

Stature Estimation from Dry Bone and Radiographic Clavicular Measurements in A Thai Population

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ABSTRAK

Perawakan merupakan salah satu ciri biologi utama yang berguna dalam pengelasan rangka si mati yang belum dikenalpasti. Malah, data tepat dari populasi adalah penting dalam kerangka antropologi forensik. Namun begitu, kajian mengenai tajuk ini adalah terhad disebabkan tumpuan biasanya diberikan kepada "long bones". Kajian ini cuba mewujudkan persamaan (equation) mengenai anggaran perawakan daripada ukuran tulang klavikular kering dan radiografi. Kedua-dua belah tulang klavikular dari si mati perempuan (25) dan lelaki (112) diasingkan di sebuah bilik autopsi di Bangkok, Thailand. Dua belas pembolehubah diukur bagi setiap sisi tulang. Hasil dapatan kajian menunjukkan bahawa ketinggian dapat ditentukan dengan menggunakan 3 pembolehubah dalam sebuah model analisis regresi bertahap bagi mayat yang jantainya belum dikenalpasti, dengan $R^2 = 0.49$ serta ralat piawai anggaran (SEE) 5.238 cm. Malah, ketinggian hujung sternal tulang klavikular boleh diguna pakai bagi menganggar perawakan bagi kes yang melibatkan serpihan tulang klavikal yang dijumpai di tempat kejadian ($R^2 = 0.238$ dan SEE 6.353 cm). Panjang maksimum dari pengukuran radiografi menunjukkan korelasi serta "model fit" yang terbaik dengan perawakan ($R = 0.562$, $R^2 = 0.316$ dan SEE 6.020 cm). Hasil kajian ini menunjukkan teknik yang komplementari dan

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berguna kepada pakar forensik antropologi untuk menghasilkan profil biologi bagi kerangka mayat yang belum dikenal pasti dalam kes dimana "long bones" tidak dijumpai. Tambahan pula, penganggaran perawakan daripada ukuran radiografi mampu diguna pakai dalam kes yang melibatkan "skeletonisation" separa.

Kata kunci: anggaran ketinggian, antropologi forensik, klavikula, populasi Thai, profil biologi

ABSTRACT

Stature is one of the main biological features which can be used to classify unidentified skeletal deceased. Also, precise population data is crucial for forensic anthropology frameworks. Nonetheless, the studies concerning this subject in Thailand are limited and regularly focus on long bones. This study attempts to establish stature estimation equations from clavicular dry bone and radiographic measurements. Both sides of the clavicular bones are separated from 25 female and 112 male deceased in an autopsy room situated in Bangkok, Thailand. Twelve variables of each side of the clavicle are measured. The study outcomes show that stature can be estimated by applying 3 variables in a stepwise regression analysis model in unidentified sex remains, with $R^2 = 0.49$ and standard error of estimation (SEE) 5.238 cm. Moreover, the height of the sternal end of clavicle bones can be used to estimate stature in cases of fragmented clavicles recovered from crime scenes with $R^2 = 0.238$ and SEE 6.353 cm. Maximum length shows the best correlation and model fit with stature ($R = 0.562$, $R^2 = 0.316$ and SEE 6.020 cm) from radiographic measurements. Therefore, this study presents a complementary, beneficial method for forensic anthropologists to create biological profiles of unidentified skeletal remains in cases where the long bones are not obtainable. Moreover, stature estimation from radiographic measurements can be applied in cases of partial skeletonisation.

Keywords: biological profiles, clavicle, forensic anthropology, stature estimation, Thai population

INTRODUCTION

Death investigations need to be carried out by a multidisciplinary team, including forensic pathologists, crime scene investigators and the police. The medical examiner is also needed for medicolegal investigations, depending

on the country's laws (Saukko & Knight 2015; Spitz 2006). An identification of the deceased is obligatory for medicolegal analyses, since the associated medicolegal enforcers can use this evidence as the basis of an investigation. However, the condition of the corpse's soft tissues can make

accurate identification problematic. For instance, progressively decomposed or severely burnt bodies cannot be identified by visual identification alone, since a fingerprint is not obtainable from skeletonised remains (Ranson 2016).

