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Original Article

Sex determination from different sternal measurements: A study in a Thai population

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ABSTRACT

Introduction: Estimation of sex is an important initial step for personal identification of unknown skeletal remains in forensic investigation. The aim of the present study was to evaluate the applicability of the sternum for sex estimation of adult skeletal remains by measuring the sternum of Thai individuals.
Methods: A study of 281 adult Thai dry sterna with known sex (192 males and 89 females) was carried out for sexing by using measurements. Discriminant function analysis was used.
Results: The results showed that all parameters included in this study were significantly sexually dimorphic except sternal width index. By using discriminant function analysis, it was observed that the best parameter was the combined length of manubrium and mesosternum yielded cross-validated sex allocation accuracy rate 85.8% (82.4% for male and 95.7% for female), followed by sternal area with classification accuracy rate 82.9% (79.2% for males and 91.2% for females) and the length of mesosternum with classification accuracy rate 81.1% (78.8% for males and 88% for females). A stepwise discriminant function, which included 5 linear measurements from both manubrium and mesosternum yielded highest classification accuracy rate of 86.4%.
Discussion: The results of the present study proved that the sternum is a reliable element for sex determination in Thai population and it may be a useful tool in forensic investigations.

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1. Introduction

In forensic investigations, one of the most important aspects is identification of human skeletal remains by creating biological profiles. The biological profile consists of individual's sex, age, stature, and ancestry. Accurate estimation of sex is important because other biological profiles, such as age, stature, and ancestry, are sex dependent.[1] Generally, forensic anthropologists rely mainly on sex assessment methods based on analyses of pelvis and skull, which are known to be highly accurate, but relying heavily on those two bones within a forensic context is limiting because they have been subjected to trauma, prone to taphonomic process, such as animal scavenging, burning, and dismemberment, or may not be present, at all.[2] Without skull and pelvis, it becomes difficult for the expert to judge the age and sex accurately. Therefore, it is of utmost need that an alternative element of the skeleton be investigated as potential indicators of sex.

The skeleton, which resists putrefaction for long time, is useful for sex determination. The sternum is one of such bones and is usually found together with anterior thoracic cage in forensic investigations. The human sternum consists of three parts, named superior to inferior, i.e. the manubrium, the body or mesosternum, and the xiphoid process. The xyphoid process is often varied, so only the manubrium and mesosternum are usually used for sexing purpose.[3] Numerous studies had shown that analyzing the sternum may lead to an accurate estimation of sex. However, most of the previously published methods showed the sternum is population specific signifying that the data would not prove useful in the Thai population.[1,2,4–8] This prompted us to develop osteometric standards for estimating sex from the sternum of a Thai population.

In Thailand, several parts of the skeletons have been used to determine sex, including the femur,[9] humerus,[10] vertebral column,[11] radius,[12] calcaneus,[13] mastoid process,[14] the metacarpals,[15] proximal hand phalanges,[16] and sternum.[17] A previous study of sexing the sternum in Thai population resulted in no significant sexual dimorphism and that finding was different from other previous studies conducted around the world. However, the populations may experience secular changes, after more than one decade, and thus require using new representative skeletal collections for the determination of sex. Hence, the main objective of this study was to evaluate the applicability of the sternum for sex estimation of adult skeletal remains by measuring the sternum of Thais.

2. Materials and methods

The adult dried human sterna of 281 Thai individuals of known sex (192 males and 89 females) were procured for the present study. The specimens were collected from the Forensic Osteology Research Center at Chiang Mai University, Thailand. The ages at death of the specimens used in the present study ranged between 28 and 96 years (mean age of 67.34 years for males and 65.84 years for females).

The definitions of measurements and calculated indices are described in Table 1 and correspond to the illustration provided in Fig. 1. Measurements of the sternum were provided by McCormick et al.[18] and Jit et al.[19] All the parameters were measured in millimeters by using Mitutoyo Digimatic Caliper®. Any sterna with signs of pathology, trauma or fracture, and deformity were excluded from the present study.

