Original article

Could zygomatic angles be used for determining the sex of Thai skeletal remains?

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Objective To study if and how zygomatic angles could be used to determine the sex of Thai skeletal remains.

Method From 100 skulls, 50 were male and 50 female. This study was divided into two phases, with the first to determine the cut off in gender distribution using the size of the zygomatic angle, and the second to determine the gender distribution of the cut off precisely.

Results The mean left zygomatic angle was shown to have a statistically significant difference between males and females (p =0.027). Discriminate analysis showed distinguishable potential with 57% accuracy between males and females by using the cut off.

Conclusion It is improper to use the zygomatic angle to determine the sex of Thai skeletal remains. However, the zygoma is obviously different between the sexes in the Thai population. Further study should determine other osteometric landmarks, instead of using the zygomatic foramen. **Chiang Mai Medical Journal 2014;53(2):75-79.**

Keywords: Zygomatic angle, Sex determination, Thai skeletal remains

Introduction

According to disaster victim identification guidelines[1], there are 2 categories of identification (ID) criteria, specific and general. Specific ID criteria apply when only one item is required for positive ID, for example, fingerprints, dental profile, DNA profile and unique findings such as certain bone imaging appearance, implant number, etc. General criteria consisting of personal effects and a physical profile have lower capability in identification. Two or three positive ID features are needed in this category to give a positive ID result.

Although a physical profile alone is insufficient for victim ID, it is valuable in cases of a destroyed body, such as extreme combustion, advanced decomposition and skeletal remains, when DNA and fingerprint evidence are damaged completely or absent. Mass fatality is another situation when physical profile ID is regarded as helpful. Using only DNA or dental matching

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for ID is costly and time consuming. Time and expense can be reduced by narrowing down the number of bodies or body parts for matching to a missing person by grouping them into a particular race, sex, age and height.

The skull is second only to the pelvis when using bones in sex determination[3] that uses complete skulls and is not difficult. However, when the skull is incomplete, sex determination becomes complicated. While there have been many studies that identify sex by using complete skulls at various key times, those using incomplete skulls are scarce.

Although cheekbones are notably higher in Mongoloid skulls than in Caucasoid and Negroid ones for examples[4], the difference in zygomatic angle is not so obvious in identifying sex; which is contrary to the muscle ridge, supraorbital ridge, mastoid process, frontal eminence, parietal eminence, palate, orbit, nasal aperture, forehead and mandible[5,6]. There are only a few studies concerning zygomatic angles for the benefit of sexing[6], including a study of Japanese cadavers[7]. Nevertheless, studies in the Thai population are still necessary, as genetic, environmental, dietary and daily routine differences may affect bone morphology[8-13].

This study was conducted to determine whether the zygomatic angle could be used effectively for sex determination in the Thai population.

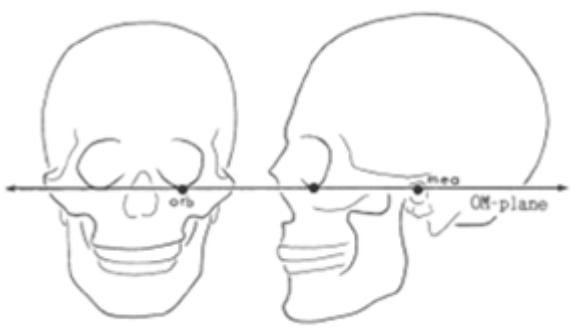

Figure 1. Orbitomeatal plane; reference to the orbitomeatal line is an imaginary line from the outer canthus of the eye to the ipsilateral mid-tragus.

Materials and method

This study was divided into two phases. Firstly, to determine the cut off in gender distribution, the size of the zygomatic angle was used by measuring the zygomatic angle on both sides in 100 cases, comprising 50 male and 50 female individuals. Secondly, the gender distribution of the cut off was determined precisely. The skulls used in this study were taken from Thai skeletons aged between 40 and 90 years. All of them were taken from bodies that had been donated to the Department of Anatomy, Faculty of Medicine, Chiang Mai University for physiological anatomy education. The individuals used had no history of illness or injury that may affect the shape of the bone.

