ANATOMY

Stature Estimation from Vertebral Column in a Thai Population

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ABSTRACT

Objective: **Stature estimation is one of the major components in forensic identification. Vertebral column was considered to be a reliable indicator for stature estimation. The length of vertebral column contributes around 30% of the total skeleton stature. Several studies reported the regression formulae for stature estimation in a Thai population using measurements of long bones of the extremities. However, there is no study on stature estimation applying vertebral column in Thais. The purpose of this study was to estimate stature from vertebral column in a Thai population.**

Design: **To measure the vertebral body from C3 to S1 vertebrae for estimating stature.**

Materials and Methods: **The present study was carried out on a sample of 100 vertebral column belonged to Thai individuals with age ranged between 22-94 years housed in Forensic Osteology Research Center, Faculty of Medicine, Chiang Mai University. Measurements of the vertebral body, including anterior body height, middle body height, and posterior body height were obtained from C3 to S1 vertebrae.**

Results: **Pearson correlation analysis showed moderate to high correlation coefficients between stature and each measurement which are 0.459 to 0.717 (anterior body height), 0.593 to 0.710 (middle body height), and 0.523 to 0.725 (posterior body height). Regression formulae showed the standard error of estimation (SEE) ranged from 5.796 to 6.831 cm. The measurements from each vertebrae delivered relatively high relationship with stature. Therefore, it might aid in stature estimation even only a single vertebrae is found.**

Conclusions: **Vertebral body height could be useful for stature estimation in personal identification in forensic circumstances.**

KEY WORDS

forensic science, forensic anthropology, stature estimation, vertebral column, Thailand

INTRODUCTION

Estimation of stature is one element of biological identification, consists of sex, age, ancestry, and stature[1]. Estimation of living stature of an individual from various body parts is considered to be an important tool in personal identification. This is based upon the definite biological relationship of stature with all body parts like extremities, head, trunk, vertebral column, etc[2]. Vertebral column was also considered to be a reliable indicator for stature estimation. The length of vertebral column contributes around 30% of the total skeleton stature[3]. It is particularly useful for forensic anthropology. Several studies have been conducted on the estimation of stature from various parts of the body including long bones of the upper limb and lower limbs[4,5], sternum[6], scapula[7], and small bones such as metacarpals[8] and metatarsals[9]. However there is no study on stature estimation applying vertebral column in Thais.

The purpose of this study is to estimate stature from measurements of the vertebral body, including anterior body height, middle body height and posterior body height obtained from C3 to S1 vertebrae.

MATERIALS AND METHODS

The vertebral column of 100 Thai individuals of known sex, and age at death ranging from 22-94 years, were obtained from the Forensic Osteology Research Center (FORC), Faculty of Medicine, and Chiang Mai University. Vertebrae exhibiting fractures or pathologies were excluded from this study. The vertebral body measurements were taken by using standard landmarks, techniques and instruments also following the methods in Martin (1928)[10]. Descriptions of vertebral body measurements are presented in Table 1 and Figure 1.

Data was analyzed by using the SPSS software package (SPSS for Windows, Version 15, Chicago, IL, USA). The descriptive analysis was performed to obtain minimum, maximum, and mean. The correlations between stature and each of the vertebral body measurement were assessed with Pearson correlation coefficients. Regression models were generated to estimate stature and measurements of the vertebral body.

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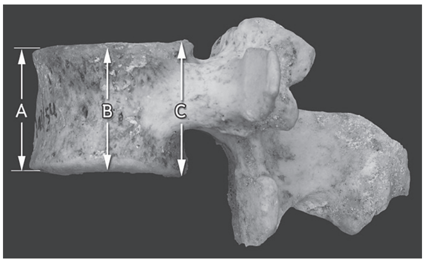

Figure 1. Vertebral body measurements measured in this study. (A) Anterior body height, (B) Middle body height, and (C) Posterior body height. Written descriptions of these measurements can be found in Table 1.

Table 2. Pearson correlation coefficient between measurements of the vertebral body height and stature for each vertebra.

Vertebrae	Correlation (r)			*p*-value
	Anterior body height	Middle body height	Posterior body height	
C3	0.537	0.613	0.668	< 0.001
C4	0.517	0.596	0.653	< 0.001
C5	0.529	0.593	0.634	< 0.001
C6	0.571	0.645	0.628	< 0.001
C7	0.571	0.613	0.582	< 0.001
T1	0.530	0.611	0.618	< 0.001
T2	0.610	0.694	0.648	< 0.001
T3	0.637	0.698	0.670	< 0.001
T4	0.650	0.700	0.672	< 0.001
T5	0.717	0.710	0.656	< 0.001
T6	0.639	0.694	0.649	< 0.001
T7	0.553	0.675	0.680	< 0.001
T8	0.506	0.659	0.533	< 0.001
T9	0.503	0.642	0.655	< 0.001
T10	0.672	0.688	0.682	< 0.001
T11	0.690	0.665	0.644	< 0.001
T12	0.479	0.660	0.712	< 0.001
L1	0.459	0.634	0.707	< 0.001
L2	0.504	0.594	0.703	< 0.001
L3	0.579	0.601	0.701	< 0.001
L4	0.556	0.644	0.725	< 0.001
L5	0.567	0.663	0.523	< 0.001
S1	0.477	-	-	< 0.001

Table 1. Descriptions of the vertebral body measurements used in the present study.