The data obtained were then analyzed by descriptive statistics, utilizing IBM SPSS® version 20.0 statistical package for window to find the mean, standard deviation, minimum, and maximum of all the data in each sex. The independent t-test was applied to test the significance of differences between mean values of various parameters in both sexes. One-Sample Kolmogorov–Smirnov Test was conducted for all parameters to determine whether the data were normally distributed. Five linear measurements from both manubrium and mesosternum were subjected to stepwise discriminant analysis to select the most important variable, which classify between males and females with higher correct percentage. Other stepwise discriminant functions were also generated for manubrium dimensions (two linear measurements) and mesosternum (three linear measurements). Lastly, direct discriminant function analysis was generated for all parameters to find out which

Table 1 – Definitions of the measurements used in the present study followed McCormick et al.[18] and Jit et al.[19] The measurements are illustrated in Fig. 1.

Measurement	Definition
1. Manubrium length (M)	Direct distance, from the anterior aspect and in the midline, from jugular notch to manubriosternal junction
2. Sternal body length (B)	Direct distance, from the anterior aspect and in the midline, from manubriosternal junction to mesoxiphoidal junction
3. Combined length of manubrium and body (CL)	Sum of the manubrium and sterna body lengths (M + B)
4. Manubrium width (MW)	Width between the left and right facets for the first costal cartilage
5. Corpus sterni width at first sternebra (CSWS1)	Minimum distance at the level of the line passing from the point between the facet for the second and third costal cartilage on each side
6. Corpus sterni width at second sternebra (CSWS2)	Minimum distance at the level of the line passing from the point between the facet for the third and fourth costal cartilage on each side
7. Corpus sterni width at third sternebra (CSWS3)	Minimum distance at the level of the line passing from the point between the facet for the fourth and fifth costal cartilage on each side
8. Sternal Index (SI)	Calculated as the division of M by B, multiplied by 100: $[(M/B) \times 100]$
9. Sternal Area (SA)	Calculated by: $[(M + B) \times (MW + CSWS1 + CSWS3)/3]$
10. Sternal Width Index (SWI)	Calculated as the division of CSWS1 by CSWS3, multiplied by 100: $[(CSWS1/CSWS3) \times 100]$

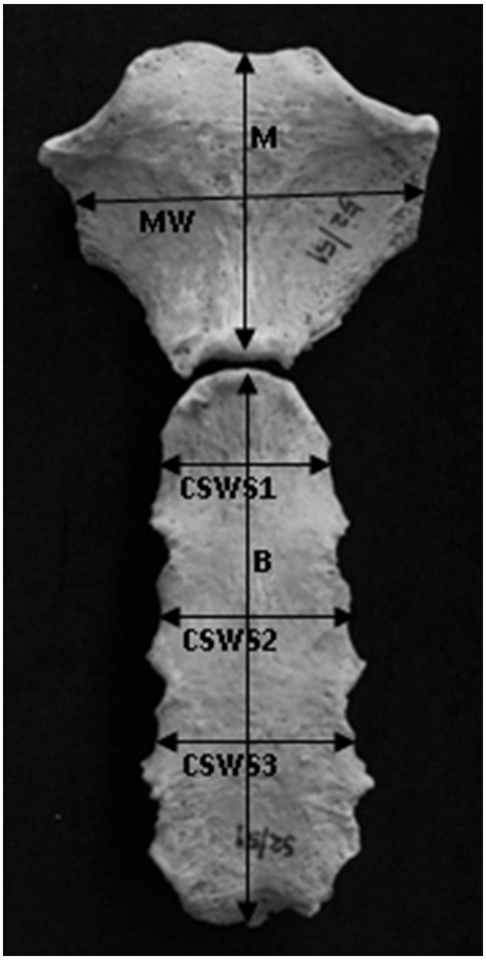

Fig. 1 – Measurements of the sternum provided by McCormick et al.[18] and Jit et al.[19] The measurements are as follows: M – manubrium length, B – sternal body length, MW – manubrium width, CSWS1 – corpus sterni width at first sternebra, CSWS2 – corpus sterni width at second sternebra, CSWS3 – corpus sterni width at third sternebra.

