7: Maximum ramus breadth (MARB), which the measurement is taken at the same point as when measuring the dried mandible.

Once all, the variables had been measured and recorded, a comparison was made between the means of males and females in each of the two groups based on the collected data, which are the dried mandible group as well as the radiography group, and then the results were analyzed and summarized. In order to find out whether there was a significant difference between the samples of males and females, it was decided to analyze the discriminant function analysis to determine if there were any significant differences between them. Then, the researchers used discriminant function analysis to compare the differences between males and females to create a univariate discriminant function and multivariate discriminant function equation by stepwise method at the level of statistical significance at $p < 0.05$. During the construction of the equations, it was decided to include some variables in the equation construction process. Only variables that

exhibited statistically significant differences in sex discrimination were incorporated into the calculation of equation accuracy. Furthermore, in order to compare the mean values of dried bone samples and radiographs between the two groups of the same gender, an independent t-test was used to compare the means between the two groups.

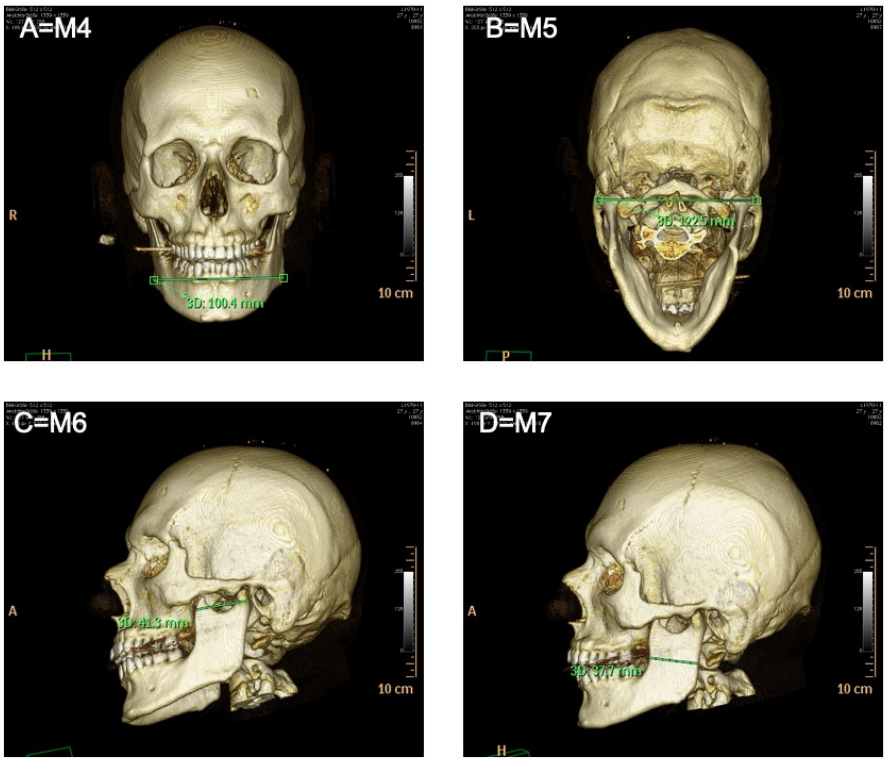

Figure 2 The M4-M7 measurement point on mandible; A (M4): Bigonal width (go-go), B (M5): Bicondylar breadth (cdl-cdl), C (M6): Minimum ramus breadth (MIRB) and D (M7): Maximum ramus breadth (MARB)

Results

The results showed that there were significantly different between the dried mandibles of both sexes on four out of the 10 variables found in the study. The variables included in this group are M5, M7, M8 and M9, respectively. The following table illustrates the variables and the results obtained for each of the variables, as shown in the Table 1.

Table 1 The mean, standard deviation (SD) in males and females and p-value of sample variables in dry mandibular measurement.

Variables	males		females		p-value
	mean (mm.)	SD	mean (mm.)	SD	
M1	28.81	3.62	27.71	3.77	0.361
M2	27.64	3.65	26.39	3.08	0.284
M3	12.43	1.45	12.00	2.88	0.514
M4	98.31	6.90	95.57	4.73	0.197
M5	123.14	5.50	115.67	7.68	0.001*
M6	35.07	4.07	33.65	4.90	0.319
M7	44.59	2.46	42.49	3.00	0.019*
M8	65.34	6.05	61.00	5.36	0.029*
M9	89.07	5.68	84.55	4.38	0.013*
M10	98.80	6.31	96.70	4.67	0.282

According to the results as shown in Table 1. There were four variables in the conventional measurements of dried mandibles that showed statistically significant differences ($p < 0.05$) between males and females. This was based on the conventional measurement. There were four variables: M5, M7, M8 and M9. In the next phase of this study, the equation for predicting sex was formulated. Based on the sex prediction equation, it was calculated whether the sex prediction equation could accurately predict the sex of both males and females. The details of the information are provided in Table 2. A method for applying sex prediction equations to sexual dimorphism prediction. The values of the unknown mandible bones were substituted into equations for both genders when measured at the points of interest. The questionable bones have a greater probability of sex if the resultant value of the sex equation is higher and there is also the percentage accuracy of the prediction equation that can be seen in Table 2.

