



Stature estimation using the sternum in a Thai population

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Abstract: Stature estimation is an important process of biological profile analysis for the identification of skeletal remains. In forensic practice, non-long bones might be needed for estimating stature, in case long bones were not recovered or well preserved. This study developed the stature estimation model from dry sterna in a Thai population. The combined length of manubrium and mesosternum (CMM) was the best single stature estimation indicator for males and combined sex samples, whereas the sternal area (SA) was the best stature estimation indicator for females in our study. The best multiple regression analysis models of our study were stature equal $122.685+0.182$ (CMM)+ 0.592 (intercostal length between the third and fourth ribs [ICL₃₄]) with a standard error of estimation (SEE) of 6.134 cm for males, stature equal $130.676+0.005$ (SA) with SEE of 5.370 cm for females, and stature equal $79.412+0.342$ (CMM)+ 0.506 (corpus sterni width at first sternebra [CSW_{S1}])+ 0.794 (ICL₃₄) with SEE of 6.222 cm for unknown sex samples. The results indicated that a sternum can be used for estimating the stature of skeletal remains in a Thai population. However, these models might not be suitable for other populations, especially, in case the suspected stature is over the stature range in our study.

Key words: Forensic anthropology, Stature estimation, Sternum, Thai population

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Introduction

Personal identification is an important process of a legal proceeding. Without definite personal identification, the criminal and civil proceedings related to the deceased will be delayed. According to disaster victim identification guidelines of Interpol, DNA, fingerprints, and dental profiles are the primary criteria of victims' identification and only one matching method is enough for definite identification [1]. However, these methods need the antemortem data of possible missing persons before matching with the unknown

deceased.

Biological profiles of the deceased, which consist of ancestry, age, sex, and stature, are valuable data that assist to narrow down the number of possible missing persons. Stature is a valuable piece of biological profile information, that may provide a valuable clue of the personal identification process when the unknown deceased or missing person is tall or short in their population [2]. The method of stature estimation from skeletal remains can be classified into two categories. The first is an anatomical method which uses the summation lengths of the bones that are the main composite of body height to calculate the stature. The second is a mathematical method which calculates the stature from the length of the one or more pieces of bones. The anatomical method indicates the higher accuracy of stature estimation than those of the mathematical method, but requires the complete skeletal remains to estimate the stature [3]. By the

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limitations of the anatomical method, the mathematical method might be more suitable for forensic cases, in which the complete skeletal remains are not usually recovered.

The long bones were recommended for estimating the stature of the skeletal remains. Previous reports indicated femur, tibia, fibular, humerus, radius, or ulnar could predict the stature of the skeletal remains with a high rate of accuracy [4-8]. However, variations of bone length and stature, and stature estimation models exist between populations. A stature estimation model generated from one population might not be proper to use with another population [2, 3]. Thus, a specific stature estimation of each population is required.

In 2011, Mahakkanukrauh et al. [5], reported a highly accurate stature estimation model in a Thai population by using the long bone lengths. The correlation coefficient of bone length and height ranged from 0.660 to 0.769, and the stature estimation model using fibular length provided the lowest standard error of estimation (SEE) as 4.59 cm in male samples. In the female samples, the femur provided the lowest SEE as 5.21 cm among the stature estimation model, and the correlation coefficient bone length and height ranged from 0.552 to 0.762. However, in situations such as mass disasters, terrorist attacks, and plane crashes, long bones might not be recovered or may be damaged, and cannot be used for estimating heights. Therefore, stature estimation using other bones instead of long bones is still needed. In addition, in the cases of dismemberment with only the thorax recovered, stature estimation of the remains using the sternum might be necessary.

Previous studies reported a significant correlation between sternal dimension and height. Saraf et al. [9] reported a high correlation between sternal dimension with height with a SEE of fewer than three centimeters in Mysore India (South India) population. However, discrepancies in the results of studies in Portuguese, Spanish, Central, and Northern Indian samples indicated a low correlation between sternal dimension and height [10-13]. These demonstrated variations of the relationship between sternal dimension and height among populations.

