Sex Determination in Thai Skulls by Using Craniometry: Multiple Logistic Regression Analysis

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ABSTRACT

Objective: To evaluate sexual dimorphism in the cranium and mandible of Thais by using Jorgensen's craniometry and to develop a statistical model to determine sex from craniometrical measurements and indices.

Methods: One hundred and one Thai skulls (66 males and 35 females) which ranged in age from 18 to 86 years were studied.

Results: According to craniometry, the skull of a male is larger and higher than that of a female. Considering each individual measurement, although 26 of 30 measurements and 5 of 14 indices showed a statistically significant difference between males and females, they had some overlaps. To predict gender more accurately, 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) was developed as follows: In (odds) = Z = -52.5312 + 0.27 M5 - 0.1867 M8 + 0.1268 M40 + 0.319 M45 The probability of being males (P) is then $e^z/(1+e^z)$. Using a cut off point for P of 0.5, this logistic model could correctly predict 82.9% (95% CI: 66.4%, 93.4%) of females and 92.1% (95% CI: 82.4%, 97.4%) of males respectively with the overall accuracy of 88.8% (95% CI: 80.8%, 94.3%).

Conclusion: Jorgensen's craniometry of the cranium and mandible can be used to determine gender among Thais via a multiple logistic regression model on M5, M8, M40 and M45.

Keywords: Cranium; craniometry; multiple logistic; regression analysis; sex determination; Thais

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Sex determination of skeletons has always been of importance to anthropology. Various parts of a skeleton are useful in sex determination such as the pelvis, femur, tibia, humerus, radius, mandible and cranium.[1-7] Among these, the skull can be used to ascertain individual sex with a high accuracy. Most of the previous studies of sex differences in the skull were centered on morphological traits in a descriptive manner (cranioscopy)[5,8], whereas the recent studies were focused on morphometry or craniometry (e.g. discriminant function analysis) in a largely quantitative and statistical aspects.[6-13] Crainiometry is the scientific measurement of the dimensions of the bases of skull and face. It further provides individual information according to race. The underlying assumption of craniometry is that skull size and shape determine brain size.

With regard to the Thai skull studies, there were only 2 previous reports. A study by Uttayanang[14] focused on the cranial capacity and the cranial module in Thai and Chinese skulls. The difference in mean, range, and index between Thai and Chinese skulls was reported. Another study by Sangvichien[15] investigated the physical anthropological characters of the Thai skulls by using cranioscopy and craniometry. However sexual determination of Thai skulls was not studied. This study was aimed to evaluate sexual dimorphism in the cranium and mandible using Jorgensen's craniometry and to develop a statistical model for sex determination based on several skull measurements.

MATERIALS AND METHODS

Materials

All 101 dried skulls in this study were obtained from bone collections housed at the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand. The skulls were either willed or donated. There were 66 male and 35 female skulls with the mean age of 51.1 (range 18-86) years. Identification of Thais was by death certificates.

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Methods

In order to eliminate inter-observer variation, all craniometrical study was performed by Komon Boonkaew. Physical anthropology, the bony landmarks and measurements in this study were based on Jorgensen's method[16] which is a modification of Martin's Standard method.[17] However, only thirty remarkable measurements and 14 indices had been chosen for this study (Table 1).

TABLE 1. Thirty measurements and 14 indices used in the study.