parameter can be useful for sex determination and create formulae that may be useful in the cases where well preserved sternum with both manubrium and mesosternum could not be found. To evaluate the performance of discriminant function model obtained for sex determination in unknown cases, the cross-validation method was used in this study. To evaluate the intraobserver error, all linear measurements of manubrium and mesosternum of 50 specimens were measured three times at least 2 weeks apart. The data obtained were analyzed to find out mean, standard deviation, and by using Univariate Analysis of Variance, to calculate the significant mean differences between 1st time, 2nd time, and 3rd time measurements.

3. Results

Table 2 shows mean values and standard deviation of the first time, second time, and third time measurements with significant level of differences between mean values. The results revealed there were no significant differences between first, second, and third time measurements for all linear measurements ($p > 0.05$) except corpus sterni width at 2nd sternebra ($p < 0.05$). It was possibly due to degenerative changes, such as osteophyte, that were more frequently found at CSWS2 than other sternebra widths. However, the mean values of CSWS2 for first, second, and third time measurements were almost the same (Table 2). Therefore, for CSWS2, average of the three times measurement was used for other statistical analyses.

Descriptive statistics of studied sternal measurements and calculated indices for both sexes are presented in Table 3. The results of the present study showed that mean values for the male samples were greater than those of the female samples for all parameters except sternal index, which was greater in females. The differences between male and female mean values for all parameters were highly significant ($p < 0.01$) except sternal width index, which did not differ significantly between the sexes ($p = 0.176$). Therefore, that parameter was not included in the classification analysis. The mean difference between two sexes, as indicated by t-value, was found to be the highest for the combined length of manubrium and mesosternum ($t = 15.159$) followed by the mesosternal length (t-value = 13.337) and sternal area ($t = 10.21$). The smallest mean difference between two sexes was corpus sterni width at 2nd sternebra ($t = 3.296$).

The results of stepwise and direct discriminant function analyses are presented in Table 4. To obtain discriminant score, each variable was multiplied by its classification function coefficient, summing them and then adding in the

Table 2 – Comparison between 1st, 2nd, and 3rd time measurement by univariate analysis of variance.

Parameter	N		1st	2nd	3rd	p-Value
M	50	Mean	46.89	46.92	46.97	0.254
		SD	4.36	4.33	4.37	
B	50	Mean	93.57	93.29	93.26	0.057
		SD	10.64	10.02	10.12	
MW	50	Mean	52.43	52.33	52.3	0.672
		SD	4.96	4.99	4.94	
CSWS1	50	Mean	24.7	24.72	24.73	0.495
		SD	2.87	2.91	2.9	
CSWS2	50	Mean	26.42	26.47	26.49	0.043
		SD	3.53	3.47	3.45	
CSWS3	50	Mean	29.00	29.06	29.13	0.217
		SD	4.27	4.07	4.07	

Table 3 – Statistical analysis of various sternal measurements (N = 281, Male = 192, Female = 89).

