Sex Determination Using Mastoid Process Measurement in Thais

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Background: *Analysis of skeleton is necessary for sex determination. There are several pieces of bone that are used such as pelvic bone and zygomatic arch etc. In the fieldwork of physical anthropologist and forensic physician, the skull or some pieces of the skull can be very useful. In the skull, the mastoid process is a compact and permanent process. Craniometric measurements of mastoid process are interesting parameters to distinguish sex.*

Objective: *To study the craniometric measurements of mastoid process of dry skulls in Thais and provide a method for sex determination.*

Material and Method: *One hundred normal skulls of Thais from the central region, 60 male and 40 female, were studied. The measurement of mastoid process between the three points, porion (po), mastoidale (ma), and asterion (as) were made. The three distances (po-ma, ma-as, po-as) were recorded (mm) and the mastoid triangular areas were calculated by using Heron's formula (mm^2). The student's t-test and linear discriminant analysis were used for data analysis.*

Results: *The means of mastoid dimensions and mastoid triangular area in male are significantly larger than those of the female ($p \leq 0.01$). The linear discriminant analysis shows that using the mastoid process dimensions and mastoid triangular area for determining sex in Thais are convincing. The average accuracy is 67.00 to 76.90%. The better mastoid dimension is ma-as of the right mastoid process. It shows a high average accuracy at 76.90%.*

Conclusion: *Means of the mastoid dimensions and mastoid triangular area of Thai skulls (whole skull or fragments) provide an accurate method for determining sex.*

Keywords: *Physical anthropology, Mastoid process, Sexual dimorphism, Thai skull*

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Sexing the human skull and skeleton remains has been an important task of the physical anthropologist, forensic anthropologist, and archaeologist. It is achieved by using the knowledge of human anatomy concerning osteology. The skull is the most useful structure for determining sex by anthroposcopic traits and anthropometric methods[1-4]. There have been many anthropometric studies about the dimensions of the skull for each sex by using measurements based on craniometric landmarks in several parts including the mastoid processes[5-9]. Hoshi[10] analyzed the morphology of mastoid process and specified three main types by the direction of the apex of the mastoid process. However, his research did not provide a high level of confidence.

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In 2003, De Paiva and Segre[11] developed the easy method to determine the sex of skulls by indirect mastoid process measurements. For the first step, the xerographic copy of each side of the skulls was obtained. After that, three craniometric points consisting of porion, asterion, and mastoidale for triangulation were used. Then, they calculated the area of triangle from distances between three craniometric points by Heron's formula and made a summation of each side triangle area to the total area value, and the results were used for sexing human skulls. The result showed significant differences between sexes in the right triangle area, left triangle area and total area.

The new technique was initiated by De Paiva and Segre; the validity of using the mastoid triangle for sex determination has been evaluated by Kemkes and Gobel[12]. To find out the effectiveness of this method, 97 skulls of German forensic samples and 100 skulls of the Portuguese cemetery sample were directly measured three distances with a sliding caliper, and then the triangle area was computed by using Heron's formula. However, the results of the study did not reveal the excellent results as the previous study by De Paiva and Segre. Classification results produced by discriminant function analysis appeared with an accuracy rate of 65%. Therefore, the use of the mastoid triangular area as a sex identification is doubtful. They also emphasized the population-specific diversity in mastoid triangle area, in which the Portuguese cemetery sample showed a greater sexual difference than in the German forensic sample.

Subsequently, Nagaoka et al[13] postulated the advantage of using mastoid process measurements as good discriminators of sex. They measured height, width, and length of the mastoid process in Japanese human skeletons of the medieval and early modern periods. Using student's t-test to compare between sexes for each variable, discriminant function analysis was executed. The results revealed the usefulness of the mastoid process for sex determination. The percentage accuracy of sex classification is more than 80% with one variable, and reached 82 to 92% with two variables, which indicated greater accuracy than the previous studies of sex assessment by cranium measurements.

Recently the determination of sex by mastoid process measurements has been employed in Brazilian skulls from the collection of the Museum of the Federal University of Sao Paulo[14]. The study of the linear dimensions of mastoid triangle was directly measured by digital caliper, using the three reference points, porion, mastoidale, and asterion. According to the method developed by De Paiva and Segre, the total area of mastoid triangle was calculated, after that, the descriptive statistics of the variables was calculated. The significance of the mean differences of the mastoid triangle area between sexes was computed using t-test; the results revealed that the right mastoid triangle and the total area were greater and more significant in males. In order to determine the sex by using the discriminant function analysis, they found that the mastoid dimensions analysis illustrated a low discriminant potential. The distance between porion and mastoidale was the only variable that allowed the researchers to classify man's groups from women with a general accuracy of 64.2% and showed a better sensibility for classification in males.