Measurements (mm)		Indices	
M 1	Maximum length	**I 1**	Cranial index = Maximum breadth (M 8) x 100 / Maximum length (M 1)
M 5	Nasion-basion length		
M 7	Basion-bregma height	**I 2**	Length-height index = Basion-bregma height (M 7) x 100 / Maximum breadth (M 8)
M 8	Maximum breadth		
M 9	Minimum frontal breadth	**I 3**	Breadth-height index = Basion-bregma height (M 7) x 100 / Maximum breadth (M 8)
M 10	Maximum frontal breadth		
M 16	Breadth of foramen magnum	**I 4**	Trans. frontal index = Minimum frontal breadth (M 9) x100 / Maximum frontal breadth (M 10)
M 17	Length of foramen magnum		
M 23	Circumference	**I 5**	Trans. fronto-parietal index = Minimum frontal breadth (M 9) x 100 / Maximum cranial breadth (M 8)
M 24	Transversal arc		
M 25	Median sagittal arc	**I 7a**	Sagittal frontal index = Nasion-bregma cord (M 29) x 100 / Nasion-bregma arc (M 26)
M 26	Nasion-bregma arc		
M 29	Nasion-bregma cord	**I 11**	Foramen magnum length-breadth index = Foramen magnum breadth (M 16) x 100 / Foramen magnum length (M 17)
M 40	Facial height		
M 42	Lower facial length		
M 44	Biorbital breadth	**I 12**	Facial index = Nasion-gnathion (M 47) x 100 / Bizygomatic breadth (M 45)
M 45	Bizygomatic breadth		
M 47	Facial height	**I 15**	Jugo-mandibular index = Bigonial (M 66) x 100 / Bizygomatic (M 45)
M 48	Upper facial height		
M 49	Post. Interorbital breadth	**I 16**	Alveolar index = Facial length (M 40) x 100 / Nasion-basion length (M 5)
M 50	Ant. Interorbital breadth		
M 51	Orbital breadth	**I 18**	Jugo-frontal index = Minimum frontal breadth (M 9) x 100 / Bizygomatic breadth (M 45)
M 52	Orbital height		
M 57	Min. breadth of nasal bones	**I 19**	Trans. cranio-facial index = Bizygomatic breadth (M 45) x 100 / Maximum breadth (M 8)
M 57(I)	Max. breadth of nasal bones		
M 65	Bicondylar breadth	**I 20**	Orbital index = Orbital height (M 52) x 100 / Orbital breadth (M 51)
M 66	Bigonial breadth		
M 70	Height of mandibular ramus	**I 26**	Ramus index = Breadth of mandibular ramus (M 71) x 100 / Height of mandibular ramus (M 70)
M 71	Breadth of mandibular ramus		
M 79	Mandibular angle		

Statistical data analysis

Craniometrical measurements were reported using descriptive statistics e.g., mean, standard deviation (SD), minimum and maximum. For univailable analysis, each skull measurement in males and females were compared using an unpaired t-test. P-value and 95% CI of the difference between males and females and were reported. To determine the combination of skull measurements with the best prediction of gender, a multivariable analysis i.e., a multiple logistic regression analysis using the forward method, was employed. Only 30 skull and mandible measurements, not 14 indices were considered as independent variables since indices were ratios of 2 measurements. Measurements with high collinearity were not included in the model fitting process. Due to the small number of subjects compared to the number of measurements, interaction terms were not considered. A Goodness-of-fit test was performed using the residual score test and a Hosmer-Lemeshow test.

Statistical data analyses were performed using SAS 8.0 (Cary). A 2-sided p-value of less than 0.05 was considered statistically significant.

RESULTS

All 30 measurements and 14 indices in this study were divided into 8 groups i.e., (1) length, breadth and height of cranium, (2) basis cranii, (3) circumference and curve of skull, (4) median sagittal curve, (5) length, breadth and height of face, (6) orbit and interorbit, (7) nose and mandible and (8) ratio of neuro- to viscero- cranium. The comparison of each skull measurement between males and females were reported as follows.

1. Length, breadth and height of cranium

Table 2 demonstrated the comparison of length, breadth and height of the cranium between males and females. The mean of the maximum length of cranium (M1) in males was 6.88 mm significantly longer than females ($p < 0.001$) with a 95% CI of the difference in means between males and females of 4.00, 9.77. For the measurement of breadth of the cranium, the mean maximum breadth (M8) in males was only 1.17 mm (95% CI: -1.06, 3.39) wider than females and it was not statistically significantly different ($p = 0.300$). On the other hand, the minimum (M9) and maximum (M10) frontal breadth in males were on average 3.93 mm (95% CI: 1.51, 6.34) and 2.72 mm (95% CI: 0.02, 5.41) wider than females respectively. In terms of the ratio of M9 to M10 (transverse frontal index), the index in males was higher than females (mean: 67.13, 65.33 respectively), but it was not significantly different ($p = 0.107$). However, the M9/M8 ratio (transverse fronto-parietal index) in males was significantly higher than females (mean: 56.09, 53.81 respectively; $p = 0.005$).

The mean of the Basion-bregma height of cranium (M7) in males was 6.23 mm higher than females (95% CI; 3.97, 8.50). Regarding the index determination, the mean of cranial index (M8/M1) was significantly lower in males than females (83.07, 85.84 respectively). The mean of the breadth-height index (M7/M8) was higher in males than females (97.52, 94.04 respectively). There was no significant difference in the mean of length-height index (M7/M1) between males and females (80.97, 80.56 respectively; $p = 0.599$).