To our knowledge, no report of stature estimation model using sternal dimension is reported in the Thai population. This piece of information might be necessary in case the long bone of the skeletal remains was not recovered. Therefore, this study aimed to generate a stature estimation model using the sternal dimension in a Thai population.

Materials and Methods

Samples

The 219 sterna were divided into 199 sterna (male 104, female 95), for the training sample and 20 sterna for the test sample (male 10, female 10), were derived from the Osteology Research and Training Center, Faculty of Medicine, Chiang Mai University, Thailand. The samples were derived from donated bodies, which are Thai who lived in the Northern Thai area and died between 2006 and 2019. The mean age of training samples was 66.5 years and a standard deviation of 14.4 years (males, 66.47±14.20 years; females, 66.59±14.78 years). The age range was from 26 to 94 years because the epiphyseal closure process occurs between 16 and 25 years old affecting the bone-lengthening process. Therefore the ages of samples lower than 25 years were not included in this study. In addition, the samples that demonstrated anomalies, congenital or acquired deformities affecting measurements were also excluded. The mean age of the test samples was 66.80 years with 14.54 years of standard deviation (males, 62.10±5.82 years; females, 71.50±3.43 years), and the age range was from 45 to 94 years.

The length of the cadaver was measured from the vertex of the head to the heel of the foot with the cadaver in a supine position before skeletal processing then all of the sternums were macerated and allowed to dry. The range of cadaver length of training samples was between 140 to 180 cm. with the mean and the standard deviation of cadaver length of 159.51±9.518 cm (males, 166.19±116.7 cm; females, 152.2±10.87 cm). The range of cadaver length of the test sample was between 145 to 175 cm with the mean and the standard deviation of cadaver length of 159.7±7.83 cm (males, 166.19±6.83 cm; females, 152.2±6.017 cm).

The study was approved by the ethical committee of the Faculty of medicine, Chiang Mai University (FOR-2564-08394). The informed consent was waived.

Measurement

The sternal dimensions were measured by using digital vernier calipers in millimeters by one of the researchers (VJ), and 20 sterna were randomly chosen from the training sample to repeat measurements by VJ and WK to test the intra and inter-observer agreement. The details of the measurements were demonstrated in Table 1 and Fig. 1 [14, 15].

Table 1. Description of the sternal measurements

Measurement	Abbreviation	Description
Manubrium length	MBL	The distance from the center of the jugular notch of the manubrium and the manubriosternal junction [12, 14].
Manubrium width	MBW	The midpoint of the first costal cartilage facet on each side [14, 15].
Mesosternum length	MSL	The distance from the manubriosternal junction to the mesoxiphoidal junction [12, 14].
Combined length of manubrium and mesosternum	CMM	The straight distance from the center of the jugular notch of the manubrium and the mesoxiphoidal junction [12, 14].
Intercostal 2nd–3rd	ICL ₂₃	The distance from the center of costal cartilage of 2nd rib and the center cartilage of 3rd rib [12].
Intercostal 3rd–4th	ICL ₃₄	The distance from the center of costal cartilage of 3rd rib and the center cartilage of 4th rib [12].
Intercostal 4th–5th	ICL ₄₅	The distance from the center of costal cartilage of the 4th rib and the center cartilage of the 5th rib [12].
Corpus sterni width at 1st sternebra	CSW _{S1}	The distance at the midpoint between the costal cartilage of 2nd rib and the costal cartilage 3rd rib on each side [15].
Corpus sterni width at 3rd sternebra	CSW _{S3}	The distance at the midpoint between the costal cartilage of 4th rib and the costal cartilage 5th rib on each side [15].
Sternal index	SI	Calculated by the division of Manubrium length by Mesosternum length and multiplied by 100 ((MBL/MSL)×100) [15].
Sternal area	SA	Calculated by multiplying the sum of Manubrium Length and Mesosternum Length with the sum of Manubrium Width, Corpus sterni width at first sternebra, and Corpus sterni width at third sternebra divided by three ((MBL+MSL)×[MBW+CSW _{S1} +CSW _{S3}]/3) [15].