Forensic anthropology is the study of legal inquests, which can be valuable in partially or completely skeletonised cases. Biological profiles of skeletonised remains consist of the following factors i.e. ancestry, age, sex and stature. Medicolegal investigators can apply this information to narrow down the possible ante-mortem data before progressing to the next process, achieving a positive identification of the unknown deceased (Blau & Ubelaker 2016).

There are many advantages to using clavicles to determine biological profiles of unknown skeletal remains (Akhlaghi et al. 2012). Firstly, the clavicle does not support the body weight and is not manipulated by childbirth, unlike the pelvis. Therefore, the clavicle's degenerative changes are less affected by human diversity and multiplicity than the pelvis. Secondly, the clavicle has a characteristic shape which can be identified by forensic anthropologists. Thirdly, forensic practitioners do not need specific equipment or much time to make clavicular measurements. Fourthly, the clavicle could endure, and be retrieved from, crime scenes, and might be useful to create biological profiles since its configuration is a compact bone. Fifthly, the clavicle can be easily removed from the body in an autopsy. Finally, recent studies suggest that

assessment of the clavicle yields good results in sex estimations (Akhlaghi et al. 2012; Frutos 2002; Králík et al. 2014; Papaioannou et al. 2012; Sehrawat 2018; Spradley & Jantz 2011; Tise et al. 2013) and could be used to estimate stature, even though studies are few (Rani et al 2011; Balvir et al 2012).

Stature Estimation from Clavicular Measurements

Stature is one of the key biological features which contributes to recognising unknown skeletal remains. There are two approaches. Firstly, body height is calculated from measurements of the skull, vertebrae, sacrum, femur, tibia, talus and calcaneus, which all contributed to the human physique, supplemented by a soft tissue correction value (Fully 1956). The soft tissue value was adjusted by Raxter et al. (2006). The method gives more exact results than other methods, because the authors calculated all skeletal parts that contribute to stature. Nevertheless, the effectiveness of this technique depends on the measurements of all bone elements, any of which may not be present in forensic cases. Also, this method takes time and might not be practical in real life circumstances (Willey 2016). The second approach is measurement of the long bones, using a regression equation to estimate stature. This technique is more common practice, since the discovery of complete skeletal remains is rare in forensic work. Nonetheless, it is possible that the long bones are not discovered at crime scenes. Therefore, considering

other skeletal measurements might be useful in estimating the stature of the deceased (Willey 2016; İşcan & Steyn 2013).

Rani et al. (2011) studied 7 variables of the clavicles of 70 male and 30 female corpses in an Iranian population, proposing that the variable that is most useful in stature estimation is the maximum length. Balvir et al. (2012) measured the maximum clavicular lengths of 48 male and 12 female bodies, suggesting a regression formula for stature estimates. However, these researches do not disclose the Pearson's correlation, normality test of the dependent variable or standard error of estimation (SEE) of the regression analysis.

The expansion of studies into this subject is focused on population-specific data, since the growth rate and degeneration process tend to vary between populations (İşcan & Steyn 2013; Ubelaker 2008). Even though stature estimation techniques from measurements of limb bones in Thai skeletal remains have been established (Mahakkanukruah et al. 2011; Gocha et al. 2013; Fongkete et al. 2016; Inchai et al. 2019), research into stature estimations from clavicle measurements in a Thai population had not yet been done. Therefore, this study aims to establish a stature estimation equation from clavicular assessment in a Thai population.

Stature Estimation from Conventional Radiography

Moore (2012) points out the usefulness of applying medical imaging

techniques to the examination of the skeletal deceased for several reasons i.e.: (i) imaging techniques are non-destructive procedures; (ii) since most skeletal collections are scarce in young and adolescent remains, there is a possibility of applying imaging techniques to assess adolescent population data from living individuals; and (iii) imaging techniques can help medicolegal investigators diagnose pathology and trauma in skeletal individuals. There are medical imaging techniques which can be applied in forensic medicine; for example magnetic resonance imaging, computed tomography (CT), traditional radiographic X-rays and X-ray absorptiometry which can assess bone density.