2. Basis cranii

Comparison of basis cranii between males and females (Table 3) showed that the mean nasion-basion length (M5) in males was 7.20 mm longer than females (95% CI: 5.45, 8.95 respectively). The length (M17) and breadth (M16) of the foramen magnum in males were on average significantly longer than females ($p = 0.03$, 0.007 respectively). However, there was no significant difference in the length-breadth index of the foramen magnum (M16/M17) between males and females ($p = 0.975$).

TABLE 2. Comparison of length, breadth, height, ratio of length, breadth and height of cranium between males and females.

Measurements	Sex	n	Mean	SD	Min, Max	Difference (M-F) Mean	95% CI	p-value
Length of cranium								
M1 (Maximum length)	M	66	175.68	6.83	160, 190	6.88	4.00, 9.77	<0.001
	F	35	168.80	7.18	155, 185			
Breadth of cranium								
M8 (Maximum breadth)	M	65	145.82	5.20	135, 158	1.17	-1.06, 3.39	0.300
	F	35	144.66	5.59	130, 155			
M9 (Minimum frontal breadth)	M	66	81.73	5.58	70, 100	3.93	1.51, 6.34	0.002
	F	35	77.80	6.27	65, 90			
M10 (Maximum frontal breadth)	M	65	121.92	6.55	100, 132	2.72	0.02, 5.41	0.048
	F	35	119.20	6.33	100, 130			
M9/M10 (Transverse frontal index)	M	65	67.13	5.49	56.0, 85.0	1.80	-0.39, 3.99	0.107
	F	35	65.33	4.82	54.4, 75.0			
M9/M8 (Transverse fronto-parietal index)	M	65	56.09	3.67	48.3, 64.5	2.28	0.69, 3.87	0.005
	F	35	53.81	4.10	44.2, 64.3			
Height of cranium								
M7(Basion-bregma height)	M	66	142.09	5.35	130, 155	6.23	3.97, 8.50	<0.001
	F	35	135.86	5.67	120, 145			
Ratio of length, breadth, height								
M8/M1 (Cranial index)	M	65	83.07	4.13	73.7, 91.2	-2.77	-4.58, -0.95	0.003
	F	35	85.84	4.79	75.7, 95.5			
M7/M1 (Length-height index)	M	66	80.97	3.80	73.0, 93.8	0.41	-1.13, 1.96	0.599
	F	35	80.56	3.56	73.9, 90.6			
M7/M8 (Breadth-height index)	M	65	97.52	4.87	88.4, 110.7	3.48	1.44, 5.53	0.001
	F	35	94.04	5.00	80.0, 103.7			

TABLE 3. Comparison of basis cranii, circumference and curve of skull, single component of median sagittal curve, length, breath and height of face between males and females.

Measurements	Sex	n	Mean	SD	Min, Max	Difference (M-F) Mean	95% CI	p-value
Basis cranii								
M5 (Nasion-basion length)	M	66	101.77	4.10	95, 110	7.20	5.45, 8.95	<0.001
	F	35	94.57	4.43	90, 105			
M17 (Foramen magnum length)	M	65	32.42	3.10	23, 39	1.37	0.14, 2.60	0.030
	F	35	31.06	2.66	27, 39			
M16 (Foramen magnum breadth)	M	66	27.04	2.22	21.5, 32.0	1.21	0.33, 2.08	0.007
	F	35	25.83	1.88	21.0, 30.0			
M16/M17 (Foramen magnum	M	66	19.04	1.60	15.7, 23.1	0.01	-0.63, 0.65	0.975
length-breadth index)	F	35	19.03	1.47	16.2, 21.7			
Circumference and curve of skull								
M23 (Horizontal circumference)	M	66	264.16	13.99	235, 300	7.05	1.18, 12.91	0.019
	F	35	257.11	14.39	220, 290			
M24 (Transverse arc)	M	65	320.14	12.42	290, 355	8.57	3.68, 13.45	0.001
	F	35	311.57	10.34	295, 335			
M25 (Median sagittal arc)	M	65	371.03	13.90	340, 410	9.77	3.95, 15.60	0.001
	F	35	361.26	14.18	325, 392			
Median sagittal curve								
M26 (Nasion-bregma arc)	M	66	132.49	6.34	120, 150	4.39	1.70, 7.09	0.002
	F	35	128.09	6.78	110, 140			
M29 (Nasion-bregma cord)	M	66	110.65	4.96	98.5, 125	3.69	1.56, 5.83	0.001
	F	35	106.96	5.51	94.0, 117			
M29/M26 (Sagittal-frontal index)	M	66	83.55	1.74	80.4, 89.2	0.02	-0.73, 0.76	0.963
	F	35	83.53	1.89	80.0, 89.2			
Length, Breath and Height of Face								
M40 (Facial height)	M	66	95.78	5.60	85, 110	6.01	3.63, 8.39	0.001
	F	35	89.77	6.01	78, 101			
M42 (Lower facial length)	M	66	109.72	7.64	91.5, 130	5.42	2.08, 8.76	0.002
	F	35	104.30	8.77	86.5, 130			
M44 (Biorbital breadth)	M	66	96.79	4.07	88, 105	4.70	3.08, 6.32	<0.001
	F	35	92.09	3.56	85, 102			
M45 (Bizygomatic breadth)	M	66	136.33	5.75	125, 150	8.78	6.45, 11.12	<0.001
	F	35	127.54	5.39	115, 140			
M47 (Facial height)	M	66	108.55	16.19	72, 136	10.00	3.50, 16.50	0.003
	F	35	98.54	14.61	66, 123.5			
M48 (Upper facial height)	M	66	67.12	4.94	55, 78	4.98	2.85, 7.10	<0.001
	F	35	62.14	5.44	48, 71.5			
M47/M45 (Facial index)	M	66	79.76	12.21	52.1, 99.6	2.41	-2.56, 7.39	0.338
	F	35	77.35	11.56	52.8, 92.3			