The study was carried out by measuring the zygomatic angle. The skull was photographed with a high quality digital camera in the orbitomeatal plane (Figure 1), which is the standard plane for examining fractures of the zygoma[14]. The pictures were measured by Autodesk AutoCAD 2010 (CMU License). Four points of the zygoma were marked: (a) maxillary process tip, (b) zygomatico-facial foramen[14], (c) point on the zygomatic arch where bending begins in the temporal process tip, and (d) temporal process tip. Two lines were drawn connecting the two points (a) to point (b) and point (c) to point (d) respectively. The zygomatic angle is taken where the two lines intersect (Ø). The data were analyzed using SPSS to determine the cut off for gender distribution.

The sample used for the cut off analysis comprised 50 skulls divided equally into 25 male and 25 female. The zygomatic angle was measured from a person different to the first group. The zygomatic angles in this group were compared with the cut off angle in the first phase. The results were analyzed by discriminant analysis for precise results in gender distribution.

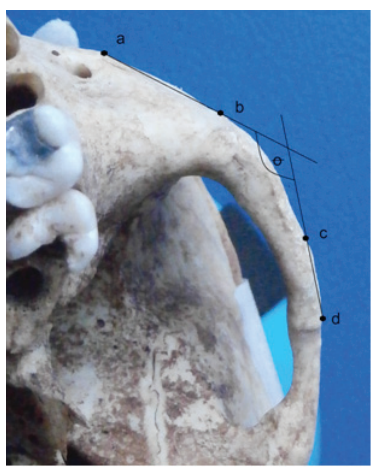

Figure 2. Four points of the zygoma as landmarks, **a**) maxillary process tip, **b**) zygomatico-facial foramen, **c**) acute inward turning point on the zygomatic arch, **d**) temporal process tip.

Table 1. Zygomatic angle distribution among ages

Age	Researcher (n=100)							
	Lt.		Rt.		Lt.		Rt.	
	Mean	SD.	Mean	SD.	Mean	SD.	Mean	SD.
41 - 50	131.2	5.1	128.3	4.7	128.3	4.3	128.3	4.2
51 - 60	132.9	6.3	132.0	8.3	130.4	5.6	131	4.6
61 - 70	130.7	2.1	130.2	4.6	129.1	5.3	130.2	5.3
71 - 80	133.3	5.4	128.0	8.2	127.6	5.8	128.0	4.8
81 - 90	129.7	5.7	129.4	9.1	130.3	6.0	129.4	8.7

Results

One hundred skulls, 50 male and 50 female, aged from 41 to 89 years (mean 65.1 years) were classified into 5 groups, namely: 41-50 years, 51-60 years, 61-70 years, 71-80 years and 81-90 years.

Results by age are shown in Table 1, the mean zygomatic angle of all ages in the males was 131.6° and 130.6° on the left and right, respectively. The mean zygomatic angle of all ages in the females was 129.1° and 129.4° on the left and right, respectively.

Normal distribution curves were drawn from the value of the zygomatic angle for both sexes on both sides. The difference in size was statistically significant, with a p-value of <0.05.

The T-test showed no statistically significant difference between male and female skulls in each age group, except the one for 71-80 years. The mean left zygomatic angle in males was significantly different to that of females (p =0.027), but with no significance on the right side (p = 0.349) (Table 2).

The calculated cut off for gender distribution was 130.3° (median value).

Discriminant analysis showed potential for distinguishing between males and females, with 57% accuracy using the cut off.

Table 2. Comparison of the zygomatic angle between male and female skulls

Parameters	Male (n=50)		Female (n=50)		p
	Mean	SD.	Mean	SD.	
Left zygomatic angle	131.6	5.2	129.1	5.4	0.027
Right zygomatic angle	130.6	7.1	129.4	5.6	0.349

Discussion

The accuracy of sex classification was not less than 80% by using the skull in previous studies [13], from which: Inoue measured 39 craniometric points on the skull resulting in 86% accuracy[15]; Kajanoja achieved 80% (8 measurements)[16]; Giles and Elliot 82-89% (11 measurements)[17]; and Hanihara 90% (9 measurements)[7].

