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Original article

Thai Human Skeleton Sex Identification by Mastoid Process Measurement

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Abstract

The mastoid process has quite a high potential for sex identification and is a relatively strong part of the skull. If the skull is broken into pieces, the mastoid process often stays intact. Therefore, it is appropriate to use the mastoid to identify sex if the skull is fractured or not intact. This study tried to establish the discrimination functions for identifying sex from the Thai population based on width and height of the mastoid. Then, these functions were tested with skulls in a test group to determine the percentage of correct classification. This study found that two functions have the highest sex classification at 78% accuracy (two and four variables). Others ranges from 66% to 76%. **Chiang Mai Medical Journal 2011;50(2):43-50**

Keywords: mastoid process, sex determination, discriminant function analysis

Although sex discrimination is an important component of body identification, it is easy in practice, as only the genitalia and internal sexual organs need to be checked. Differences between males and females are clear most of the time, but corpses in certain circumstances might have been damaged, making sex identification by traditional methods difficult in, for example, a decomposed or burned body with nothing left but skeletal remains. All of these cases require bones for sex identification. In general, it is not difficult to determine sex from the pelvic bone, which differentiates sex best.(1) However, some corpses consist of only the head, as in murder cases when criminals cut up the body into several pieces to hide the victim's identification. In those cases, characteristic examination of the skull to identify sex has significant potential if the pelvic bone is not available.

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Generally, inspection of the skull for sex determination involves evaluating the general appearance, size, frontal and brow ridges, supraorbital margin, nuchal area, mastoid and chin together.[1] However, if the skull is broken into several pieces, such as in death caused from an airplane crash or explosion, sex identification by reviewing the nature of the skull is difficult or impossible.

The mastoid bone is a part of the skull that has good potential in sex identification. Generally, sex can be identified by using the mastoid bone based on inspecting its size, i.e. large or small. The size of the male mastoid is larger than that of the female, but the problem is there are no standard criteria for identification purposes. Also, simply calling the mastoid “small” or “large” is subjective, and may vary depending on the inspector. Therefore, errors may occur easily, when inexperienced inspectors are uncertain of what determines the size of a particular mastoid as large or small. For these reasons, this study tried to find a criterion for identifying sex by measuring the size of the mastoid.

MATERIAL AND METHOD

The bone samples used for analysis comprised 150 skulls divided into two groups. The first group had 100 skulls divided equally into the male and female sex. From this group, the function for sex identification was calculated (functional group). The second group, comprising 50 skulls divided equally into 25 male and 25 female, was selected for function testing (test group). All of the skulls were taken from donated bodies for physiological anatomy education from the Department of Anatomy, Faculty of Medicine, Chiang Mai University. All of the samples were Thai, Mongoloid, and each one was at least 18 years old. The information of sex and age was derived from the registered files of the donated bodies.

The first step in this study involved measuring the width and height of the mastoids in the functional group. Then, the values obtained were used to calculate the function for identifying sex. Finally, the sex of the skulls was identified in the test group, based on calculated functions, in order to determine the percentage of correct classifications.

The mastoid bones were measured by employing the Nagaoka T[2] method. The two parameters (height and width of the mastoid bone) were measured on both sides. The skulls were selected randomly for measurement. The mastoid bones with abnormalities and/or pathological changes were excluded. The measurement details are as follows.

1. Mastoid height

Measurement of the mastoid height involved the distance between the porion and incisura mastoidea, then setting the midpoint between them. Next, the distance between the midpoint and end of the mastoid was measured using a vernier caliper (Insize IS11205-200-2) (Fig. 1).

2. Mastoid width

With the base of the skull turned upward, one leg of the vernier caliper was placed on the incisura mastoidea. Then the width of the mastoid bone was measured by placing the other leg of the caliper on the outside of the mastoid (Fig. 2).

Measurement of the width and height were repeated three times in each sample. Then, the mean of the three measurements

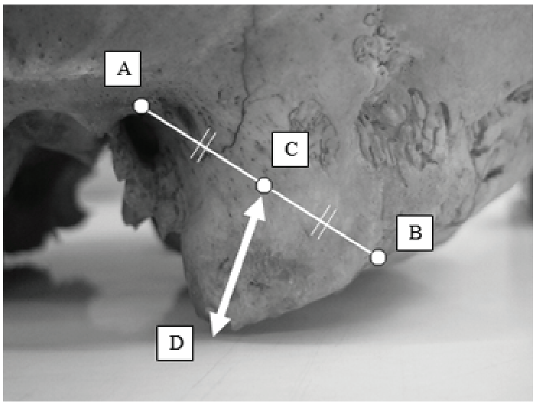

Figure 1. Mastoid height measurement; A = porion, B = posterior end of incisura mastoidea, C = mid-point between A and B, D = tip of the mastoid process.