The objective of the present study was to ascertain the sexual dimorphism in the dimensions and triangle area of the mastoid process in Thais by using descriptive statistics and discriminant function analysis for individual measurements.

Table 1. Sex and age distribution of the sample

Sex	n	Age			
		Mean	SD	Minimum	Maximum
Male	60	47.29	19.24	16	80
Female	40	51.60	17.39	18	81

Material and Method

The craniometric data of the mastoid process were based on dry skulls from the central region of Thailand; these were obtained under authorization of the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand. This study was approved by the Siriraj Institutional Review Board (SIRB) in protocol No.197/2554 (Exempt). One hundred human skulls, 60 male and 40 female, were used. The demographic traits of all samples are demonstrated in Table 1. The dimensions of the both sides of mastoid triangles were directly measured by digital sliding caliper, using the three craniometrical landmarks (Fig. 1).

1. Porion (po): the highest middle point on the margin of the external auditory meatus.

2. Mastoidale (ma): the lowest point of the mastoid process

3. Asterion (as): the meeting point of the lambdoid, occipitomastoid and parietomastoid sutures

Distances between the three landmarks were located and measured by a single investigator in order

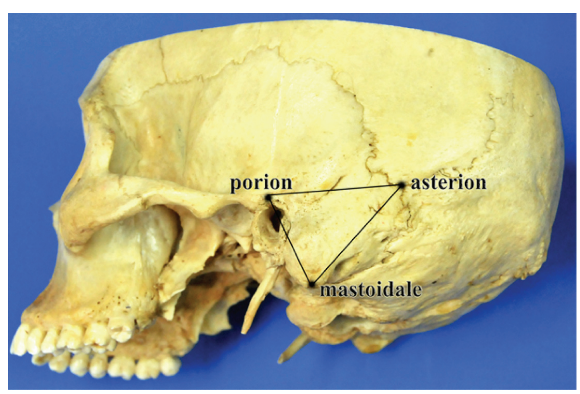

Fig. 1 Measurement of the mastoid process limited by three craniometric landmarks, porion, asterion and mastoidale

to eliminate interobserver partiality. Heron's formula was used for calculating the area of the mastoid triangular area in mm^2. When the authors knew the lengths of sides, the area of a triangle can be calculated by this formula.

$$\Delta = \sqrt{s\,(s - a)\,(s - b)\,(s - c)}$$

a, b and c are the lengths of the sides

$s = (a + b + c) \div 2$

After that, the descriptive statistics of all dimensions and mastoid triangle area was calculated; the mean difference between the sexes was calculated by student's t-test. In the last step, the linear discriminant analysis, consisting of univariate and multivariate methods, was used to distinguish between the two sexes. A p-value of less than 0.05 was considered to be statistically significant difference between sexes.

Results

The descriptive statistics with means, standard deviations, minimum, maximum of mastoid process dimensions including the mastoid triangular area in males and females for right and left side are presented in Table 2. All of the mastoid measurements were found to be significantly larger in males than females. The mean differences between both sexes for all measurements were statistically significant, at the $p \leq 0.01$ level.

Each of the measurements were conducted to discriminant function analysis using univariate, multivariate consisted of the direct and stepwise methods. The results of univariate discriminant function analysis are given in Table 3. This table shows the six measured variables of the mastoid process and their corresponding unstandardized coefficients, constants, sectioning points and percentage average accuracies of all functions. The "leave-one-out" classification procedure was used, which included the original and cross-validated group cases in order to evaluate the effectiveness of the functions. The distance between the mastoidale and asterion on the right side produced highest average accuracies (76.90%) in correct sex classification. The sensitivity and specificity of this function were 78% and 76% respectively. Determining the sex of an individual could use the discriminant functions for each single variable as in Table 3. In order to calculate the discriminant score from the functions, each mastoid dimension will be multiplied by its coefficient and added to the corresponding constant. For example, the discriminant function score(y) for the distance between porion and mastoidale on the left side will be:

$$y = 0.225 \times (\text{left po-ma}) + (-7.282)$$

The unknown skull will be classified as male if the discriminant function score is greater than the sectional point of -0.093 and as female if the score is less than or equal to the sectional point.

