Int. J. Morphol.,
40(3):768-773, 2022.

Sex Determination Using Scapular and Clavicular Parameters in Modern Thai Population

Determinación del Sexo Utilizando Parámetros Escapulares y Claviculares en la Población Tailandesa Moderna

Phattarapong Kharuhadetch[1]; Sunitta Wattanawaragorn1; Chaiwit Tiamtongon[1]; Thawatchai Wathanyutakon[1]; Pagorn Navic[2] & Pasuk Mahakkanukrauh[2,3]

KHARUHADETCH, P.; WATTANAWARAGORN, S.; TIAMTONGON, C.; WATHANYUTAKON, T.; NAVIC, P. & MAHAKKANUKRAUH, P. Sex determination using scapular and clavicular parameters in modern Thai population. *Int. J. Morphol., 40(3)*:768-773, 2022.

SUMMARY: As natural disasters or crimes, precise postmortem identification is needed especially in case of unknown human remains. The aim of the study is to assess sexual dimorphism by formulating new multivariate equations based on scapular and clavicular parameters for a modern Thai population. Eight left scapular and six left clavicular parameters were measured from 278 individuals (124 males and 124 females for training group; and 15 males and 15 females for test group) of a modern Thai population with age ranges from 19 to 101 years. All scapular and clavicular parameters were sexually dimorphic. Direct and stepwise multivariate discriminant function analysis was performed to generate models. Three direct multivariate discriminant functions showed accuracy rates from 91.1c to 92.3 % (cross-validated range from 90.3 % to 91.5 %). Similarly, three stepwise multivariate discriminant functions showed accuracy rates from 90.7 % to 92.7 % (cross-validated range from 90.7 % to 92.7 %). Moreover, the test group showed 86.67 % to 100 % of sex determination accuracy in six discriminant functions. As recommendation for sex determination by using combination of the scapular and clavicular parameters yields statistically high accuracy for sex determination. Therefore, the accuracies of these multivariate discriminant function equations obtained from scapula and clavicle can be applied for forensic sex determination, especially in modern Thais.

KEY WORD: Forensic anthropology; Sex determination; Scapula; Clavicle; Thais.

INTRODUCTION

In the scenario when the corpses only showed skeletal remains from inevitable deterioration, forensic investigation is crucial for assessing postmortem identification by inspecting body characteristics such as specific bone parts. Sex determination is the primary step to investigate the bone that yields a distinguishing outcome of male or female bodies and can scope down the unknown decedent sample pool (Krishan *et al*., 2016).

Currently, there have been several discriminant functions that used metric analysis of sexual dimorphism from most parts of the human bones such as skull (Mahakkanukrauh *et al*., 2016), sternum (Myint tun *et al*., 2015), scapula (Peckmann *et al*., 2017), clavicle (Kaewma *et al*., 2017; Ungchittrakool & Sinloyma, 2018), radius (Jongmuenwai *et al*., 2021), carpal bones (Barnes *et al*., 2020), hand phalanges (Mahakkanukrauh *et al*., 2013), and so forth. Moreover, the combination of spontaneous more than one bony parameter or two parts of different bony parameters are interested and will enhance the accuracy of sex determination, for example, sex determination from scapula and clavicle. According to Frutos (2002), Papaioannou *et al*. (2012) and Koukiasa *et al*. (2017), they reported that analyzing the scapular and clavicular measurement together may lead to an accurate determination of sex. Moreover, the availability and validity of each discriminant function equation are dependent on the integrity of the bones that must be used in the specific equations in which compact bones such as the scapula and clavicle commonly appear combined as skeletal remains in most criminal scenarios.

[1]Medical Student, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand.
[2]Department of Anatomy, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand.
[3]Research Cluster in Osteology Research and Training Center (ORTC), Chiang Mai University, Chiang Mai, Thailand.

Received: 2022-04-01 Accepted: 2022-04-29

To date, although discriminant function equations of each scapula and clavicle have existed for a Thai population (Kaewma *et al*., 2017; Peckmann *et al*., 2017; Ungchittrakool & Sinloyma, 2018), the combination of scapular and clavicular discriminant function equation has not been reported. To the best of our knowledge, the aims of this study were to formulate new multivariate functions equations based on scapular and clavicular measurement and to assess sexual dimorphism in the modern Thai population.

MATERIAL AND METHOD

Ethical approval for this study was granted by the Research Ethics Committee of the Faculty of Medicine at Chiang Mai University (clearance no. 7818/2563).