3. Circumference and curvature of skull

Table 3 revealed that the mean horizontal circumference (M23) in males was 7.05 mm longer than females (95% CI: 1.18, 12.91). The transverse arc (M24) and the median sagittal arc (M25) in males were as much as 8.57 (95% CI: 3.68, 13.45) and 9.77 (95% CI: 3.95, 15.60) mm longer than females respectively.

4. Median sagittal curve

The comparison of the single component of the median sagittal curve (Table 3) showed that males had a 4.39 mm (95% CI: 1.70, 7.09) and a 3.69 mm (95% CI: 1.56, 5.83) longer nasion-bregma arc (M26) and nasion-bregma cord (M29) than females. However, there was no significant difference in the ratio of M29 to M26 (sagittal-frontal index) between males and females ($p = 0.963$).

5. Length, breadth and height of face

Analyses of face measurements (Table 3) revealed that males had the following measurements significantly higher than females: face height (M40) 6.01 mm higher (95% CI: 3.63, 8.39), lower facial length (M42) 5.42 mm longer (95% CI = 2.08, 8.76), biorbital breadth (M44) 4.70 mm wider (95% CI: 3.08, 6.32), bizygomatic breadth (M45) 8.78 mm wider (95% CI: 6.45, 11.12), face height (M47) 10 mm higher (95% CI: 3.50, 16.50) and upper face height (M48) 4.98 mm higher (95% CI: 2.85, 7.10) respectively. For the ratio of M47 to M45 (facial index), there was no significant difference between males and females ($p = 0.338$).

6. Orbit, interorbit

Regarding orbit dimension, males had a significantly 2 mm (95% CI: 1.17, 2.85) wider orbit (M51) than females (Table 4). However, there was no statistically significant difference in the height of orbit (M52) between females and males (33.44, 32.89 respectively; $p = 0.255$). For the ratio of height to breadth of orbit (M52/M51), males had a significantly lower ratio than females (83.50, 86.61 respectively; $p = 0.027$). With regard to the anterior and posterior inter-orbital breadth, they were 1.25 (95% CI: 0.30, 2.20) and 1.75 (95% CI: 0.82, 2.69) wider in males than females.

7. Nose and mandible

Table 4 displays the difference in nose and mandible

TABLE 4. Comparison of orbit and interorbit, nose and mandible between males and females.