Parameters	Sex	N	Mean	±SD	Minimum	Maximum	Mean difference	Level of significance for the difference between the mean
M	M	172	48.04	±4.55	36.04	69.48	3.72	$p < 0.001$, $t = 6.358^*$
	F	86	44.32	±4.2	35.73	57.60		
B	M	156	98.12	±9.1	79.27	129.19	15.05	$p < 0.001$, $t = 13.337^*$
	F	50	83.08	±6.09	68.49	95.05		
CL	M	136	146.20	±9.64	125.77	180.46	19.33	$p < 0.001$, $t = 15.159^*$
	F	47	126.87	±6.65	106.53	138.43		
SI	M	136	49.06	±6.4	34.52	71.30	−4.04	$p < 0.001$, $t = 3.711^*$
	F	47	53.10	±6.55	41.98	69.95		
MW	M	104	54.20	±4.89	43.94	67.51	5.72	$p < 0.001$, $t = 7.86^*$
	F	65	48.48	±4.09	38.51	56.11		
CSWS1	M	149	25.32	±2.66	18.03	31.66	2.98	$p < 0.001$, $t = 7.021^*$
	F	49	22.34	±2.31	17.58	28.04		
CSWS2	M	149	27.54	±3.31	20.72	36.85	1.87	$p = 0.001$, $t = 3.296^*$
	F	49	25.66	±3.86	17.43	34.97		
CSWS3	M	149	30.02	±4.24	21.01	42.78	2.50	$p = 0.001$, $t = 3.416^*$
	F	48	27.52	±4.88	18.04	38.45		
SWI	M	148	85.29	±10.26	59.42	112.04	2.47	$p = 0.176$, $t = 1.358^{NS}$
	F	48	82.83	±12.82	60.06	109.26		
SA	M	77	5344.28	±729	4035.82	8188.82	1206.33	$p < 0.001$, $t = 10.21^*$
	F	34	4137.95	±489.86	3087.94	5201.57		

* p-Value was measured by Student's t-test and value <0.01 = statistically significant, <0.001 = statistically highly significant.
NS p-Value >0.05 = statistically not significant.
M: manubrium length; B: sternal body length; CL: combined length of manubrium and body; MW: manubrium width; CSWS1: corpus sterni width at first sternebra; CSWS2: corpus sternebra width at second sternebra; CSWS3: corpus sterni width at third sternebra (mm); SI: sternal index and SWI: sternal width index (%); SA: sternal area (mm^2).

constant. The discriminant score for both males and females was calculated and the result with greater value was allocated to that sex.

When five linear measurements were entered in stepwise multivariate discriminant function analysis (Function 1), all measurements except manubrium width were selected, providing overall sex classification accuracy rate of 86.4% (84% for males and 93.3% for females). For manubrium measurements, manubrium length and width were entered (Function 2) and both measurements were selected, resulting in overall sex classification accuracy rate of 73.4%. For mesosternum measurements (Function 3) only, mesosternum length and corpus sterni width at 1st sternebra were selected in stepwise analysis, yielding overall sex classification accuracy rate of 82.3%.

The most effective univariate function derived from direct discriminant analysis was combined length of manubrium and mesosternum (Function 6), with 85.8% of overall sex classification accuracy rate, followed by sternal area (Function 12, 82.9%), mesosternal length (Function 5, 81.1%), and manubrium width (Function 8, 71.6%). The lowest sex prediction accuracy for univariate discriminant function was obtained for corpus sterni width at 2nd sternebra (Function 10, 56.1%), followed by corpus sterni width at 3rd sternebra (Function 11, 61.4%), sternal index (Function 7, 63.4%), manubrium length (Function 4, 65.1%), and corpus sterni width at 1st sternebra (Function 9, 69.7%). The classification accuracy rates of females were higher than males for almost all functions (Function 1–12) with the exception of (Function 2) and (Function 7). For those two functions, the classification accuracy rates for determined sexes were higher in males than in females.

4. Discussion

The results of this study clearly demonstrated that the metric analysis of the human sternum was a reliable method for estimating sex in Thai population. The most sexually dimorphic sternal dimensions and indices in this population group were combined length of manubrium and mesosternum, sternal area, and length of mesosternum. The same dimorphic pattern was revealed in the population of Western Australian,[1] North American,[2] South African blacks,[4] Spaniards,[5] North Indian,[6] West Indian,[7] and Marathwada region of India.[8] The best parameter in the present study for univariate analysis was combined length of manubrium and mesosternum (Function 6). Our finding is in agreement with most of the previous studies conducted either on dry sternums or their images, e.g., Chest radiographs or Computed Tomography scans.[1,2,4–8] Majority of the earlier studies found that the combined length of manubrium and mesosternum was the most reliable parameter for discriminating sex[3,9,10] but there were few studies in which although combined length of manubrium and mesosternum was highly sexually dimorphic in the studied population, the best parameter was sternal area with classification accuracy rate higher than that of combined length.[4,5] However, the parameters that were useful for sex determination were the same. Multivariate discriminant function analysis, incorporating dimensions of both manubrium and mesosternum (Function 1), provides the highest sex classification accuracy, 86.4%. Combined length of manubrium and mesosternum also provides a nearly similar sex prediction success rate of 85.8%. Although multivariate discriminant function analysis (Function 1) showed higher accuracy rate,

Table 4 – Stepwise and direct discriminant analysis with discriminant function equations and classification accuracies for all parameters.