The characteristics of skeletons can be transformed into quantitative data using imaging techniques from medical devices. The number of methods for biological profile examination is expanding, and forensic investigators could develop more robust methods.

One benefit of applying imaging techniques is in the scenario where the medicolegal investigator encounters a decomposed body which does not have evidence for personal identification. The imaging information can support the forensic investigator in producing a biological profile data and identifying an unknown corpse. Consequently, creating biological data from radiology should be useful in cases where autopsy is not performed, since performing CT or conventional radiography do not require the soft tissue maceration of the deceased (Torimitsu et al. 2017; Zech et al. 2012).

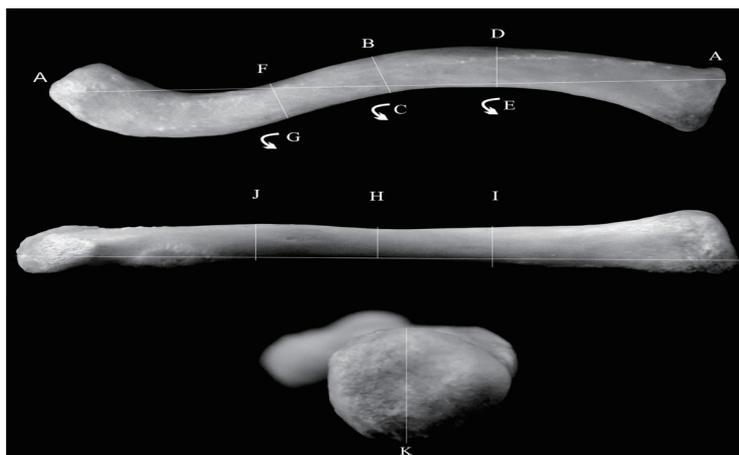


Figure 1: Measurements of clavicle. A: Measurements on maximum length (MXL); B: Anterior-posterior diameter at mid-diaphysis (F); C: Mid-diaphysis circumference (MDC); D: Anterior-posterior diameter at medial 1/3 of clavicle (APM); E: Medial 1/3 clavicular circumference (MC); F: Anterior-posterior diameter at lateral 1/3 of clavicle (APL); G: Lateral 1/3 clavicular circumference (LC); H: Superior-inferior diameter at mid-diaphysis (SIMD); I: Superior-inferior diameter at medial 1/3 of clavicle (SIM); J: Superior-inferior diameter at lateral 1/3 of clavicle (SIL); K: Height of the sternal end of clavicle (HSC).

Several studies have established stature estimations for various populations from various bones.

Giurazza et al. (2012) conducted research into 200 Italian males and females. They studied skull and femur dimensions from CT scans and established regression analyses from maximum femur length with a correlation coefficient of 0.71 and a measurement from the basion to the nasal bone with a correlation coefficient of 0.53.

Ramezani et al. (2019) studied femur and tibia measurements from plain X-rays in 166 male and female Iranians, and established stature estimations from a regression analysis which yielded a correlation coefficient of 0.736 and a standard error of 5.64 cm.

Torimitsu et al. (2017) collected clavicular dimensions from 249 (131

males, 118 females) post-mortem, using CT imaging. The study applied the same definition of measurements as their sex estimation work (Torimitsu et al. 2018) and proposed univariate regression analyses which yielded a standard error of estimation from 3.43 to 4.88 cm and correlation coefficients from 0.510 to 0.914. However, CT is rarely available to most forensic faculties in Thailand, and no study of stature estimation from clavicular plain film X-rays has yet been carried out in a Thai population. This study explores stature estimation from clavicular measurement in conventional radiography in a Thai population.