Measurements	Sex	n	Mean	SD	Min, Max	Difference (M-F) Mean	95% CI	p-value
Orbit								
M51 (Orbital breadth)	M	66	40.10	1.89	36, 44.0	2.01	1.17, 2.85	<0.001
	F	35	38.09	2.25	32, 41.5			
M52 (Orbital height)	M	66	33.44	2.33	30, 41.0	0.55	-0.41, 1.51	0.255
	F	35	32.89	2.28	29, 39.5			
M52/M51 (Orbital index)	M	66	83.50	6.00	72.3, 96.3	-3.11	-5.86, -0.37	0.027
	F	35	86.61	7.65	74.1, 112.9			
Interorbit								
M50 (Anterior interorbital breadth)	M	66	15.30	2.43	10, 22	1.25	0.30, 2.20	0.010
	F	35	14.04	2.01	10, 19			
M49 (Posterior interorbital breadth)	M	66	21.20	2.41	15, 26	1.75	0.82, 2.69	<0.001
	F	35	19.44	1.90	16, 24			
Nose								
M57 (Min. breadth of nasal bone)	M	66	5.46	2.26	0.5, 10	0.83	0.06, 1.61	0.035
	F	35	4.63	1.61	1.0, 8			
M57.1 (Max. breadth of nasal bone)	M	65	14.12	1.96	7.5, 18	0.59	-0.21, 1.39	0.146
	F	35	13.53	1.85	9.0, 18			
Mandible								
M65 (Bicondylar breadth)	M	66	119.95	5.84	107.0, 135	5.55	3.08, 8.02	<0.001
	F	35	114.40	6.15	104.5, 127			
M66 (Bigonial breadth)	M	66	97.49	5.92	83.0, 111.5	6.71	4.39, 9.03	<0.001
	F	35	90.79	4.91	82.5, 105.0			
M70 (Height of mandibular ramus)	M	66	63.11	6.94	47, 78.5	6.26	3.54, 8.98	<0.001
	F	35	56.86	5.74	43, 69.0			
M71 (Breadth of mandibular ramus)	M	66	30.40	3.11	25, 38	2.69	1.30, 4.08	<0.001
	F	35	27.71	3.78	20, 36			
M79 (Mandibular angle)	M	66	119.83	6.89	105, 139	-2.15	-5.20, 0.91	0.166
	F	35	121.97	8.16	105, 138			
M71/M70 (Mandibular ramus index)	M	66	48.63	6.34	32.9, 64.0	-0.24	-2.79, 2.32	0.855
	F	35	48.86	5.80	39.5, 65.4			
Ratio of mandible to face								
M66/M45 (Jugo-mandibular index)	M	66	71.56	4.14	64.4, 79.6	0.36	-1.09, 1.80	0.624
	F	35	71.20	3.07	65.4, 80.0			
Ratio of neuro- to viscero-cranium								
M40/M5 (Alveolar index)	M	66	94.16	5.04	85.0, 105.3	-0.90	-3.28, 1.48	0.456
	F	35	95.06	6.86	82.1, 111.1			
M9/M45 (Jugo-frontal index)	M	66	59.97	3.49	52.0, 71.4	-1.01	-2.49, 0.47	0.180
	F	35	60.97	3.72	53.9, 69.2			
M45/M8 (Cranio-facial index)	M	66	93.55	3.75	86.2. 100.0	5.32	3.77, 6.87	<0.001
	F	35	88.23	3.67	80.0, 96.3			

measurements between males and females. Males had a minimum breadth of nasal bone (M57) 0.83 mm wider than females (95% CI: 0.06, 1.61). Males also had a maximum breadth of nasal bone (M57.1) 0.59 mm wider than females but it was not statistically significantly different (p = 0.146). Regarding the mandible measurements, males had 5.55 mm (95% CI: 3.08, 8.02) wider bicondylar breadth and 6.71 mm (95% CI: 4.39, 9.03) wider bigonial breadth than females. The mandibular ramus in males was as much as 6.26 mm higher (M70) and 2.69 mm wider (M71) than females. However, there was no significant difference between males and females in the mandibular angle (M79) (119.83, 121.97 respectively; p = 0.166), in the mandibular ramus index (48.63, 48.86 respectively; p = 0.855) and in the jugo-madibular index (71.56, 71.20 respectively; p = 0.624).

8. Ratio of neuro- to viscero- cranium

Table 4 demonstrates that there was no significant difference in alveolar index and jugo-frontal index between males and females (p = 0.456 and p = 0.180 respectively). However, the cranio-facial index in males was as much as 5.32 higher than females (95% CI: 3.77, 6.87).

Since several skull measurements differed significantly between males and females, multiple logistic regression was applied to determine the combination of measurements with the best discrimination between the two genders. Based on 98 complete subjects (35 females and 63 males) and 23 independent measurements, a multiple logistic regression model was fitted via forward selection. The model revealed 4 significant predictors of gender (Table 5) i.e., the nasion-basion length (M5), the maximum breadth of the cranium (M8), the facial height (M40), and the bizygomatic breadth of the face (M45). The test of the goodness-of-fit by the Hosmer-Lemeshow test showed an appropriate fit with a p-value of 0.437. The residual score test also showed an adequate fit with a p-value of 0.761 for the global test of all 19 independent variables not included in the model and p-values between 0.217 and 0.985 for single tests of each independent variable not in the model. The multiple logistic regression equation was as follows:

In (odds) = Z = -52.5312 + 0.27 M5 - 0.1867 M8 + 0.1268 M40 + 0.319 M45 The probability of being male

TABLE 5. Results of multiple logistic regression analysis.