Measurements	Description
1. Anterior body height (A)	The distance from the most superior point to the most inferior point on the anterior of vertebral body using a sliding caliper.
2. Middle body height (B)	The distance from the most superior point to the most inferior point on the middle of vertebral body using a sliding caliper.
3. Posterior body height (C)	The distance from the most superior point to the most inferior point on the posterior of vertebral body using a sliding caliper.

RESULTS

The mean age of the samples was 65.42 years. The mean stature of the study samples was 159.88 cm. From the vertebral body measurements, anterior body height was observed to be the largest (mean = 28.61 mm) at S1 body and the smallest was anterior body height of C5 body to be observed (mean = 11.59 mm). Middle body height was observed to be the largest (mean = 22.07 mm) at L2 body and the smallest was middle body height of C6 body to be observed (mean = 9.52 mm). Posterior body height was observed to be the largest (mean = 24.70 mm.) at L2 body and the smallest was posterior body height of C5 body to be observed (mean = 11.59 mm).

The results of the current study found that the correlation coefficient values ranged from 0.459 to 0.725 showed moderate to high correlation between vertebral body height and stature. The highest correlation coefficient of anterior body height is obtained from the anterior body height of T5 (r = 0.717) and the lowest by anterior body height of L1 (r = 0.459). T5 also provided the highest correlation between stature and middle body height (r = 0.710) and the lowest by middle body height of C5 (r = 0.593). Considering posterior body height, L4 was highly correlated with stature and gave a correlation coefficient of 0.725 and the lowest by posterior body height of L5 (r = 0.523). Results of the Pearson correlation coefficient between measurements of the vertebral body height and stature for each vertebra are reported in Table 2.

The stepwise regression equations were generated to estimate stature for each measurement of vertebral body are reported in Table 3. The results of this study showed that the equation number 4 of anterior vertebral body height of C6, T4, T6, and T11 produced the highest R-square value (R^2 = 0.623) and the lowest standard error of estimation of 5.8 cm.

DISCUSSION AND CONCLUSION

Results from the present study were consistent with previous studies

Table 3. Stepwise regression equations for stature estimation.

Measurement	Equation	R	R^2	SEE (cm.)
Anterior body height	1. Y = (83.131) + (3.823)(T11 anterior body height)	0.683	0.466	6.754
	2. Y = (74.910) + (2.638)(T11 anterior body height) + (1.901)(T4 anterior body height)	0.740	0.547	6.266
	3. Y = (67.542) + (2.118)(T11 anterior body height) + (1.671)(T4 anterior body height) + (1.806)(C6 anterior body height)	0.776	0.602	5.917
	4. Y = (65.016) + (1.549)(T11 anterior body height) + (1.442)(T4 anterior body height) + (1.699)(C6 anterior body height) + (1.107)(T6 anterior body height)	0.789	0.623	5.796
Middle body height	1. Y = (96.495) + (3.720)(T10 middle body height)	0.673	0.452	6.831
	2. Y = (85.834) + (2.736)(T10 middle body height) + (1.292)(L5 middle body height)	0.708	0.502	6.562
Posterior body height	1. Y = (92.047) + (2.774)(L3 posterior body height)	0.716	0.513	6.585
	2. Y = (93.181) + (2.045)(L3 posterior body height) + (1.376)(C3 posterior body height)	0.741	0.550	6.376

in various populations. There was statistical significant relation between height of vertebra and individual's stature. This finding reinforced the results of recent studies in Asian population. In a study by Nagesh and Pradeep (2006)[11)] reported the correlation between vertebral length and stature of South Indian samples. They also proposed stature prediction models from vertebral length for both sexes with standard error of 4.38-5.56 cm in males and 4.16-5.58 cm in females.

Furthermore, similar results were found in studies on Japanese and Chinese samples. Milani and Panattoni (2013)[3)] revealed an effective stature estimation model from vertebral measurements in Japanese samples. The model provided the standard error ranged between 4.05-6.16 cm. In addition, a study of Zhang *et al*. (2015)[12)] confirmed that vertebral measurements could be used for stature estimation in East Asian population. They delivered models for stature prediction for Chinese individuals which gave 3.219-3.683 cm standard error in females and 4.331-4.398 cm in males.

The results in this study were also similar to that of the study on German population. Klein *et al*. (2015)[13)] reported stature estimation equation for this population which is body height = 141.9 cm + 3.4 (central Height of L_2) with standard error of 5.9 cm.

In a study of stature estimation, body proportions vary widely between the different populations[3,14)]. The regression models should be suitable for the specific population because many factor such as genetic, health care, nutrition, physical activity, and environment can affect bones[15)]. Additionally, in a study of black and white skeletons, Raxter *et al*. (2006)[16)] proposed the revision of the Fully method for stature estimation. They found that the aging process could affect the stature. In older adults have total or partial vertebral collapses that cause decrease in stature.

In conclusion, the present study provides the stature prediction equations utilizing vertebral measurements which could be a vital tool for forensic anthropologists and law enforcement authorities in estimating stature of unknown skeletal remains of Thai population. In addition, the current study suggests that vertebral measurements could be used for estimating stature when other skeletal parts, required for traditional stature estimation methods are not available or found in forensic circumstances. Furthermore, the method of this study is simple and requires only a caliper. However, limitations of this study are the vertebral body in subadults cannot be used in this method. Vertebral body must not be damaged or severely collapsed vertebra for measurements. In future studies, researchers may be able to evaluate intra- and interobserver reliability. Also, the derived equations from this study can be tested on a holdout sample to test their reliability for stature estimation.

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