Table 2 The equations derived from the discriminant analysis in the group of dried mandible samples.

Variable	Sex prediction equation	Percentage of accuracy rate
M5	Male = 3.236(M5) - 199.955 Female = 3.040(M5) - 176.506	76.10%
M7	Male = 6.503(M7) - 145.676 Female = 6.197(M7) - 132.363	60.90%
M8	Male = 1.897(M8) - 62.657 Female = 1.771(M8) - 54.697	69.60%
M9	Male = 3.106(M9) - 139.025 Female = 2.948(M9) - 125.340	67.40%

A study in medical radiographs samples has shown that the mean differences between the male and female samples, as well as the mean differences between them, were also greater in males as compared to females, according to the results of the study based on medical radiographs. There was also a significant difference between the sex dimorphism of measurements obtained from our radiographic imaging study that revealed a significant difference ($p < 0.05$) between males and females. It was found to be present in three of the four variables comprising of M4, M5, and M7, as can be seen in Table 3.

Table 3 The mean, standard deviation (SD) in males and females and p-value of sample variables measured from medical radiographs.

Variables	Males		Females		p-value
	mean (mm.)	SD	mean (mm.)	SD	
M4	104.32	15.73	93.92	4.88	0.008*
M5	121.74	6.14	115.66	8.07	0.011*
M6	32.49	5.23	29.75	7.97	0.208
M7	43.64	5.76	40.30	4.28	0.045*

Using discriminant analysis, this study was able to analyze the data to come up with an equation for sexual prediction based on the data. The researchers discovered that M4 had the highest gender prediction accuracy out of all the variables analyzed. As a result of the measurement of this variable, we found that the accuracy was 70.0%. Moreover, it was found that multivariate discriminant functions have 77.5% accuracy based on stepwise method when used. Compared to any equation for a univariate discriminant function, it was higher than any other equations according to Table 4 below.

Table 4 The equations derived from the discriminant analysis in the group of CT scan samples.

Variables	Sex prediction equation	Percentage of accuracy rate
M4	Male = 0.769 (M4) - 40.824 Female = 0.693 (M4) - 33.225	70.00%
M5	Male = 2.368 (M5) - 144.807 Female = 2.249 (M5) - 130.758	67.50%
M7	Male = 1.698 (M7) - 37.732 Female = 1.568 (M7) - 32.294	65.00%
Multivariable using stepwise method	Male = 0.824 (M4) + 1.827 (M7) – 83.512 Female = 0.743 (M4) + 1.684 (M7) – 69.523	77.50%

In addition, based on the analysis of the data collected in this study, it appears evident that there does not appear to be a significant difference in mean values between groups in which samples were taken from conventional measurements taken on a dry mandible, as compared to groups in which samples were taken from radiographic images taken for each gender to assess selected measurement variables, as shown in Table 5.

Table 5 The comparison of mean value between conventional dried mandible measurement and the group of medical radiographs (CT scans) measurement.

Variables	Males					Females				
	Dried bone		CT scan			Dried bone		CT scan		
	mean (mm.)	SD	Mean (mm.)	SD	Sig.	mean (mm.)	SD	mean (mm.)	SD	Sig.
M4	98.31	6.90	104.32	15.73	0.060	95.57	4.73	93.92	4.88	0.345
M5	123.14	5.50	121.74	6.14	0.395	115.67	7.68	115.65	8.07	0.997
M6	35.07	4.07	32.49	5.23	0.051	33.65	4.90	29.75	7.97	0.126
M7	44.59	2.46	43.64	5.76	0.407	42.49	3.00	40.30	4.28	0.120