MATERIALS AND METHODS

The sample of the study is 137 clavicles (112 from males, 25 from females) from Thai deceased who died an unnatural

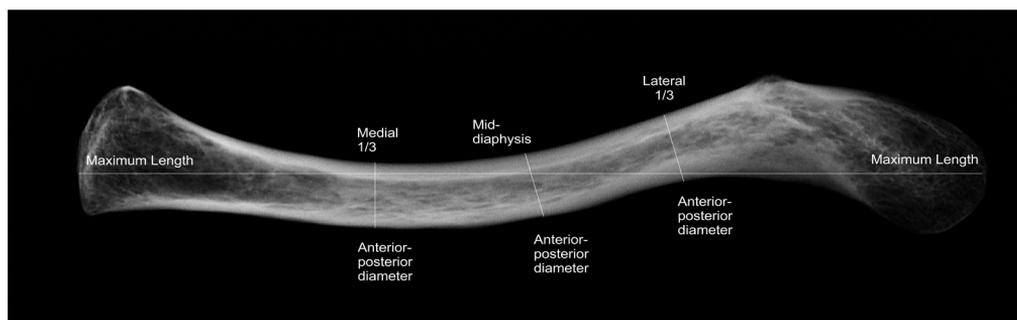


Figure 2: Clavicular measurements from radiograph.

death and were autopsied in a forensic context. The sex, stature and age data of the deceased were obtained from national identification cards. The forensic autopsies were conducted in the Department of Forensic Medicine, Faculty of Medicine, Chulalongkorn University in Bangkok, Thailand. This research was permitted by the ethics committee of Chulalongkorn University (COE No. 028/2018), and consent was granted by the relatives of the deceased.

Since the clavicular samples were derived from deceased who died in an unnatural manner and an urban area, the causes of death vary with the occupations of the deceased are mixed with white- and blue-collar workers, unemployed and retired citizens. Both sides of the clavicles were detached from the deceased when performing the autopsies, and the remaining soft tissues and cartilage were macerated by water and parched up at room temperature. The exclusion criteria were any fractured clavicles, observable clavicular pathology and age less than 24 years. The cadavers' statures were measured from crown to heel (Saukko & Knight 2015).

A total of 12 variables (Figure 1) from

both clavicles were assessed using an osteometric board and a digital sliding calliper. Common variables were maximum length, mid-diaphysis circumference and robustness index (Akhlaghi et al. 2012; Frutos 2002; Králík et al. 2014; Papaioannou et al. 2012; Sehwat 2018; Spradley & Jantz 2011; Tise et al. 2013). Variables from sites at both medial 1/3 and lateral 1/3 of maximum length were included in the study. All sizes were noted in centimetre units. Consequently, plain radiographs were obtained using a Toshiba Rotanode X-ray generator. Left and right clavicles were anatomically oriented and placed on the X-ray table. The focus to film distance was 120 cm with a 0.020s exposure at 43 kV and 200 mA. X-rays can pierce perpendicularly through the clavicle. The images were digitalised using a Examvue CR Pro scanner, analysed using Radiant DICOM software and measured on a centimetre scale. However, only 4 variables from the radiographic examination (Figure 2) were available for comparison with dry bone measurements: maximum length (MXL), anterior-posterior diameter at mid-diaphysis (APMD), anterior-posterior diameter at medial 1/3 of

Table 1: The definition of dry bone and radiographic clavicular measurements.

Measurement	Description
Maximum length (MXL)	Length from each furthest point on acromial end and sternal end
Anterior-posterior diameter at mid-diaphysis (APMD)	Anterior to posterior length at ½ of maximum length
Superior-inferior diameter at mid-diaphysis (SIMD)	Superior to inferior length at ½ of maximum length
Mid-diaphysis circumference (MDC)	Shaft circumference at ½ of maximum length
Anterior-posterior diameter at medial 1/3 of clavicle (APM)	Anterior to posterior length at 1/3 medial end of maximum length
Superior-inferior diameter at medial 1/3 of clavicle (SIM)	Superior to inferior length at 1/3 medial end of maximum length
Medial 1/3 clavicular circumference (MC)	Shaft circumference at 1/3 medial end of maximum length
Anterior-posterior diameter at lateral 1/3 of clavicle (APL)	Anterior to posterior length at 1/3 lateral end of maximum length
Superior-inferior diameter at lateral 1/3 of clavicle (SIL)	Superior to inferior length at 1/3 lateral end of maximum length
Lateral 1/3 clavicular circumference (LC)	Shaft circumference at 1/3 lateral end of maximum length
Robustness index (RI)	MDC/MXL * 100
Height of the sternal end of clavicle (HSC)	Superior to inferior point at the sternal end

clavicle (APM) and anterior-posterior diameter at lateral 1/3 of clavicle (APL). All variables regarding the anterior to posterior diameter were measured perpendicular to the clavicular cortex. Table 1 gives descriptions and reference points of the clavicular measurements used in this research.