However, these methods require many parameters, meaning that the skull must be in perfect condition, whereas a broken skull or one with missing parts is found normally in extreme events, such as violent circumstances. These skulls cannot be used, due to missing parameters. Therefore, this study focused on developing principles to identify sex using a specific part of the skull, namely the zygoma.

Studies by Ikeda *et al*. concerned the zygomatic angle in the Japanese population[6] by using MRI images to measure the angle formed by the intersection of a line drawn on the same plane as the anterior and lateral surface of the zygoma. This was different to the landmark of this study, and it gave different results. Therefore, the zygomatic angles of Japanese people are different from those in Thais. The mean values of the zygomatic angle, measured by MRI, were 110.2 on the right and 112.1 on the left in males,

while in females they were 103.7 on the right and 105.3 on the left.

Some studies on sexing the skull used the zygomatic angle measured by MRI or CT scan, which calculated 17 dominant features of the skull, including the zygoma, and gave data that was 96% accurate[20]. However, this method needed a complete skull, non-moveable implements and must be practiced by an experienced technician. For those reasons, it is inconvenient and complicated.

On the other hand, this study measured zygomatic angles with osteometric landmarks on the zygoma, which can be done on either a complete or fragmented skull. Furthermore, this method only needs a high quality digital camera and a laptop computer with Autodesk Autocad 2010. However, the results showed differences when compared to those from using digital CT scans and MRI, due to the osteometric landmarks being used to measure dissimilar zygomatic angles.

In this study, the calculated cut off could not be used for gender identification because the accuracy was too low at 57%, and only the left zygoma was statistically significant. The variance may be due to lack of experience in identifying the zygomatic foramen on digital images, which caused a discrepancy when determining zygomatic angle landmarks. In addition, the sample size was too small for the data to be statistically significant.

Thus, further study should determine other osteometric landmarks besides using the zygomatic foramen. From this review, there has never before been an osteometric landmark for determining the zygomatic angle on the human skull.

Acknowledgement

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มุมของกระดูกโหนกแก้มสามารถใช้จำแนกเพศของโครงกระดูกคนไทยได้หรือไม่

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วัตถุประสงค์ เพื่อทำการศึกษาว่ามุมของกระดูกโหนกแก้มสามารถนำมาใช้ระบุเพศของโครงกระดูกคนไทยได้หรือไม่

วิธีการศึกษา ศึกษาโครงกระดูกจำนวน 100 ร่างแบ่งเป็นชาย 50 ร่างและหญิง 50 ร่าง, การศึกษาแบ่งออกเป็นสองระยะ ระยะแรกเป็นการศึกษาเพื่อระบุค่า cut off ของมุมกระดูกโหนกแก้มสำหรับการจำแนกเพศ และระยะที่สองเพื่อทดสอบความแม่นยำของค่า cut off ที่ได้นั้น

ผลการศึกษา พบว่ามุมของกระดูกโหนกแก้มข้างซ้ายมีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติระหว่างเพศชายและหญิง (p =0.027) จากการทดสอบค่า cut off ที่ได้ด้วย discriminant analysis พบว่าความแม่นยำในการจำแนกเพศของค่า cut off นี้คือร้อยละ 57

สรุปผลการศึกษา ยังไม่สามารถนำมุมของกระดูกโหนกแก้มมาใช้จำแนกเพศของโครงกระดูกคนไทยได้ แต่อย่างไรก็ตามควรมีการศึกษาเพิ่มเติมเพื่อระบุ osteometric landmarks เพื่อวัดมุมของกระดูกโหนกแก้มอื่นแทน **เชียงใหม่เวชสาร 2557;53(2):75-79.**

คำสำคัญ: มุมของกระดูกโหนกแก้ม การจำแนกเพศ โครงกระดูกคนไทย