Table 4 demonstrates the results of direct discriminant function analysis of all measured variables, left and right mastoid measurements. This table exhibits three discriminant functions of combined variables, coefficients, constants, sectioning points and percentage average accuracies of all functions. The third function including three measurements of the right mastoid process provided the highest average accuracy (76.90%) followed by all variables of mastoid process measurements (75.80%) and the left mastoid process dimensions (73.6%). The best discriminant function was obtained from the direct method:

Table 2. Basic statistics of all measurements (in mm or mm^2) and p-value for differences in means between males and females with each variable

Measurement	Male				Female				p-value
	Mean	Min	Max	SD	Mean	Min	Max	SD	
po-ma (left)	33.41	23.00	42.00	3.82	30.42	24.00	40.90	5.37	0.003
po-ma (right)	35.05	25.00	42.00	4.02	31.21	25.00	36.00	2.90	0.000
ma-as (left)	57.03	46.00	70.00	4.55	52.30	40.00	62.00	4.64	0.000
ma-as (right)	57.16	45.70	68.30	4.57	52.15	45.00	60.20	4.00	0.000
po-as (left)	53.00	41.30	66.40	3.86	49.18	30.20	60.40	5.08	0.000
po-as (right)	53.52	46.00	63.90	4.37	49.64	44.00	60.30	3.35	0.000
Area (left)	867.75	470.91	988.33	135.28	733.83	404.94	874.49	133.30	0.000
Area (right)	912.70	449.25	975.64	140.78	752.50	448.30	846.90	119.50	0.000
Total area	1,778.47	920.16	1,848.20	138.80	1,486.33	878.93	1,683.32	137.40	0.000

Table 3. Univariate discriminant function analysis from both sexes

Variable	Unstandardized coefficient	Constant	Sectioning point	Average accuracy (%)	
				O	C
po-ma (left)	0.225	-7.282	-0.093	68.12	68.10
po-ma (right)	0.273	-9.204	-0.144	70.30	70.30
ma-as (left)	0.218	-12.078	-0.142	73.60	73.60
ma-as (right)	0.229	-12.655	-0.157	76.90	76.90
po-as (left)	0.230	-11.891	-0.121	67.00	67.00
po-as (right)	0.248	-12.927	-0.133	74.70	74.70

O = original group cases correctly classified; C = cross-validated group cases correctly classified

Table 4. Direct discriminant function analysis from both sexes

Functions	Variables	Unstandardized coefficient	Constant	Sectioning point	Average accuracy (%)	
					O	C
All variables	po-ma (left)	-0.101	-13.950	-0.191	75.80	70.30
	po-ma (right)	0.222				
	ma-as (left)	-0.004				
	ma-as (right)	0.134				
	po-as (left)	0.015				
	po-as (right)	0.033				
Left mastoid	po-ma (left)	0.038	-12.787	-0.147	73.6	70.30
	ma-as (left)	0.157				
	po-as (left)	0.056				
Right mastoid	po-ma (right)	0.149	-13.626	-0.184	76.90	73.60
	ma-as (right)	0.140				
	po-as (right)	0.017				

O = original group cases correctly classified; C = cross-validated group cases correctly classified

Table 5. Stepwise discriminant analysis from both sexes

Function variables	Unstandardized coefficient	Constant	Sectioning point	Average accuracy (%)	
				O	C
po-ma (right)	0.151	-13.441	-0.184	76.90	74.70
ma-as (right)	0.151				

O = original group cases correctly classified; C = cross-validated group cases correctly classified

y = 0.149 x (right po-ma) + 0.140 x (right ma-as) + 0.017 x (right po-as) + (-13.626)

The sensitivity and specificity of the best function from direct discriminant analysis method were 72% and 67% respectively.

The result of the stepwise discriminant analysis of all measurements of the mastoid process can be seen in Table 5. All of six mastoid process measurements were entered in stepwise analysis, but only two measurements of the right mastoid process (po-ma and ma-as) were selected by the computer program for derivation of the best discriminant function equation, which can then be used for calculation of the discriminant function score. The function obtained from stepwise method with an average accuracy of 76.90% was Y = 0.151 x (right po-ma) + 0.151 x (right ma-as) + (-13.441).

The sensitivity and specificity of the function from stepwise discriminant analysis method were 72% and 79% respectively.

Discussion

In the present study, all dimensions of the mastoid process and the triangle area in males were discovered to be statistically greater than females. The results from mean values comparison between both sexes resemble the earlier studies in that female mastoid process dimensions are steadily smaller than males in different human race groups[5-9,11-14]. Average mastoid measurements in the present study were larger when compared to the study in the German forensic sample, Portuguese cemetery sample[12], Japanese human skeletons[13] and Brazilian skulls[14].