Statistical analysis was performed using SPSS version 22 (IBM Corp., Armonk, NY, USA), with a significance level of 0.05. Intra- and inter-observer errors from both dry bone were verified in 30 left clavicles using the intraclass correlation coefficient (ICC), inter-observer measurement was undertaken by a postgraduate student in forensic science with experience of skeletal remains examination.

The descriptive statistics of the samples were evaluated, and the distributions of all variables were

analysed by the Kolmogorov-Smirnov test. The associations between the left and right side variables were examined using the Pearson correlation. The differences between dry bone and radiograph examinations were tested using the paired t-test. The correlations of all variables with stature were tested with the Pearson correlation.

Finally, stature estimation equations were computed by univariate and multiple regression analysis. Since the sample of this study was restricted, a split test sample was not created.

RESULTS

Clavicular Measurements Descriptive Statistics

A total of 137 samples were taken, with ages ranging from 24 to 83 years, with

Table 2: Descriptive data of all figures from clavicular measurements

Variables	Male (n = 112)				Female (n = 25)				
	Mean	Minimum	Maximum	SD	Mean	Minimum	Maximum	SD	
Age (years)	45.8	24.0	81.0	11.7	45.0	25.0	83.0	17.4	
Stature (cm)	169.0	152.0	183.0	6.2	159.6	147.0	173.0	6.8	
MXL (cm)	L	15.446	13.500	17.700	0.886	13.936	12.000	15.800	0.780
	R	15.229	13.100	17.900	0.849	13.712	12.200	15.600	0.784
APMD (cm)	L	1.244	0.939	1.909	0.129	1.044	0.922	1.273	0.086
	R	1.273	0.899	1.609	0.132	1.083	0.852	1.309	0.098
SIMD (cm)	L	1.072	0.872	1.556	0.128	0.909	0.732	1.220	0.126
	R	1.058	0.822	1.395	0.120	0.919	0.747	1.249	0.117
MDC (cm)	L	3.732	3.100	5.200	0.328	3.184	2.900	3.900	0.264
	R	3.762	3.000	4.500	0.297	3.208	2.700	4.000	0.283
APM (cm)	L	1.309	1.008	1.746	0.150	1.098	0.852	1.364	0.143
	R	1.344	1.064	1.712	0.153	1.176	0.895	1.415	0.142
SIM (cm)	L	1.299	0.942	1.958	0.197	1.109	0.876	1.475	0.192
	R	1.287	0.912	2.160	0.197	1.067	0.824	1.483	0.186
MC (cm)	L	4.192	3.400	5.700	0.407	3.584	3.000	4.300	0.380
	R	4.298	3.400	5.700	0.422	3.688	3.000	4.500	0.341
APL (cm)	L	1.405	1.068	1.890	0.159	1.238	1.016	1.533	0.139
	R	1.451	1.089	1.923	0.161	1.296	0.974	1.573	0.146
SIL (cm)	L	1.176	0.873	1.750	0.169	0.996	0.768	1.205	0.125
	R	1.179	0.932	1.639	0.154	0.961	0.683	1.155	0.111
LC (cm)	L	4.187	3.400	6.000	0.442	3.652	3.200	4.400	0.363
	R	4.135	3.300	5.200	0.392	3.648	3.000	4.400	0.403
RI	L	24.213	20.130	32.100	2.250	22.884	19.860	26.810	1.881
	R	24.756	19.500	29.610	2.166	23.457	19.480	27.820	2.305
HSC (cm)	L	2.588	2.015	3.243	0.250	2.340	1.935	3.155	0.283
	R	2.485	1.958	3.215	0.278	2.306	1.967	3.037	0.274

a mean age of 45.7 years and standard deviation of 12.8 years. The mean age of the 112 male samples was 45.8 years, the minimum age was 24.0 years, the maximum age was 81.0 years, and there was a standard deviation of 11.7 years. The mean age of the 25 female samples was 45.0 years, the minimum age was 25.0 years, the maximum age was 83.0 years, and the standard

deviation was 17.4 years.