Function	Variables	Classification function coefficients		% Original grouped			% Cross-validated		
		M	F	Overall	M	F	Overall	M	F
Stepwise analysis									
For specimen with complete manubrium and body (5 linear measurements)[a]									
1	M	2.829	2.552	89.2	86.3	97.8	86.4	84	93.3
	B	1.352	1.142						
	CSWS1	2.719	2.286						
	CSWS3	−0.462	−0.279						
	Constant	−162.205	−125.483						
For specimen with only manubrium (manubrium measurements)									
2	M	1.941	1.782	74	76	70.8	73.4	75	70.8
	MW	2.199	1.959						
	Constant	−107.306	−87.580						
For the specimen with only mesosternum (mesosternum measurements)[b]									
3	B	1.235	1.041	82.3	79.2	91.8	82.3	79.2	91.8
	CSWS1	3.384	2.996						
	Constant	−104.155	−77.367						
Direct analysis									
4	M	2.444	2.254	65.5	62.2	72.1	65.1	62.2	70.9
	Constant	−59.388	−50.643						
5	B	1.366	1.157	81.6	79.5	88	81.1	78.8	88
	Constant	−67.730	−48.747						
6	CL	1.813	1.573	85.8	82.4	95.7	85.8	82.4	95.7
	Constant	−133.234	−100.502						
7	SI	1.184	1.282	63.4	64.7	59.6	63.4	64.7	59.6
	Constant	−29.740	−34.723						
8	MW	2.562	2.292	71.6	70.2	73.8	71.6	70.2	73.8
	Constant	−70.127	−56.254						
9	CSWS1	3.810	3.361	69.7	67.1	77.6	69.7	67.1	77.6
	Constant	−48.927	−38.240						
10	CSWS2	2.311	2.154	56.1	55	59.2	56.1	55	59.2
	Constant	−32.515	−28.332						
11	CSWS3	1.547	1.419	61.4	60.4	64.6	61.4	60.4	64.6
	Constant	−23.920	−20.217						
12	SA	0.012	0.009	82.9	79.2	91.2	82.9	79.2	91.2
	Constant	−32.915	−20.010						

[a] Variable MW was not selected in the analysis.
[b] Variable CSWS3 was not selected in the analysis.

length and breadth dimensions of both manubrium and mesosternum are needed to calculate this equation and when compared to the combined length of manubrium and mesosternum (Function 6), only the length of manubrium and mesosternum is needed. The univariate discriminant function equation for sternal area and length of mesosternum yielded an allocation accuracy rate of 82.9% and 81.1%, respectively. The latter should prove to be more useful in forensic contexts because it can be employed in situations in which the manubrium of the sternum is damaged or missing.

The classification accuracies for various sternal parameters presented in this study ranged between 56.1% and 86.4%

Table 5 – Comparison of overall classification accuracy rate of various parameters of sternum for sex discrimination with previous study.