Sample Composition. This study collected two hundred and seventy-eight scapulae and clavicles (139 males, 139 females) from blind peer review, which are ranging in age from 19 to 101 years, with a mean age of 63.45 (15.52SD) years for males and 63.91 (15.69SD) years for females. The samples were collected from the Forensic Osteology Research Center (FORC), Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand. All individuals used in this study are the modern Thais who died between 2007 and 2019. The skeleton exhibiting fractured bone in the measuring area, bone with pathologies, and bone with anatomical ambiguous landmarks were excluded from present study.

Total bone collections were grouped into two; (i) training group consisted of 124 males and 124 females. The first group was conducted for the derivation of discriminant function equations for the sex estimation. After discriminant function equations were formulated, the second group; (ii) test group was performed by using thirty scapulae and clavicles (15 males, 15 females) within 278 bone collection cases to test whether those newly formulated equations were valid in practice.

Measurement. Eight left scapular and six left clavicular parameters were measured following the protocol of Papaioannou *et al*. (2012). The description of all variables is defined in Tables I and II and shown in Figures 1 and 2. All measurements were performed by measuring three times non-consecutively and calculated the average of these three times measurements.

Table I. The Definition of eight scapular parameters.

Parameters	Abbreviation	Description
Maximum scapular height of the glenoid surface	S1	Maximum distance from the prominent superior margin of glenoid to the inferior margin.
Maximum scapular width of the glenoid surface	S2	Maximum distance across glenoid cavity measured perpendicularly to the axis of glenoid cavity height.
Scapular spine length	S3	Distance from the medial margin of scapular spine to the lateral margin.
Scapular height	S4	Maximum distance between the superior angle to the inferior angle of scapula.
Scapular width	S5	Maximum distance between the center of the glenoid fossa (black circle) to spinal axis terminal on the vertebral margin (black arrow).
Infra-scapular height	S6	Distance from spinal axis terminal on the vertebral margin to the tip of the inferior angle of scapula.
Supra-scapular height	S7	Distance from the superior angle of scapula to spinal axis terminal on the vertebral margin.
Acromial width	S8	Distance from the superior point to the inferior point of acromion process.

Table II. The Definition of six clavicular parameters.

Parameters	Abbreviation	Description
Maximum clavicular length	C1	The greatest distance between the sternal and acromial ends of the clavicle.
Midshaft circumference	C2	The smallest circumference that passes through the midpoint of midshaft.
Midshaft maximum diameter	C3	The minimum distance from the superior surface to the inferior surface at midshaft.
Midshaft minimum diameter	C4	The minimum distance from the ventral surface to the dorsal surface at midshaft.
Maximum width of sternal end	C5	Using the digital osteometric board to measure it perpendicularly to the sternal end.
Maximum width of acromial articular surface	C6	Define the articular surface by articulating the distal end of the clavicle with the equivalent surface of the digital osteometric board to measure the maximum width of it.

Data analysis. All collected data was analyzed by IBM SPSS Statistic 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were reported. Independent sample t-test was also used to test sexual dimorphism. Direct and stepwise multivariate discriminant function analysis were used to create population-specific functions for sex estimation based on measurement variables. Section points were specifically calculated by applying a weighted average of group centroids from each specific discriminant function equations (Sarkar & Mukhopadhyay, 2018). Sex determination accuracy was calculated in percentage based on test group. The statistics were tested at a significance level at an alpha level of 0.05.

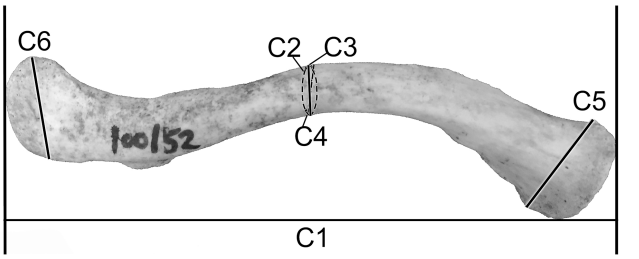

Fig. 2. Six clavicular parameters. C1: Maximum clavicular length; C2: Midshaft circumference; C3: Midshaft maximum diameter; C4: Midshaft minimum diameter; C5: Maximum width of sternal end; C6: Maximum width of acromial articular surface.