The mean stature of the 137 samples was 167.3 cm, in a range from 147.0 to 183.0 cm, with a standard deviation of 7.2 cm. The mean stature of the 112 male samples was 169.0 cm, the minimum stature was 152.0 cm and the maximum stature was 183.0 cm, with a standard deviation of 6.2 cm. The mean stature of the 25 female

Table 3: Stature estimation from regression analysis for unknown sex skeletonized remains

Equations	R	R ²	SEE (cm)
Multivariate			
Stature (cm) = 2.131 (MXL) + 13.966 (APM) + 7.633 (HSC) + 97.788	0.700	0.490	5.238
Univariate			
Stature (cm) = 3.88 (MXL) + 108.41	0.559	0.312	6.035
Stature (cm) = 27.3 (APMD) + 134.31	0.546	0.298	6.098
Stature (cm) = 20.622 (SIMD) + 145.783	0.404	0.163	6.659
Stature (cm) = 9.519 (MDC) + 132.694	0.500	0.250	6.303
Stature (cm) = 23.321 (APM) + 137.633	0.546	0.298	6.100
Stature (cm) = 11.698 (SIM) + 152.476	0.337	0.114	6.852
Stature (cm) = 8 (MC) + 134.622	0.513	0.264	6.246
Stature (cm) = 18.661 (APL) + 141.613	0.434	0.188	6.558
Stature (cm) = 14.296 (SIL) + 150.922	0.347	0.121	6.825
Stature (cm) = 6.593 (LC) + 140.31	0.432	0.186	6.565
Stature (cm) = 0.518 (RIL) + 154.865	0.160	0.026	7.184
Stature (cm) = 12.979 (HSC) + 134.266	0.488	0.238	6.353
Radiographic measurements			
Stature (cm) = 3.842 (MXL) + 108.606	0.562	0.316	6.020
Stature (cm) = 24.928 (APMD) + 137.648	0.509	0.259	6.264
Stature (cm) = 22.228 (APM) + 139.026	0.524	0.274	6.200
Stature (cm) = 16.730 (APL) + 144.538	0.390	0.152	6.703

samples was 159.6 cm, the minimum stature was 147.0 cm and the maximum stature was 173.0 cm, with a standard deviation of 6.8 cm. The other descriptive data of the variables of both side clavicles are given in Table 2. With regards to the intra- and inter-observer analysis applying the ICC, MXL yielded the best results in both tests, 0.998 in the former and 0.996 in the latter. APM produced the smallest intra-observer ICC (0.8140), and APL produced the least inter-observer ICC (0.802). However, the ICC from the radiographic measurements had better results in all variables. MXL

gave the best result, both intra- and inter-observer (0.997 and 0.999, respectively). APL yielded the lowest intra-observer (0.987) result, while lowest inter-observer result was for APM (0.982).

Differences between Left and Right Clavicular Measurements

The Pearson correlation reveals that MXL yielded the best correlation between left and right (0.941), while HSC yielded the least correlation (0.716) ($p < 0.05$). Since the correlations were decent and the standard guidelines

advise measuring the left side of skeletons (Buikstra & Ubelaker 1994), this study applied measurements of the left clavicle in the regression analysis.

Differences between Dry Bone and Radiographic Clavicular Measurements

The paired t-test reveals differences in all variables ($p=0.000$) between dry bone and radiographic measurements. Therefore, this study calculated the stature estimation equations from both dry bone and radiographic measurements.

Stature Estimation from Clavicular Measurements

Table 3 gives the results of the stature estimation equations from combined sex univariate and multivariate regression analysis in all variables of both dry bone and radiographic measurements of clavicle: MXL, APMD, superior-inferior diameter at mid-diaphysis (SIMD), mid-diaphysis circumference (MDC), APM, superior-inferior diameter at medial 1/3 of clavicle (SIM), medial 1/3 clavicular circumference (MC), APL, superior-inferior diameter at lateral 1/3 of clavicle (SIL), lateral 1/3 clavicular circumference (LC), robustness index (RI) and height of the sternal end of clavicle (HSC).