Discussion

As part of a study aimed at determining sex identity using radiographs and conventional measurements, total mandibular specimens were randomly assigned to 50 males and 50 females in each group, comprising 200 individuals in total. Based on the analysis of the data, the means of each parameter were compared for males and females to determine the difference. For all 10 measurement variables, the mean values for the males were higher than the means for the females. According to the results of the t-test, only four variables were

statistically significantly different between the sexes: M5 (Bicondylar breadth (cdl-cdl)), M7 (Maximum ramus breadth (MARB)), M8 (Maximum ramus height (MARH)) and M9 (Mandibular length (ML)). The accuracy percentages for these variables were calculated when they were used to create a sex prediction equation, and they were 76.1%, 60.9%, 69.1%, and 67.4%, respectively. The variable M5 provides the highest degree of accuracy of all the variables. Based on the discriminant function analysis of all four variables, it was shown that only M5 has an impact on the equation stepwise based on the discriminant function analysis and there was a 76.1% accuracy for the sexual prediction equation, as well. In contrast, the stepwise method gives higher values in the group of medical radiographic than in the conventional measurement of dry bone. There were two variables selected for the creation of the equation in this assessment, which are M4 and M7, which pertain to medical radiography. In both radiographic and conventional dry bone measurement groups, however, both sex prediction equations provided similar gender prediction accuracies of 77.5% and 76.1%, respectively in the radiographic and conventional dry bone measurements.

Based on the methodology used in the present study, the variables or measurement positions did not appear to be distributed equally between the two populations. A dried mandible sample consists of ten measurement positions in total, whereas a medical radiography sample consists of only four measurements, in total. The reason for this is that there are limitations to medical imaging, which causes this to happen. To determine the effects of the research, the researchers used images obtained from a variety of head scans of generic patients who do not qualify for mandibular imaging, to obtain images of their head scans. Because of this, medical radiography has a limited degree of rotation or lack of completeness in certain parts of bone images. If it needs to be done to get all the measurements may require more tooling or increased running costs. Therefore, only four variables were measured for this study to compare the conventional method with the radiographic method. Even though the measuring positions were not equal, based on the results of this study, it appeared that the positions that could be used to distinguish between sexes were the same, that is, M5 and M7 and it is also interesting to note that the percent accuracy values for the two samples are similar. According to the t-test mean for all measurement variables in dry mandible samples and medical radiographs in both genders, there was no statistically significant difference between their mean values. This suggests that the means of the two methods used to measure variables were not different between males and females. The findings of this study are likely to be very beneficial in forensic anthropology as they may provide a handy way to measure parameters that in some cases, can't be easily measured with dry bones. As an example, burned corpses and fragments of charred bodies have been found.[22] In terms of values, there was no difference in values when measurements were taken from medical radiographs. The method may also be used in place of traditional measurement techniques if limitations exist in the case.

Additionally, the researchers compared the values of variables with statistically significant differences between males and females from dry mandible samples with those from other populations. In general, across all populations, there was a tendency for the mean of males to be higher than that of females in all groups. There is a possibility that the reason why the size of male bones is larger than that of female bones could be because the growth rate of males receiving testosterone has a greater effect on bone growth than that of females.[23] It is also possible that other factors could arise from the fact that male and female activities are different, or from the fact that the forces acting on bones and muscles differ from the forces acting on males and females.[24] As a result of these factors, the bones of males tend to be larger and the ridges, crests, and sizes of the bones tend to be larger than those of females. According to the results of the study, when compared with the four other populations[25-27] which show in Table 6, the mean values for various variables for the Thai population were found to be similar to those of the Chinese population when compared to the other four populations. As a matter of fact, there may be a causal relationship between this and the fact that the Chinese and Thai populations are both parts of the Mongoloid population. This is one of the ethnic

groups in the world. In addition, the Thai Chinese population makes up an estimated 11-14% of the overall Thai population, according to the latest statistics.[28] This may be one of the reasons why two populations may appear to have the same facial features due to the similarities in the size of the mandible between them.

Table 6 The mean value among the Thai population compared to other populations.

Populations	M5		M7		M8		M9	
	male	female	male	female	male	female	male	female
Iran	121.93±5.24	115.35±5.13	37.41±3.76	35.03±2.89	60.81±4.59	54.69±4.14	75.41±4.29	71.61±4.59
Brazilian	118.48±5.99	110.03±4.65	-	-	54.36±4.73	49.41±3.84	70.37±4.65	67.14±3.93
Chinese	130.00±5.31	121.44±4.75	45.41±3.72	41.99±2.69	65.96±6.16	58.28±4.32	86.46±6.10	81.46±5.39
Thai	123.14±5.50	115.67±7.68	44.59±2.46	42.49±3.00	65.34±6.05	61.00±5.36	89.07±5.68	84.55±4.38

Conclusion

There were significantly different between males and females in the measurements made using the dry bone conventional measurement method (M5, M7, M8 and M9), and we found significant differences in measurements using the radiographic measurement method (M4, M5 and M7). To create equations that predict sexual dimorphism from this study, one can use the results from this study. In addition, when conventional dried bone and radiographs measurements were compared between the two groups, there were no statistically significant differences in mean values. It was concluded that variables can be measured by using two methods and used interchangeably based on the situation and limitation of mandible samples.

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