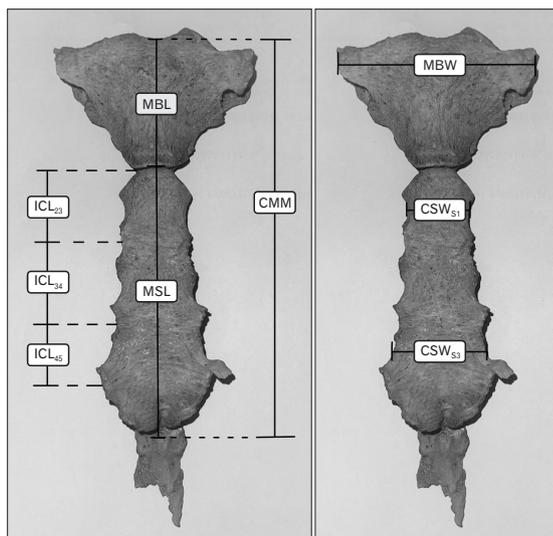


Fig. 1. Measurement on the sternum. MBL, manubrium length; MBW, manubrium width; MSL, mesosternum length; CMM, combined length of manubrium and mesosternum; ICL₂₃, intercostal length between 2nd rib and 3rd rib; ICL₃₄, intercostal length between 3rd rib and 4th rib; ICL₄₅, intercostal length between 4th rib and 5th rib; CSW_{S1}, corpus sterni width at first sternebra; CSW_{S3}, corpus sterni width at third sternebra.

Statistical analysis

The data were analyzed using IBM SPSS software version 22 (IBM Corp., Armonk, NY, USA). The observer agreement was tested by the technical error of measurement, and an independent *t*-test was performed to compare the difference in height, age, and sternal dimensions between the sexes. Karl

Pearson's correlation was analyzed to observe the correlation between stature and sternal dimension. Regression analysis was performed to generate the stature estimation model, and the constant of the model will be subtracted 2 cm to refer to the living stature, in which 2 cm is generally accepted to subtract from cadaver length to approximate living stature [4, 5, 16]. To test the accuracy of stature estimation equations, the equations were applied to test samples, and the mean percent error to the corrected stature and percent of accuracy within the first SEE and 95% confident interval (CI) were calculated. The *P*-value of less than 0.05 was considered statistically significant.

Results

There was no significant statistical difference of age between male and female samples ($P=0.94$), however, the average cadaver length of male samples was significantly higher than those of female samples at 12.4 cm ($P<0.01$). The relative technical error of measurement of all measurements was less than 1.5 for intra-observation error and less than 2 for inter observation error, which was the acceptable range [17], and the R-value of all measurements was more than 0.9. These results indicated the measurements in this study were reliable.

Sternal dimension and index of males were significantly larger than those of females, except sternal index (Table 2), and the correlation between stature and all sternal measurements were shown in Table 3. The majority of sternal mea-