No.	Author	Target population	M	B	CL	SA	MW	CSWS1	CSWS3	SI	CSWS2	Multivariate
1	Franklin et al.[1]	Western Australian		83.4	83.4	80.7	77.5	72.2				84.5
2	Bongiovanni and Spradley[2]	North American	64.5	78.5	81.5			66	63			84.12
3	Macaluso[4]	South African blacks	68.4	83.5	83	86.9	79.1	68.4	69.4	68.9		86.4
4	Macaluso[5]	Spaniards	72.4	79.3	81	88.8	85.3	73.3	70.7	58.6		89.7
5	Singh and Pathak[6]	North Indian	67.1	75.5	82.2	82.05		71.4	68.8	65.6		84.8
6	Present study	Thai	65.5	81.6	85.8	82.9	71.6	69.7	61.4	63.4	56.1	86.4

(Table 5). These results were compared to other studies in different populations. Bongiovanni and Spradley applied discriminant function analysis to North American black's and white's sterna and found that classification accuracy of 81.5% in the study sample could be sexed correctly utilizing combined length of manubrium and mesosternum. By using multivariate discriminate function analysis, the accuracy rate increased to 84.12%.[2] Another study concerning the discrimination of sex from sternal measurements obtained from multislice spiral computed tomography scans of Western Australians demonstrated that combined length of manubrium and mesosternum and sternal body length gave classification accuracy of 83.4% for each variable and sternal area got 80.7%, while multivariate analysis incorporating mesosternum length and corpus sterni width at the first sternebra provided a maximum classification accuracy rate of 84.5%.[1] Recently in Asia, researchers studied North Indian sterna for sex discrimination by using discriminant function analysis and yielded overall classification rate of 82.2% for combined length of manubrium and mesosternum, 82.05% for sternal area, and 84.8% for multivariate analysis.[6] Although, slightly higher but still then, comparable classification accuracy was found in South African blacks and Spaniards population studied by Macaluso[4,5] in 2010 and 2014 and the results yielded overall classification accuracy rates for the sternum ranging from 81% and 89.7%, utilizing both univariate and multivariate statistical methods.

The highest sex allocation accuracy obtained from the present study was 86.4% from multivariate analysis of 5 linear measurements of both manubrium and mesosternum, and closely followed by combined length 85.8% and mesosternum length 81.6%. These results were also comparable to those reported in previous studies concerning the sex determination in Thais, such as vertebral column (70–86.5%), mastoid process (66–78%), radius (86.9–89.4%), calcaneus (90.5–91%), metacarpals (83.2–89.8%), and proximal hand phalanges (87.6–92.3%).[11–16]

In the present study, the parameter that proves least reliable for sex estimation was corpus sterni width at 2nd sternebra (Function 10) with classification accuracy rate 56.1%, which was a totally new parameter used for determination of sex from sternal measurements and proved not useful. The manubrium length, manubrium width, corpus sterni width at 1st sternebra and 3rd sternebra, and sternal index also proved not useful for determination of sex in Thai population with the classification accuracy rate ranging between 61.4% and 71.6% (Table 4). Similar results were found in previous researches done on other population, including North American,[2] Indians,[6–8] and Southern Nigerian.[20] However, on utilizing both length and width dimensions of the manubrium with multivariate discriminant function analysis, it provided classification accuracy rate about 81% in South African blacks[4] and 87.1% in Spaniards.[5] Manubrium width alone can also be useful to determine sex in Spaniards with classification accuracy rate 85.3%.[5] These differences showed population specificity in sexual dimorphism of sternum, and could possibly be due to geographical, environmental, genetic, socio-cultural, and lifestyle differences among populations.

In addition, a comparative analysis of absolute sternal measurements from different population samples with mean

Table 6 – Comparison of mean value and differences between mean of various parameters with different workers.