The population specificity is an influential important factor regarding to the size and sexual dimorphism of the mastoid process[12-14]. There are some reports from the past that are concordant with this conclusion. In the report of Kemkes and Gobel[12], they emphasized the different expression of sexual dimorphism and population-specific variability of the German and Portuguese samples. Furthermore, they stated that the anatomical variation of asterion location is related to population-specific variability in sexual dimorphism, which have been supported by many authors who investigated anatomic position of the asterion in different populations[15-19].

Comparison between the present study and the original article of De Paiva and Segre[11] indicate that the average values of each side triangular area and total area of mastoid process in Thais are greater in both sexual groups but the sex difference of mean values in Thais sample are smaller than their study. These differences may be the effect of their method, which was using xerographic copy for indirect dimensions measuring.

Kemkes and Gobel[12], reported the evaluation of method's validity that was proposed by De Paiva and Segre[11] which used the total triangular mastoid area for sex determination. They stated that the measurements show disparity in the population-specific of sexual dimorphism between German forensic and Portuguese cemetery samples but the technique is not practical when the skull remains have to be independently assessed. Hence, they concluded that using mastoid triangle area as a sex determination is highly questionable. The authors also used linear discriminant analysis in a final step to determine between sex groups but they did not show the discriminant functions in the article. The results exhibited percentage accuracy classification that only 65% were lower than the results of linear discriminant analysis in the present study (76.90%).

The present study was definitely unlike the investigation by Nagaoka et al[13] who conducted on Japanese human skeletons of the medieval and early modern periods in that six dimensions were measured and some of the variables were used to produce the discriminant functions for sex classification. The results obtained an accuracy of sex classification of over 80% in which they used the different of craniometric points and measurements as comparison to the present report. According to the study of Suazo and co-workers[14] they evaluated the equality of mean values by t-test; three variables including the dimension between porion and mastoidale, the right mastoid triangular area and total area showed the statistically significant difference between both sex groups ($p < 0.01$). As can be seen, these average values of males were greater than females. After that, they used the discriminant function analysis, and their result revealed a low discriminant capacity. Only the distance between porion-mastoidale is the parameter that allowed one to discriminate male from female with a general accuracy of 64.20%. Furthermore, they pointed out that sex determination by using the dimensions of mastoid triangle is debatable for sex diagnosis in practice. The present study illustrates different results, and all dimensions of the mastoid triangle and triangular areas revealed statistically significant differences ($p < 0.01$) between male and female skulls within the Thai population. The linear discriminant function analysis of the present study consisted of direct and stepwise methods; the results provided ten discriminant functions for determining the sex. The best discriminant function from all methods furnished an average accuracy of 76.90%, which is higher than the precedent studies in which the craniometric landmarks and measurement methods were identical to the present study.

The population-specifics should of concern when estimating the sex of an unknown skull by the mastoid process measurements. Therefore, each of the discriminant functions should be used appropriately. The unknown skull must use the functions that are developed from the skulls of the same population.

Conclusion

The dimensions measurement of the mastoid process is a simple useful method for determining the sex for the Thai population. Using the best function that could be developed from all procedures of the discriminant function analysis, the results revealed a 76.90% average accuracy in correct sex classification. The present study proposed the several discriminant functions including dimension variables of both sides of mastoid process. Hence, these functions are available for either a complete or a fragmented skull. The findings presented can be applied in the procedures of Physical anthropology, Forensic anthropology, and Bioarchaeology.

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Potential conflicts of interest

None.

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การแยกเพศโดยการวัดขนาดส่วนมาสตอยด์โปรเซสในคนไทย