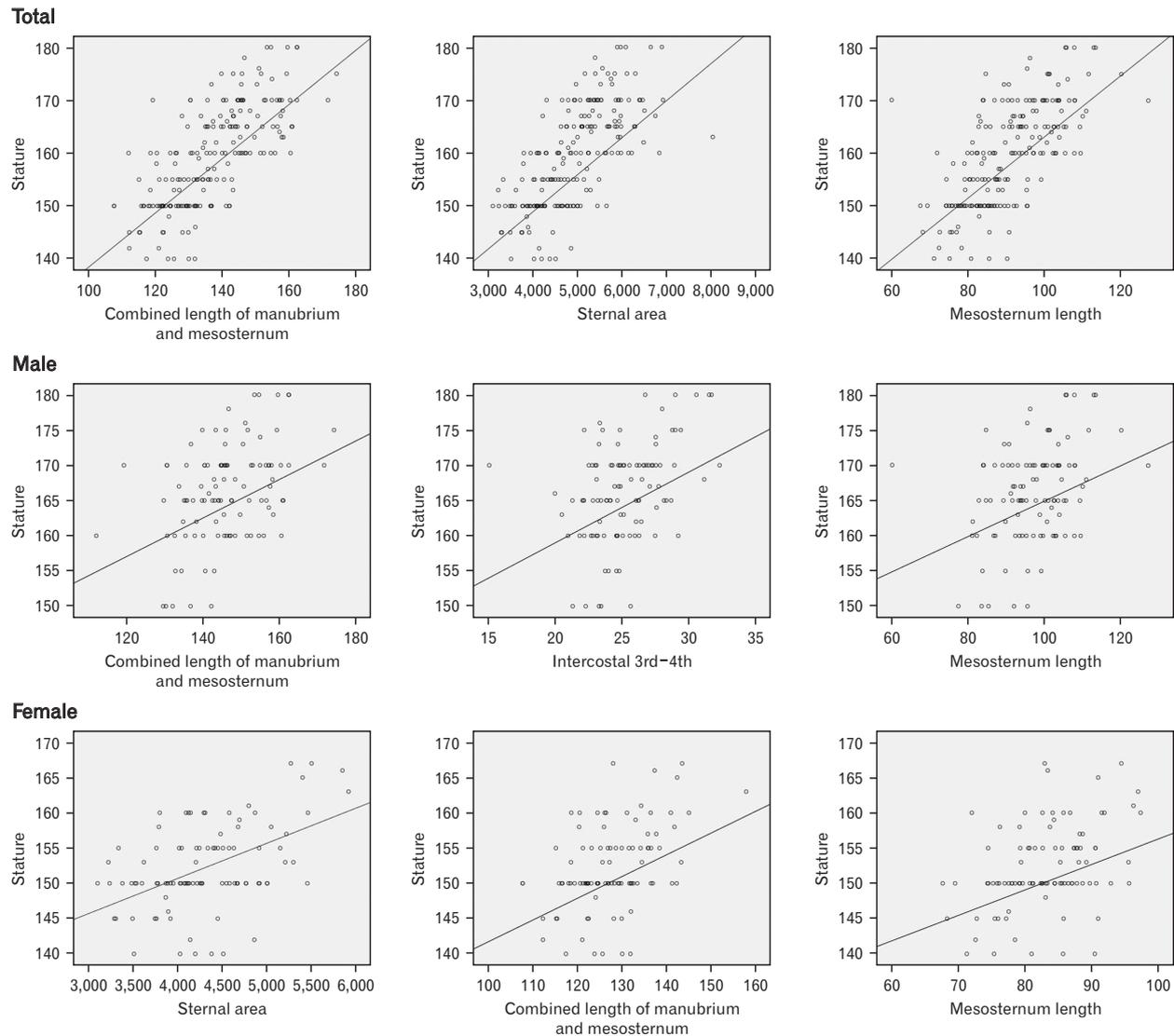


Fig. 2. Scatter plots for correlation between stature and sternum measurements.