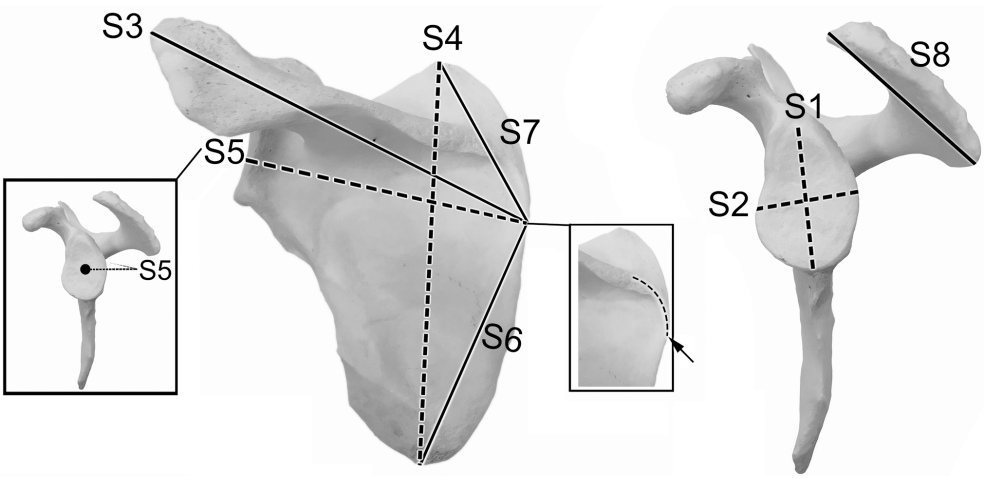

Fig. 1. Eight scapular parameters. S1: Maximum scapular height of the glenoid surface; S2: Maximum scapular width of the glenoid surface; S3: Scapular spine length; S4: Scapular height; S5: Scapular width; S6: Infra-scapular height; S7: Supra-scapular height; S8: Acromial width; black circle: the center of the glenoid fossa; black arrow: the most spinal axis terminal on the vertebral margin.

RESULTS

Table III shows descriptive statistics and sexual dimorphism for scapular and clavicular measurements on modern Thai population. The results showed that mean value of both scapular and clavicular variables for males showed greater than those of females. Moreover, all scapular and clavicular variables also showed statistically significant sexual dimorphism ($p < 0.001$). Therefore, all statistic data showed that all parameters can be applied for sex determination.

Table IV shows direct and stepwise multivariate discriminant function analysis. Three direct multivariate discriminant functions (Function 1, 3, and 5) were performed by directed combination all scapular and clavicular variables; only scapular variables; and only clavicular variables, respectively. Sex classification accuracy rate from Function 1 as combination of all variables of scapula and clavicle yields highest accuracy acquired accuracy at the rate of 92.3 % (cross-validated 91.5 %), while others such Function 3 yields at rate of 91.5 % (91.5 cross-validated), and Function 5 yields at rate of 91.1 % (90.3 % cross-validated), respectively. For stepwise multivariate discriminant functions (Function 2, 4, and 6), scapular stepwise variables (Function 4) yield the highest accuracy at the rate of 92.7 % (92.7 % cross-validated), following by combination stepwise between scapular and clavicular variables (Function 2) yields at rate of 91.9 % (91.9 % cross-validated), and clavicle stepwise variables (Function 6) yields at rate of 90.7 % (90.7 % cross-validated), respectively.

Table V shows the percentage accuracy for sex determination when tested in test group.

Table III. Descriptive statistics for scapular and clavicular measurements and test sex-difference between males and females.

Variables	Males					Females					*p*-value
	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD	
Scapula											
S1	124	26.87	40.44	33.5	2.25	124	23.53	37.02	29.67	2.34	<0.001*
S2	124	18.24	28.75	24.67	1.8	124	18.15	27.59	21.66	1.7	<0.001*
S3	124	122.43	172.31	143.09	7.81	124	111.23	150.99	129	7.52	<0.001*
S4	124	122.51	171.72	147.72	8.17	124	113.01	164.43	130.67	8.66	<0.001*
S5	124	91.51	137.93	104.8	6.54	124	82.08	130.23	96.21	8.23	<0.001*
S6	124	67.17	103.18	88.64	6.9	124	60.1	105.22	77.99	7.23	<0.001*
S7	124	52.16	86.14	70.37	6.06	124	50.61	85.03	61.86	5.94	<0.001*
S8	124	33.08	62.16	46.96	4.48	124	25.86	49.84	40.96	3.93	<0.001*
Clavicle											
C1	124	124.29	171.51	150.05	9.47	124	116.7	164.37	134.09	7.57	<0.001*
C2	124	29.67	46.18	37.67	2.92	124	27.9	44.34	32.76	3.14	<0.001*
C3	124	10.13	15.03	12.44	1.03	124	8.47	15.75	10.64	1.29	<0.001*
C4	124	7.93	13.06	10.15	1.02	124	6.99	11.26	8.67	0.84	<0.001*
C5	124	18.5	34.66	26.17	2.73	124	15.72	32.73	24.08	2.83	<0.001*
C6	124	16.07	40.55	24.81	3.57	124	13.97	29.45	21.55	3.01	<0.001*

S1: Maximum scapular height of the glenoid surface; S2: Maximum scapular width of the glenoid surface; S3: Scapular spine length; S4: Scapular height; S5: Scapular width; S6: Infra-scapular height; S7: Supra-scapular height; S8: Acromial width C1: Maximum clavicular length; C2: Midshaft circumference; C3: Midshaft maximum diameter; C4: Midshaft minimum diameter; C5: Maximum width of sternal end; C6: Maximum width of acromial articular surface. * Significant difference between sexes: males-females value (p-value < 0.05)

Table IV Discriminant equations for the scapula and clavicle measurements.