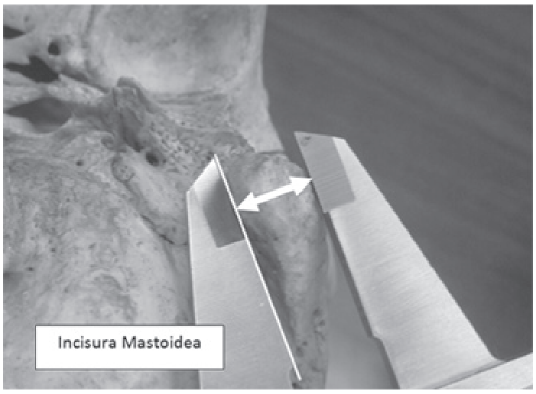

Figure 2. Mastoid width measurement

determined the functions to be used for identifying sex.

The variables of mastoid measurement were summarized by mean and standard deviation (SD) in sex groups. The comparison between sex groups in each variable was evaluated using the Student's t-test with a significant level of about 0.05. Discriminant analysis was used to derive the functions in order to classify the sex of an individual with each variable, or a combination of variables. After that, the percentage of correct classifications in each function was evaluated. The cut points in each discriminant function were optimized in order to classify between gender groups with the highest correct percentage. To determine the optimal cut point, all potential cut points were used to evaluate the percentage of correct classification. To derive the predicted group, each estimated discriminant score was compared to the optimal cut point. If the estimated discriminant score exceeded the optimal cut point, the predicted group was equal to male; otherwise it was equal to female.

After establishing the functions, they were tested for their accuracy by replacing the variable with the width and length (measured randomly by the same method, as in the functional group) from the test group. Then the percentage of predictive correct classifications was calculated.

RESULTS

In this study, four parameters of the mastoid bone were left mastoid width (w), right mastoid width (W), left mastoid height (h), and right mastoid height (H), and the average size of the male mastoid bone was larger than that of the female one on both the left and right sides. This difference in size was statistically significant according to the t-test, with a p-value of <0.001 (Table 1).

The width and height were used to calculate the discrimination functions according to a single variable, two variables and four variables, as shown in Table 2.

Among the male group, the individual function that had the highest correct clas-

Table 1. Comparison of mastoid width and height between male and female skulls.

Parameters	Male (N=50)		Female (N=50)		P value
	Mean	SD	Mean	SD	
Left mastoid width (w)	11.77	2.10	9.66	1.72	<0.001
Right mastoid width (W)	11.63	1.83	10.05	1.68	<0.001
Left mastoid height (h)	25.31	3.00	20.95	2.91	<0.001
Right mastoid height (H)	25.17	3.66	20.57	2.25	<0.001

Table 2. Discrimination functions for sex identification by mastoid process measurement in the functional group.

Discrimination function (mm)	Cut point (mm)	Correct classification		
		Male (%)	Female (%)	Both (%)
f (w) = -5.574 + 0.520w	-0.047	68	70	69
f (h) = -7.810 + 0.338h	0.036	82	84	83
f (w,h) = -7.990 + 0.153w + 0.275h	-0.018	80	82	81
f (W) = -6.153 + 0.568W	-0.031	66	68	67
f (H) = -7.538 + 0.330H	0.073	80	84	82
f (W,H) = -7.870 + 0.088W + 0.303H	0	80	80	80
f (w,W) = -6.040 + 0.427w + 0.135W	-0.031	64	72	68
f (h,H) = -8.284 + 0.167h + 0.193H	0.099	76	92	84
f (w,W,h,H) = -8.486 + 0.041w + 0.049W + 0.158h + 0.169H	0.003	76	88	82

sification (CC) percentage was f (h), with a cut point of 0.036 mm, which correctly identified 82% of the cases. In the female group, the function that had the highest CC percentage was f (h,H), with a cut point of 0.099 mm, which correctly predicted sex in 92% of the cases.

Due to the fact that results obtained from the functional group were derived from testing the model itself, the percentage of correct classifications may have been specific only to the functional group. Therefore, another set of skulls (50 skulls) was used as a test group, measuring the same parameters and replacing the variables in the functions. If the calculated values were greater than the cut point, the skull was identified as male, but if less than the cut point, it was identified as female. The percentage of correctly identified skulls was then determined.