Table 2. Descriptive statistics of the measurements

Sternal measurement	Total		Male		Female		P-value
	Range (mm)	Mean (SD)	Range (mm)	Mean (SD)	Range (mm)	Mean (SD)	
Manubrium length	25.04–61.07	46.85 (5.42)	25.04–59.29	48.90 (5.28)	33.94–61.07	44.61 (4.74)	<0.01
Manubrium width	39.31–72.98	52.69 (5.82)	46.32–72.98	55.76 (4.78)	39.31–65.44	49.33 (4.96)	<0.01
Mesosternum length	60.11–127.07	90.42 (10.85)	60.11–127.07	97.12 (9.57)	67.66–97.20	83.07 (6.59)	<0.01
Combined length of manubrium and mesosternum	107.83–174.26	137.28 (13.29)	112.18–174.26	146.02 (10.41)	107.83–157.89	127.70 (8.73)	<0.01
Intercostal 2nd–3rd	18.88–36.07	27.91 (3.25)	18.88–36.07	29.30 (3.11)	19.19–32.05	26.40 (2.67)	<0.01
Intercostal 3rd–4th	15.14–32.29	23.33 (3.13)	15.14–32.29	25.20 (2.71)	16.01–25.93	21.28 (2.12)	<0.01
Intercostal 4th–5th	9.46–28.17	18.24 (2.79)	9.46–28.17	19.56 (2.87)	12.57–21.60	16.80 (1.84)	<0.01
Corpus sterni width at 1st sternebra	17.25–42.25	24.96 (3.95)	19.05–42.25	26.46 (3.82)	17.25–37.97	23.32 (3.41)	<0.01
Corpus sterni width at 3rd sternebra	19.64–52.45	29.79 (4.82)	23.49–52.45	31.07 (4.45)	19.64–44.58	28.39 (4.84)	<0.01
Sternal index	28.74–98.62	52.39 (7.97)	28.74–98.62	50.96 (8.82)	39.79–70.42	53.96 (6.62)	<0.01
Sternal area (mm ²)	3,108.09–8,039.43	4,942.97 (879.40)	3,956.96–8,039.43	5,519.12 (665.47)	3,108.09–5,914.03	4,312.24 (611.89)	<0.01

Table 3. Correlation between stature and sternal measurements

Correlation of stature with	Total		Male		Female	
	R	P-value	R	P-value	R	P-value
Manubrium length	0.425	<0.01	0.182	0.065	0.268	<0.01
Manubrium width	0.531	<0.01	0.095	0.335	0.369	<0.01
Mesosternum length	0.666	<0.01	0.354	<0.01	0.398	<0.01
Combined length of manubrium and mesosternum	0.719	<0.01	0.418	<0.01	0.448	<0.01
Intercostal 2nd–3rd	0.490	<0.01	0.267	<0.01	0.266	<0.01
Intercostal 3rd–4th	0.626	<0.01	0.401	<0.01	0.178	0.084
Intercostal 4th–5th	0.451	<0.01	0.158	0.108	0.133	0.198
Corpus sterni width at 1st sternebra	0.343	<0.01	0.058	0.559	0.109	0.293
Corpus sterni width at 3rd sternebra	0.277	<0.01	0.002	0.986	0.237	0.021
Sternal index	-0.183	0.01	-0.079	0.426	-0.045	0.664
Sternal area	0.685	<0.01	0.295	<0.01	0.460	<0.01

R, correlation coefficient.

Table 4. Linear regression of stature estimation model for males, females, and combined samples

Sample	Model	R	R ²	SEE (cm)
Total	S=122.826+0.740 (MBL)	0.425	0.176	8.637
	S=111.863+0.866 (MBW)	0.531	0.278	8.088
	S=104.677+0.584 (MSL)	0.666	0.441	7.115
	S=86.908+0.514 (CMM)	0.719	0.514	6.636
	S=117.439+1.435 (ICL ₂₃)	0.490	0.236	8.317
	S=113.168+1.901 (ICL ₃₄)	0.626	0.389	7.438
	S=129.481+1.536 (ICL ₄₅)	0.451	0.200	8.514
	S=136.907+0.825 (CSW _{S1})	0.343	0.113	8.964
	S=141.225+0.547 (CSW _{S3})	0.277	0.072	9.169
	S=120.850+0.007 (SA)	0.685	0.467	6.949
Male	S=139.636+0.253 (MSL)	0.354	0.117	6.423
	S=124.144+0.274 (CMM)	0.418	0.167	6.240
	S=147.011+0.586 (ICL ₂₃)	0.267	0.062	6.618
	S=138.766+1.009 (ICL ₃₄)	0.401	0.152	6.293
	S=147.495+0.003 (SA)	0.295	0.078	6.564
Female	S=135.072+0.339 (MBL)	0.268	0.062	5.829
	S=128.122+0.448 (MBW)	0.369	0.127	5.622
	S=120.046+0.363 (MSL)	0.398	0.149	5.551
	S=110.767+0.309 (CMM)	0.448	0.192	5.407
	S=134.438+0.597 (ICL ₂₃)	0.266	0.060	5.832
	S=141.852+0.294 (CSW _{S3})	0.237	0.046	5.878
	S=130.676+0.005 (SA)	0.460	0.204	5.370