The maximum length of clavicles yielded the best correlation and model fit with stature (Pearson correlation coefficient=0.559). The univariate regression analysis from maximum length has $R^2 = 0.312$ and SEE 6.035

cm. Multivariate stepwise regression analysis using 3 variables, MXL, APM, HSC, produced $R = 0.700$, $R^2 = 0.49$ and SEE 5.238 cm for stature approximation in unspecified sex individuals. Moreover, the height of the sternal end of the clavicle can be used to estimate stature in fragmented clavicles which could be retrieved from crime scenes with $R = 0.488$, $R^2 = 0.238$ and SEE 6.353 cm.

With regards to radiographic measurements, MXL showed the best correlation and model fit with stature ($R = 0.562$, $R^2 = 0.316$ and SEE 6.020 cm), while APL produced the least model fit equation ($R = 0.390$, $R^2 = 0.152$, and SEE 6.703 cm).

DISCUSSION

The study outcomes reveal that stature estimations can be calculated by applying regression analysis to the maximum lengths of left clavicles, as shown by previous studies (Rani et al. 2011; Balvir et al. 2012). However, neither of the previous researches disclose the normality tests of the stature variables, the Pearson correlations between maximum length and stature, R^2 or the standard error of estimation from the regression analyses. Furthermore, the earlier studies used both side clavicles in their stature determination equations, which might not be opportune for forensic examiners since both clavicles may not be recovered from crime scenes. The number of female samples (Rani et al. 2011) in the previous research might be too small for statistical sturdiness in the female regression formula.

There are a few of research concerning stature estimations from long bone measurements in Thailand (Mahakkanukrauh et al. 2011; Gocha et al. 2013). Since the multivariate regression analysis of the current study applies 3 variables, MXL, APM and HSC, as might be expected, the correlation shown by this study (0.700) was inferior to the values derived from long bone regression analysis, 0.831 (Mahakkanukrauh et al. 2011) and 0.839 (Gocha et al. 2013). The standard error of estimation of this study was 5.2 cm, less than the study of Mahakkanukrauh et al. (2011) which was 5.3 cm but higher than the study of Gocha et al. (2013) which was 2.5 cm.

Although the maximum length of a clavicle can determine the stature, with 6.0 cm of standard error of estimation, more sound results (SEE 5.2 cm) can be generated using multivariate regression equations with two more variables, the anterior-posterior diameter at medial 1/3 of the clavicle and the height of the sternal end of the clavicle. Consequently, this study proposes that forensic practitioners use multivariate regression analysis instead of applying univariate regression analysis.

In cases where fragmented clavicles are discovered at a crime scene, the heights of the sternal ends of the clavicles can be used to estimate stature, with 6.4 cm of standard error of estimation. However, the value of the standard error of estimation in this study was more than previous studies of fragmentary femur measurements (Fongkete et al. 2016) (SEE = 5.2 cm).

Since research into stature estimation

from clavicular measurement by conventional radiography does not exist in other populations, the results from this study cannot be compared to any previous study.

The stature estimation equations in this research were based on both male and female samples, so forensic investigators can undertake regression analysis to estimate the stature of unknown sex skeletal remains. The maximum length of the right clavicle can be applied in the equation if the left clavicle is not available, since the correlation is very respectable.

One limitation of this study was the number of female samples, limited to 25, which was not sufficient to calculate stature estimations for the female population. There was also a possibility that the clavicle preparation process might affect the variable measurements; as such, we recommend the user prepare the clavicle sample in the manner of this study to ensure the best results.

CONCLUSION

This research attempted to establish a correlation between stature and the clavicular measurements in a Thai population using osteometric methods and radiography. This can help to generate biological profiles in cases where long bones are not available, by applying an equation to the maximum length of the clavicle of an unspecified sex individual. The height of the sternal end of the clavicle can likewise be used to estimate the stature in cases of fragmented clavicles recovered from crime scenes, with $R=0.488$, $R^2=0.238$

and standard error of estimation 6.353 cm. This study could be useful in cases of dry bone recovered from crime scenes and the examination of partially skeletonised bodies, where stature can be estimated by applying the equation to radiographic measurements.

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