No.	Name of workers	Number of specimens	M		B		CL		MW		CSWS1		CSWS3		Sternal Index		Sternal Area	
			Mean	Difference	Mean	Difference	Mean	Difference	Mean	Difference	Mean	Difference	Mean	Difference	Mean	Difference	Mean	Difference
1	Franklin et al.[1]	M (93)	49.02	3.7	102.94	18.51	151.96	21.74	57.16	6.95	27.24	3.83	31.17	2.11	48.02	6.3	5976	1510
	(Western Australian)	F (94)	45.32		84.89		130.22		50.21		23.41		29.06		54.32		4466	
2	Bongiovanni and Spradley[2]	M (285)	51.84	3.6	104.8	15.42	154.97	18.22	–	–	27.35	3.06	34.47	4.32	48.41	5.27	–	–
	(North American)	F (125)	48.24		89.38		136.75		–		24.29		30.15		53.68		–	
3	Macaluso[4]	M (123)	48.51	4.66	98.74	17.31	174.24	48.96	52.08	7.48	24.95	3.12	31.77	4.47	49.52	4.86	5356.75	1435.03
	(South African Blacks)	F (83)	43.85		81.43		125.28		44.6		21.83		27.3		54.38		3921.72	
4	Macaluso[5] (Spain)	M (65)	51.85	6	106.25	18.48	158.1	24.48	59.78	7.96	28.31	3.63	35.36	5.21	49.22	3.58	6506.42	1753.76
		F (51)	45.85		87.77		133.62		51.82		24.68		30.15		52.8		4752.66	
5	Singh and Pathak[6]	M (252)	52.1	4.93	94.07	15.53	145.69	20.82	54.91	6.6	27.03	3.92	33.53	5.52	56.13	5.1	5639.29	1461.37
	(North India)	F (91)	47.17		78.54		124.87		48.31		23.11		28.01		61.23		4177.92	
6	Mahakkanukrauh[17]	M (174)	54.6	7.7	94.99	12.44	149.6	20.1	–	–	–	–	–	–	–	–	–	–
	(Northern Thai)	F (86)	46.9		82.55		129.5		–		–		–		–		–	
7	Osunwoke[20]	M (68)	60.7	14.7	101.3	23.4	164.4	41.1	–	–	–	–	–	–	–	–	–	–
	(Southern Nigerian)	F (26)	46		77.9		123.3		–		–		–		–		–	
8	Present study (Thai)	M (192)	48.04	3.72	98.12	15.04	146.2	19.33	54.2	5.72	25.32	2.98	30.02	2.5	49.06	4.04	5344.28	1206.33
		F (89)	44.32		83.08		126.87		48.48		22.34		27.52		53.1		4137.95	

values of both sexes is shown in Table 6. The manubrium length of the present study was similar to South African Blacks[4] and significantly shorter than other studies. Among Asia countries, manubrium of North Indian[6] was found to be longer than others, such as Western Australians[1] and Thais. The mesosternum length and combined length of Thai female sternum were longer than most of the studies to which it was compared except Western Australian,[1] North Americans,[2] and Spaniards[5] population, where mean value of males was shorter than almost all the studied compared except North Indian.[6] In both sexes, width of manubrium, and corpus sterni widths of 1st and 3rd sternebra of this study are again in average with North Indian[6] and South African black[4] population and narrower than Spaniards,[5] North American,[2] and Western Australian[1] population. Sternal indexes of all the studies compared are nearly the same to each other except North Indians,[6] which showed significantly higher sternal index compared to other populations. The sternal area in the present study was found to be smaller than those reported in previous studies. The present study also compared the sexing of the sternum in the Northern Thai populations by Mahakkanukrauh to past studies (Table 6).[17] It was found that manubrium length and combined length in both sexes were shorter in the present study compared to a previous study in Northern Thais. However, the length of mesosternum was longer than a previous study done in both sexes. This may possibly be due to population experiencing secular changes, different living styles, and nutritional pattern. Moreover, the samples used in the present study were different from the previous study, which was conducted in the Northern Thai samples, a decade ago.

In conclusion, the present study demonstrated that metric features of the sternum in Thai population were highly sexually dimorphic. The best parameter obtained from univariate discriminant analysis was combined length of manubrium and mesosternum with overall cross-validated classification accuracy rate 85.8% (82.4% for males and 95.7% for females), followed by sterna area and length of mesosternum with overall cross-validated accuracy rate 82.9% and 81.1%, respectively. When using a stepwise discriminant function, which included 5 linear measurements from both manubrium and mesosternum, it yielded highest classification accuracy rate of 86.4%. Therefore, osteometric analysis of the sternum provides a useful method for sex determination in Thais and the discriminant function equations derived from our study should prove useful for forensic investigation.

Conflict of interest

The authors have none to declare.

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