MBL, manubrium length; MBW, manubrium width; MSL, mesosternum length; CMM, combined length of manubrium and mesosternum; ICL₂₃, intercostal length between 2nd rib and 3rd rib; ICL₃₄, intercostal length between 3rd rib and 4th rib; ICL₄₅, intercostal length between 4th rib and 5th rib; CSW_{S1}, corpus sterni width at first sternebra; CSW_{S3}, corpus sterni width at third sternebra; SA, sternal area; R, correlation coefficient; R², coefficient of determination; SEE, standard error of estimation.

surements indicated a significant positive correlation with stature, except sternal index in the combined sex samples. The combined length of manubrium and mesosternum (CMM) indicated the highest correlation with stature, followed by sternal area (SA) and mesosternum length (MSL). In the male samples, CMM also demonstrated the highest

Table 5. Stepwise multiple regression of stature estimation model for males, females, and combined samples

Sample	Model	R	R ²	SEE (cm)
Total 1	S=80.151+0.483 (CMM)+0.441 (CSW _{S1})	0.740	0.543	6.431
Total 2	S=79.412+0.342 (CMM)+0.506 (CSW _{S1})+0.794 (ICL ₃₄)	0.761	0.573	6.222
Male	S=122.685+0.182 (CMM)+0.592 (ICL ₃₄)	0.458	0.195	6.134
Female	S=130.676+0.005 (SA)	0.460	0.204	5.370

CMM, combined length of manubrium and mesosternum; CSW_{S1}, corpus sterni width at first sternebra; ICL₃₄, intercostal length between 3rd rib and 4th rib; SA, sternal area; R, correlation coefficient; R², coefficient of determination; SEE, standard error of estimation.

correlation with stature, and intercostal 3rd–4th (ICL₃₄) and MSL were second and third, respectively. Intercostal 2nd–3rd (ICL₂₃) and SA also statistically correlated with stature, but other parameters were not correlated in male samples. For the female samples, SA was the best stature correlated parameter, and CMM and MSL were in the second and third place, respectively. Manubrium length (MBL), manubrium width (MBW), ICL₂₃, and corpus sterni width at the third sternebra (CSW_{S3}) were also significantly correlated with stature (Table 3).

The simple regression analysis model for male, female, and combined samples was shown in Table 4 and Fig. 2. The stature estimation model of the male sample demonstrated a higher correlation and lower SEE than those of the male sample. The coefficient of determination (R²) and SEE of female’s stature estimation model ranged from 0.060 to 0.204 and 5.370 to 5.829 cm, respectively, whereas the R² male samples were ranged from 0.062 to 0.167 and 6.240 to 6.618 cm. for SEE. The stature estimation model generated from combined male and female samples increased the R² value (0.072–0.514) but did not improve the SEE of the model

(6.636–9.169 cm).

The stepwise multiple regression models acquired for stature estimation from sternal measurements provided superior correlation than those of simple linear regression in unknown sex and males but did not improve the accuracy for females (Table 5). The CMM, CSW_{S1*} and ICL₃₄ were selected for the stature estimation model for unknown sex samples, and CMM and ICL₃₄ were also selected for the male's stature estimation model. On the other hand, SA was the only variable that was selected for the female stature estimation model.