Functions	Scapula								Clavicle						Constant	Original (%)	Cross-validated (%)	Group centroid	
	S1	S2	S3	S4	S5	S6	S7	S8	C1	C2	C3	C4	C5	C6				M	F
									Combination										
F1: Combine all variables	0.046	0.029	0.111	0.296	-0.064	-0.025	0.135	0.058	0.014	0.024	-0.006	-0.005	0.018	0.042	-22.437	92.3	91.5	1.459	-1.459
F2: Combine stepwise variables	0.166			0.029				0.045	0.052	0.121					-22.836	91.9	91.9	1.408	-1.408
									Only Scapula										
F3: All scapular variables	0.104	0.121	0.042	0.029	0.000	0.025	0.022	0.036							-20.900	91.5	91.5	1.256	-1.256
F4: Scapular stepwise variables	0.112	0.134	0.049	0.056											-21.096	92.7	92.7	1.239	-1.239
									Only Clavicle										
F5: All clavicular variables									0.074	0.003	0.279	0.416	-0.011	0.027	-18.153	91.1	90.3	1.193	-1.193
F6: Clavicular stepwise variables									0.076		0.290	0.434			-18.223	90.7	90.7	1.189	-1.189

DISCUSSION

Sex determination by using human skeletons has been consistently developed for forensics purpose over time. Primarily, bones are affected by hormones and genetic contribution. Male and female bones, therefore, are morphologically different in size and proportion; thus, it can be applied in forensics practice. Correspondingly, environmental influence and different demographic group can reduce predictability from the bone more or less. Comparing mean value of scapular and clavicular parameters of Thai to other populations, e.g., American (Dabbs & Moore-Jansen, 2010), Mexican (Hudson *et al*., 2016), Iranian (Akhlaghi *et al*., 2012), Indian (Math *et al*., 2014), Guatemalan (Frutos, 2002), and Greek (Papaioannou *et al*., 2012; Koukiasa *et al*., 2017), mean values for scapular and clavicular parameters were different in each population as Thai population tends to be smaller than others. Therefore, it is important to develop

Table V Test of all discriminant function equation on test set (N=30).

Function	% sex determination accuracy		
	Overall	Male	Female
F1: Combine all variables	96.67	93.33	100
F2: Combine stepwise variables	90	86.67	93.33
F3: All scapular variables	90	93.33	86.67
F4: Scapular stepwise variables	93.34	100	86.67
F5: All clavicular variables	96.67	93.33	100
F6: Clavicular stepwise variables	96.67	93.33	100

discriminant function equations to determine sex for a specific population, especially in Thai population.

Currently, there have been conducted sex determination using a single bone, i.e., clavicle (Kaewma *et al*., 2017; Ungchittrakool & Sinloyma, 2018), and scapula (Peckmann *et al*., 2017) among Thai samples. No study has yet to establish a combined sex-determinant equation of more than one bone. Previous study conducted using a clavicle by Kaewma *et al*. (2017) in Thai population found that C1, C2, C3, and C4 parameters provided moderate to high accuracy, ranging from 57.5 % to 90.55 %. Whereas C5 and C6 parameters yield accuracy of 64.57 % and 33.07 % in males and 13.5 % and 34.5 % in females respectively which are deemed not adequately accurate in sex assessing. In our study, C5 and C6 parameters were absolutely selected owing that they showed statistically significant in generating a combined equation. It can be said that the possible reasons for the disparate findings might be from the bone collection of use, sample size, distribution of sex and age of the sample, and so on. Following literature review in studies using scapula, for example, Peckmann *et al*. (2017) studies sex determination by using scapula of Thai population. They found that S1 and S2 parameters are accurate perimeters which provided an accuracy up to 83 %. However, their study has not incorporated other measurements available from the scapula. Despite quite a far different number between male and female samples, the study of Dabbs & Moore-Jansen (2010) has shown high accuracy up to 91.3 %-96.8 % using S1, S3, S4, and S5 parameters. This led us to believe that though glenoid cavity is known to be sexually dimorphic, other measurements from scapula too, can likely provide high accuracy. Hence, our study has included other parameters from scapula to create a combined multi-variable equation and opting statistical optimal parameters as well.