The results (Table 3) showed that functions with the highest percentage for predicting the correct classification (84%) among the male group were f (w,h), f (W,H) and f (w,W,h,H) , with a cut point of -0.018, 0 and 0.003 mm, respectively. In the female group, the f (W) and f (w,W) both had a cut point of -0.031 mm, and the best percentage for predicting the correct classification (PCC) at 76% each.

When considering the ability to identify sex by using the overall skull, it was found that functions with a single variable the percentage of PCC was is less than in those

Table 3. Discrimination functions for sex identification by mastoid process measurement in the test group.

Discrimination function (mm)	Cut point (mm)	Predictive correct classification		
		Male (%)	Female (%)	Both (%)
f (w) = -5.574 + 0.520w	-0.047	60	72	66
f (h) = -7.810 + 0.338h	0.036	80	64	72
f (w,h) = -7.990 + 0.153w + 0.275h	-0.018	84	64	74
f (W) = -6.153 + 0.568W	-0.031	60	76	68
f (H) = -7.538 + 0.330H	0.073	80	72	76
f (W,H) = -7.870 + 0.088W + 0.303H	0	84	72	78
f (w,W) = -6.040 + 0.427w + 0.135W	-0.031	64	76	70
f (h,H) = -8.284 + 0.167h + 0.193H	0.099	80	72	76
f (w,W,h,H) = -8.486 + 0.041w + 0.049W + 0.158h + 0.169H	0.003	84	72	78

with 2 variables and, furthermore, the right mastoid had a higher percentage of PCC than the left. Regarding the functions with 4 variables, it was found that the percentage of PCC was not significantly different from the functions with 2 variables on the right mastoid. When comparing the percentage of PCC between the functional and test group, it was found that the percentage of PCC in the test group decreased in almost all functions, except f (W) and f (w,W), which slightly increased by one and two percent, respectively.

DISCUSSION

The accuracy of sex classification by the skull in previous studies was not less than 80%;[1] 86% by Inoue (39 craniometric points);[3] 80% by Kajanoja (8 measurements);[4] 82-89% by Giles and Elliot (11 measurements);[5] and 90% by Hanihara (9 measurements).[6] However, these methods require too many parameters in which the skull must be in perfect condition, and a broken skull or a skull with missing parts cannot be used, due to missing parameters according to these guidelines.

This study focused on developing criteria for sex identification by using a broken or incomplete skull. The mastoid, which is fixed to the posterior cranial base, is often a well-preserved part of the fragmentary crania.[2] As a result, six functions were found that had a percentage of correct classification of more than 80% in the functional group. These functions comprised one, two and four variables, such as f (h), f (H), f (w,h), f (W,H), f (h,H) and f (w,W,h,H).

Although these 6 functions in the functional group had correct classifications of not less than 80%, testing all functions in the test group should represent in general skulls, and would be appropriate when selecting the best function for implementation in real practice.

The results (Table 3) show that f (w,h) and f (W,H) had the highest percent-predicted correct classification. Measurement of the mastoid for sex identification should include both the width and height, and calculation of their data in the function of each side. However, if the mastoid process is incomplete, the height alone can be measure and the sex determines by using f (h) or f (H), depending on which side is available. Although the percent-predicted correct classification using height alone is lower than functions using both width and height, the difference is minimal. Despite the fact that the percent-predicted correct classification for the width of the mastoid is less than that for the height, it also is not too low. Therefore, if the mastoid is broken and only the width is available, use the width alone is acceptable for identifying the sex, with a percent-predicted correct classification of higher than 65%.

It is intriguing that in the test group f (W,H) and f (w,W,h,H) have the same level of predicted-correct classification (78%), so even a piece of skull that has complete mastoids on both sides can be used to identify sex. Measurement and then calculation of the width and height of the right side is enough to identify sex. However, to measure and calculate f (w,W,h,H) would increase confidence in the diagnosis.

When comparing sex identification with different parts of the skull in other studies, accuracy of sex classification in this study was more than that of the foramen magnum (68%),[7] mandible canine index (70%),[8] bizygomatic (67.5%)[9] and supranasal region (57.5%),[10] but lower than that in the forehead (85%),[11] mandible (85%)[12] and base of the crania (71-90%).[13]

In comparison to other studies that used the mastoid to identify sex, the use of width and height of the mastoid in this study had a better level of accuracy than using the mastoid triangle area (64.2%).[14] Nagaoka T[2] studied the size of the mastoid in 87 Japanese skulls and their function had an accuracy of sex classification of 82-92%. However, this percentage may be specific only in the one sample group it was based on. Unlike this study, the functions were tested in the test group, which represented skulls in the general population.