The multiple regression equations were applied to the test samples (Table 6). The female-specific equation demonstrated the highest mean percent error to the corrected stature than those of males and the combined sex's equation. The mean percent error to the corrected stature of the female-specific equation was 3.81%, whereas the mean percent error to the corrected stature of the male and combined sex's equation

ranged from 2.58% to 3.46%. However, the predicted stature using multiple regression equations of all test samples were in the range of first SEE and 95% CI.

Discussion

Stature estimation is an important process of biological profile analysis to identification of the skeletal remain. Long bones have proved to be a useful indicator for estimating stature, however, in routine forensic practice, the long bone might not be recovered or well-preserved enough to use as stature estimation tools. Therefore, stature estimation using non-long bones is still necessary. The results of our study indicated the sternum can be used for estimating the stature of skeletal remains in a Thai population. The stature estimation models of our study can estimate the stature with SEE of 6.134 cm for males, 5.370 cm for females, and 6.222 cm for unknown sex samples.

Previous studies of stature estimation using sternum dimension indicated different levels of accuracy results. In 2018, Saraf et al. [9] reported the stature estimation models using sternal dimensions can estimate the stature with the coefficient of determination (R^2) was more than 0.75 and the SEE was less than 2 cm, in Mysore India (south India) population. The study of stature estimation in Turkish and other South Indian populations indicated the sternal dimension can estimate the stature with the highest R^2 of 0.640 and 0.408, and the lowest SEE of 3.1 cm and 4.11 cm, respectively

Table 6. Mean percent to the corrected stature and percent of accuracy of the test samples

Function	Number	Mean percent error to the corrected stature (%)	Percent of accuracy within first SEE	Percent of accuracy within 95% CI
Total 1	20	2.58	100	100
Total 2	20	2.81	100	100
Male	10	3.46	100	100
Female	10	3.81	100	100

SEE, standard error of estimation; CI, confident interval.

Table 7. Comparing results of stature estimation using sternum with previous studies

Study	Population	Sex	Regression	R	R^2	SEE (cm)
Saraf et al. [9]	Mysore Indian	Total	Simple linear	0.891	0.794	1.620
		Male	Quadratic	0.932	0.869	1.180
		Female	Quadratic	0.904	0.817	1.530
Macaluso and Lucena [10]	Spanish	Male	Simple linear	0.391	-	6.200
		Female	Simple linear	0.461	-	5.560
Marinho et al. [11]	Portuguese	Male	Simple linear	0.329	0.110	6.590
Singh et al. [12]	Northwest Indian	Male	Multiple linear	-	0.160	6.660
		Female	Simple linear	0.318	0.100	6.650
Tumram et al. [13]	Central Indian	Male	Simple linear	0.550	0.302	7.400
Menezes et al. [18]	South Indian	Male	Simple linear	0.638	-	5.640
Menezes et al. [19]	South Indian	Female	Simple linear	0.639	0.408	4.110
Yonguc et al. [20]	Turkish	Male	Simple linear	0.721	0.521	0.045
		Female	Simple linear	0.740	0.547	0.077
Zhang et al. [21]	Western Chinese	Male	Simple linear	0.459	-	4.760
		Female	Simple linear	0.541	-	6.730
Our study	Thai	Total	Simple linear	0.761	0.573	6.222
		Male	Simple linear	0.458	0.195	6.134
		Female	Simple linear	0.460	0.204	5.370

R, correlation coefficient; R^2 , coefficient of determination; SEE, standard error of estimation.