ชญานิษฐ์ มนูญผล, วาสนา ผลากรกุล

***ภูมิหลัง**: การแยกเพศของมนุษย์โดยดูจากโครงกระดูก มีกระดูกหลายส่วนที่ใช้บ่งบอกเพศได้ เช่น กระดูกเชิงกราน กะโหลกศีรษะ เป็นต้น การแยกเพศจากกะโหลกศีรษะ มีจุดสังเกตได้หลายแห่ง เช่น โค้งโหนกคิ้ว รอยนูนของกระดูกหน้าผาก รอยนูนหยาบของกระดูกออกซิปิตัล เป็นต้น การแยกเพศโดยดูจากโครงกระดูกทั้งร่าง จะทำได้ง่ายและมีความถูกต้องสูง เนื่องจากมีข้อมูลจากกระดูกหลายส่วนประกอบกัน แต่ถ้าพบกระดูกเพียงบางส่วนจะแยกเพศได้ยาก ซึ่งเป็นปัญหาที่พบในการตรวจแยกเพศทางโบราณคดี และการตรวจแยกเพศทางนิติเวชศาสตร์ จึงมีความจำเป็นต้องศึกษาเพื่อหาวิธีแยกเพศในกรณีที่พบกระดูกเพียงบางส่วน มาสตอยด์โปรเซสของกระดูกเทมโปรัล เป็นกระดูกที่มีขนาดใหญ่ หนา ทนทาน มีโอกาสคงอยู่มากส่วนอื่น ๆ ของกะโหลกศีรษะ จึงเป็นส่วนที่ควรศึกษา เพื่อใช้เป็นมาตรฐานในการแยกเพศของคนไทยต่อไป*

***วัตถุประสงค์**: เพื่อหาค่ามาตรฐานของมาสตอยด์โปรเซสของเพศชายและเพศหญิง และวิเคราะห์เปรียบเทียบการใช้ค่าต่าง ๆ ในการแยกเพศ เพื่อหาค่าที่ใช้แยกเพศได้โดยความถูกต้องสูงสุดในคนไทย*

***วัสดุและวิธีการ**: ศึกษาจากกะโหลกศีรษะคนไทยที่อาศัยในภาคกลางของประเทศไทย และใช้ศึกษาในภาควิชากายวิภาคศาสตร์ คณะแพทยศาสตร์ศิริราช มหาวิทยาลัยมหิดล จำนวน 100 กะโหลก เป็นของเพศชาย จำนวน 60 กะโหลก เป็นของเพศหญิง จำนวน 40 กะโหลก ศึกษาบริเวณมาสตอยด์โปรเซส ทั้งข้างซ้ายและขวา โดยอาศัยตำแหน่งสำคัญ 3 จุด คือ โพเรียน เป็นจุดกึ่งกลางและตรงกับจุดสูงสุดของรูหู มาสตอยเดล เป็นจุดต่ำสุดของมาสตอยด์โปรเซส และแอสเตอเรี่ยน เป็นจุดที่เกิดจากการบรรจบกันของรอยต่อกระดูกแลมบ์ดอยด์ รอยต่อกระดูกออกซิปิโตมาสตอยด์ และรอยต่อกระดูกพาริเอโตมาสตอยด์ ทำการวัดระยะห่าง 3 ค่า โดยใช้เวอร์เนียร์คาลิเปอร์ ได้แก่ ระยะจากโพเรียนไปยังมาสตอยเดล ระยะจากมาสตอยเดลไปยังแอสเตอเรี่ยน และระยะจากโพเรียนไปยังแอสเตอเรี่ยน นำทั้ง 3 ค่ามาคำนวนหาพื้นที่สามเหลี่ยมของมาสตอยด์โปรเซส โดยใช้สูตรของฮีรอน นำค่าต่าง ๆ มาวิเคราะห์ทางสถิติ โดยใช้ student's t- test และ linear discriminant analysis*

***ผลการศึกษา**: พบว่าค่าเฉลี่ยของระยะที่วัด รวมทั้งค่าเฉลี่ยของพื้นที่สามเหลี่ยมของมาสตอยด์โปรเซสของเพศชายมีค่ามากกว่าของเพศหญิงอย่างมีนัยสำคัญ ($p \leq 0.01$) และจากการวิเคราะห์โดยใช้ linear discriminant analysis เพื่อหาค่า discriminant function score (y) พบว่า การแยกเพศโดยใช้ระยะต่าง ๆ ที่วัด มีความถูกต้อง 67.00-76.90% และการแยกเพศโดยใช้ระยะจากมาสตอยเดลไปยังแอสเตอเรี่ยนของมาสตอยด์โปรเซสข้างขวา มีความถูกต้องสูงสุด คือ 76.90%*

***สรุป**: ค่าต่าง ๆ ที่ได้จากการวัดมาสตอยด์โปรเซสตามวิธีที่ศึกษาในงานนี้ ใช้แยกเพศในคนไทยได้ถูกต้องแม่นยำทั้งในกะโหลกที่มีสภาพสมบูรณ์ หรือ เป็นเพียงชิ้นส่วนกะโหลก จากการวิเคราะห์ทางสถิติพบว่ามีความถูกต้องสูงสุดถึง 76.90%*