Due to the fact that the skulls used in this study to calculate functions were Thai, the functions would be most specific to Thai people. However, other Mongoloid ethnic groups have a skull structure similar to Thais and, therefore, these functions may be useful to identify sex in these groups as well. Additionally, this study aimed to create functions from adult groups; therefore, further study in a juvenile group is neccessary.

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REFERENCES

1. Byers SN. Introduction to forensic anthropology: a textbook. 3rd ed. Boston, MA: Pearson Education, 2002. p. 176-86.
2. Nagaoka T, Shizushima A, Sawada J, et al. Sex determination using mastoid process measurements: standards for Japanese human skeletons of the medieval and early modern periods. Anthropol Sci 2008;116:105-3.
3. Inoue M, Inoue T, Fushimi T, et al. Sex determination by discriminant function analysis of lateral cranial form. Forensic Sci Int 1992;52:109-17.
4. Kajanoja P. Sex determination of Finnish crania by discriminant function analysis. Am J Phys An-

thropol 1966;24:29-34.

5. Giles E, Elliot O. Sex determination by discriminant function analysis of crania. Am J Phys Anthropol 1963;2:53-8.
6. Hanihara K. Sex diagnosis of Japanese skulls and scapulae by means of discriminant function. Anthropol Sci 1959;66:191-7.
7. Gapert R, Black S, Last J. Sex determination from the foramen magnum: discriminant function analysis in an eighteenth and nineteenth century British sample. Int J Legal Med 2009;123:25-33.
8. Reddy VM, Saxena S, Bansal P. Mandibular canine index as a sex determinant: A study on the population of western Uttar Pradesh. J Oral Maxillofac Pathol 2008;12:56-9.
9. Chimmalgi M, Kulkarni Y, Sant SM. Sexing of skull by New metrical parameters in western India. J Anat Soc India 2007;56:28-32.
10. Schiwy-Bochat KH. The roughness of the supranasal region – a morphological sex trait. Forensic Sci Int 2001;117:7-13.
11. Inoue M. Fourier analysis of the forehead shape of skull and sex determination by use of computer. Forensic Sci Int 1990;47:101-12.
12. Giles E. Sex determination by discriminant function analysis of the mandible. Am J Phys Anthropol 2005;22:129-35.
13. Thomas D. Sex determination of fragmentary crania by analysis of the cranial base. Am J Phys Anthropol 2005;70:203-8.
14. Suazo GIC, Zavando MDA, Smith RL. Sex Determination Using Mastoid Process Measurements in Brazilian Skulls. Int J Morphol 2008;26: 941-4.

การระบุเพศของโครงกระดูกคนไทยด้วยการวัดกระดูกแมสตอยด์

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บทคัดย่อ

กระดูกแมสตอยด์เป็นส่วนของกะโหลกศีรษะที่มีศักยภาพในการระบุเพศของเจ้าของกะโหลกศีรษะค่อนข้างสูงและเป็นส่วนที่ค่อนข้างมีความแข็งแรง แม้กะโหลกศีรษะจะแตกออกเป็นชิ้นส่วนแต่กระดูกแมสตอยด์ก็มักจะเป็นส่วนที่ยังคงอยู่ จึงมีความเหมาะสมต่อการนำมาใช้ในการระบุเพศในกรณีที่กะโหลกศีรษะแตกหักไม่สมบูรณ์ การศึกษานี้เป็นการคำนวณหาฟังก์ชั่นสำหรับใช้เพื่อการแยกเพศโดยใช้กระดูก แมสตอยด์จากกะโหลกศีรษะคนไทย เมื่อคำนวณหาฟังก์ชั่นแล้ว ได้นำฟังก์ชั่นทั้งหมดไปทดสอบกับกะโหลกศีรษะอีกกลุ่มหนึ่งเพื่อดูความแม่นยำของแต่ละฟังก์ชั่น ผลการศึกษาพบว่ามีสองฟังก์ชั่นที่ให้ค่าความสามารถในการระบุเพศที่ร้อยละ 78 ส่วนฟังก์ชั่นอื่นๆให้ค่าความสามารถในการระบุเพศในช่วงร้อยละ 66 ถึงร้อยละ 76 **เชียงใหม่เวชสาร 2554;50(2):43-50.**

คำสำคัญ: การแยกเพศ กระดูกแมสตอยด์ มนุษยวิทยา