Measurements (mm)	Coefficient (b)	SE(b)	p-value
Constant	-52.5312	13.5085	0.0001
Nasion-basion length (M5)	0.2700	0.1071	0.0117
Maximum breadth of the cranium (M8)	-0.1867	0.0784	0.0172
Facial height (M40)	0.1268	0.0659	0.0545
Bizygomatic breadth of the face (M45)	0.3190	0.0951	0.0008

(P) is then $e^Z/(1 + e^Z)$ and the probability of being female is 1-P where e = 2.718. Using a probability P of greater than 0.5 as male, these 4 measurements all together could correctly predict 82.9% (29/35, 95% CI: 66.4%, 93.4%) of females and 92.1% (58/63, 95% CI: 82.4%, 97.4%) of males respectively with the overall accuracy of 88.8% (87/98, 95% CI: 80.8%, 94.3%).

DISCUSSION

The present study deals with the accuracy for sex determination of Thai skulls using craniometry. It used the bony landmarks and bone measurements in terms of physical anthropology according to Jorgensen's method[16] which was modified from Martin's standard method.[17] However, only 30 remarkable measurements and 14 indices were used in this study. A statistically significant difference between males and females was found in 26 of 30 measurements and 5 of 14 indices (Tables 2-4). However, they had some overlapping ranges which were unable to define definite gender. The 4 measurements that did not differ between males and females were the maximum breath of cranium (M8), the mandibular angle (M79), the orbital height (M52), and the maximum breadth of nasal bone (M57.1). Briefly, the skull of a male was larger and higher than that of a female. Males had a longer and wider foramen magnum than females. These results were consistent with Texeire's report [11] that measured the length and breadth of the foramen and took the average of the two as an approximate diameter of a circle. It was concluded that a cross-sectional foramen magnum of at least 963 mm^2 represents the male skull and an area of 805 mm^2 or lesser represents the female skull.

A multiple logistic regression analysis revealed 4 measurements being significant predictors of gender i.e., the nasion-basion length (M5), the maximum breadth of the cranium (M8), the facial height (M40), and the bizygomatic breadth of the face (M45). From the following equation of Z, the probability of being a male skull (P) can be calculated through $e^Z/(1 + e^Z)$ where e =2.718. Thus the probability of being a female skull is then 1-P.

In (odds) = Z = -52.5312 + 0.27 M5 - 0.1867 M8 + 0.1268 M40 + 0.319 M45.

This multiple logistic equation had the overall accuracy of 88.8% and the accuracy of 82.9%, 92.1% among females and of males respectively. Lower accuracy among females might be due to a small sample size of only 35 females and there were as many as 23 measurements considered as independent variables. Although our study of sex determination was similar to previous reports[6-13], the equation was simpler. Study of the sexual dimorphism in the crania and mandible of 91 South African Whites (44 males and 47 females) using a discriminant analysis by Steyn[13] showed the accuracy between 80% (bizygomatic breadth) to 86% (cranium). Hanihara[7] presented his basic data on 9 variables including the standard osteometric dimensions: maximum cranial length, bigonial breadth, maximum cranial breadth, mandibular symphyseal height, cranial height, condylar height, facial breadth, minimum ramus breadth, and upper facial height. The accuracy in that study varied from 85.6% to 89.7%.

Thus, this study indicated that sexual dimorphism in Thai skulls can be assessed using craniometry via a multiple logistic model.

CONCLUSION

Sex could be determined very well from the cranium and mandible of Thais using Jorgensen's craniometry. As a result of craniometry, the multiple logistic regression model was developed based on 4 measurements (shown below) i.e., nasion-basion length (M5), maximum breadth of the cranium (M8), facial length (M40), and bizygomatic breadth of the face (M45).

In (odds) = Z = -52.5312 + 0.27 M5 - 0.1867 M8 + 0.1268 M40 + 0.319 M45.

Plugging these 4 values in the equation gives a value of Z and a probability of being a male skull (P) of $e^Z/(1 + e^Z)$. This logistic model could correctly predict 82.9% of females and 92.1% of males respectively. The overall accuracy was 88.8%. This formula is useful for evaluating the skeletal gender particularly in the case of only a few remaining bones.

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