[18-20]. However, the highest R^2 of stature estimation model using sternal dimensions in Central Indian, Portuguese, Spanish and Western Chinese were not more than 0.302 and the lowest SEE was not less than 4.76 cm [10, 11, 13, 21]. The results of the latter studies were consistent with our results that the highest R^2 was 0.204 and the lowest SEE was 5.37 cm (Table 7). The discrepancy of the results of our study and others might be from the difference in, population, genetics, nutrition, demographics, and so on. These factors affect the bone dimension and the stature of each population [22, 23]. Moreover, the difference between the type of sample such as fresh or dry skeleton, and the age and height distribution of the samples might also affect the accuracy of the results.

The CMM was the best predictive measurement for stature estimation of male and combined sex samples in our study. This result was according to previous studies [9, 12, 13, 20], however, the accuracy of the stature estimation model was different between populations. The correlation coefficient and determination of stature estimation model of males in our study were higher than those of Spanish and Northern Indian population but lower than those of South Indian, Central Indian, Turkish, and Western Chinese populations [9-13, 18, 20, 21]. The R and R^2 of the male's stature estimation model, the R and R^2 of the combined sex estimation model were also better than those of the Northern Indian population but lower than those of the South Indian and Turkish populations [9, 12, 20]. Although CMM was not the predictive measurement for stature estimation of the female sample in our study the R and R^2 of the female's stature estimation model was close to those of our male sample and also better than those of the Northern Indian population [12].

Interestingly, the SA indicated the best measurement for stature estimation of female samples and was in the second place for combined sex samples, however, the SA did not demonstrate superior results in male samples. This might be explained by the significant difference between male and female SA [15]. However, the reason that the female stature estimation model was better than those of males was unknown. In addition, no previous reports were found for using the SA to estimate the stature for comparing the results.

Not only CMM and SA but also MSL could be used for stature estimation in the Thai population. The R and R^2 of stature estimation model was the third range in male, female, and combined sex samples. In addition, the R and R^2 of

stature estimation model using MSL of our study was greater than those of Northern and Central Indian populations but inferior to those of South Indian and Turkish populations [9, 12, 13, 20].

The R and R^2 of the combined sex samples in this study were greater than those of the sex-specific model but the SEE was higher than those of the sex-specific model. This might be the effect of statistical artifacts, which combine sex samples increased the stature and measurement range. Increasing the range of variables can lead to a "range enhancement" effect, with a possibility to increase the mean [5, 24]. Thus, the result of the combined sex sample should not indicate greater accuracy than those of sex-specific samples.

Even though the accuracy of stature estimation using sternal dimension in a Thai population of our study was inferior to those of long bones which can be estimated the stature with highest R of 0.783 and 0.785, and lowest SEE was 4.95 cm and 5.10 cm, for males and females respectively [5]. However, when comparing with the stature estimation model using non-long bones in the Thai population, stature estimation using the sternum was better than those of the skull and mandible but inferior to those of vertebral columns, calcaneus, and talus [25-27]. The stature estimation using vertebral column showed best R was 0.725 and lowest SEE was 5.796 cm [25], the calcaneus and talus showed highest R in male and female was 0.63 and 0.54 and lowest SEE was 5.95 and 3.06 cm, respectively [26], whereas the stature estimation using the skull and mandible dimension indicated the highest R was 0.403 and 0.709 and the lowest SEE was 7.319 cm and 6.216 cm, for males and females, respectively.

Despite limitations of using sternum as stature estimation tools, in situations such as dismemberment remains with only the thorax recovered, the sternum might be a valuable tool for stature estimation or used as adjuvant to estimate stature with another bone. In addition, the recovery rate of the sternum was higher than those of the calcaneus and talus [28]. Thus, the sternum can be used for stature estimation in a situation where the long bone was not recovered, damaged, or used as an adjuvant tool for stature estimation of skeletal remains.

The limitations of our study were the range of cadaver lengths in males and females of our samples of 150–180 cm, 140–167 cm, respectively. That means stature estimation in a different population or different range of height could be

used with consideration. For this reason, further study was suggested in different populations in the future.

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Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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