Pertaining whether left or right side of sample should be used, few studies that have included both sides show higher accuracy from left side sample. This could naturally be due to less influence of force exertion on the left side as immensely more people are right-handed. Ungchittrakool & Sinloyma (2018), however, concluded that right side of sample is more accurate which is in controversy in comparison to the study by Math *et al*. (2014) and Koukiasa *et al*. (2017). Still, as explained above, we recommend using the left side of the sample to eradicate confounding influence due to greater force exertion on the right arm and hand.

Aforementioned statistic result by our study (Table IV) showed that clavicular parameters alone yield 91.1 % and stepwise yields 90.7 % for overall accuracy. Meanwhile, scapular parameters result in 91.5 % and stepwise yields 92.7 % for overall accuracy. Combined equation of clavicular and scapular parameters yields 92.3 % and stepwise yields 91.9 %. These accuracy rates are similar to Papaioannou *et al*. (2012) and Koukiasa *et al*. (2017) who studied in Modern Greek population and they found that both scapula and clavicle appear to provide high accuracy in sex determination. Koukiasa *et al*. (2017) also reported that multi-variable equation surpasses single variable equation in term of accuracy. With accuracies ranging from 92.4 % to 94.7 %, these two bones can definitely offer additional confidence of correct sex estimation and can even provide higher accuracy if more variables are incorporated in the discriminant function. This is also found to be in consistence with a conclusion by Steele (1976) suggesting that single measurement is less practical as there could be large overlap of range between sexes which will greatly reduce an accuracy of sex determination. Correspondingly, the accuracy rate of test group (Table V) also confirmed that the efficacy in sex determination using scapula and clavicle together was relatively high, which produced accuracies between 90 % to 96.67 % for overall and 86.67 % to 100 % for males and females. Overall, the present study demonstrates that accuracies of these multivariate discriminant function equations obtained from the scapula and clavicle are useful for estimating sex in medico-legal contexts, especially in a Thai population.

Practically, in the case of both left scapula and left clavicle are intact and available, recommendation is using the Function 4 that brings the highest accuracy of all six functions. If the result appears indeterminate, the next step is using Function 1 (the combination of all scapular and clavicular parameters) which yields the second highest accuracy of sex determinant function as resolve. If the result still is indeterminate, other four sex determinant functions are needed to be performed. In the case of only either left scapula or one left clavicle being unavailable, the highest accuracy of their sex determinant function for each available bone could be performed first (Function 3-6).

In addition, more forensic study should be developed in the future; it would be interesting to test the accuracy of these equations to other population, e.g., different regions of Thailand and Asian population. Fragments of scapula and clavicle should be also used for further study to reduce inability to determine sex due to loss or damage. Demographic data like correlation between age and height can also be a topic of interest which would help in personal identification. Moreover, finding additional measurement parameters or conducting on the medical image analysis might provide better results, for example, Sehrawat & Pathak (2016) applied various angle of clavicular aspect (lateral angle, medial angle and conoid tubercle diameter) for sex determination which we believed that the more parameters could yield more accuracy in sex dimorphism in the future study.

ACKNOWLEDGEMENTS

This work was supported by Faculty of medicine, Chiang Mai University [Grant No. 057/2565].

KHARUHADETCH, P.; WATTANAWARAGORN, S.; TIAMTONGON, C.; WATHANYUTAKON, T.; NAVIC, P. & MAHAKKANUKRAUH, P. Determinación del sexo utilizando parámetros escapulares y claviculares en la población tailandesa moderna. *Int. J. Morphol., 40(3)*:768-773, 2022.

RESUMEN: En casos de desastres naturales o crímenes se requiere una identificación post mortem precisa, especialmente en el caso de restos humanos desconocidos. El objetivo de este estudio fue evaluar el dimorfismo sexual mediante nuevas ecuaciones multivariadas basadas en parámetros escapulares y claviculares para una población tailandesa moderna. Se midieron ocho parámetros escapulares izquierdos y seis claviculares izquierdos de 278 individuos (124 hombres y 124 mujeres para el grupo de entrenamiento; y 15 hombres y 15 mujeres para el grupo de prueba) de una población tailandesa moderna con rangos de edad de 19 a 101 años. Todos los parámetros escapulares y claviculares presentaban dimorfismo sexual. Se realizaron análisis de funciones discriminantes multivariadas directas paso a paso para generar modelos. Tres funciones discriminantes multivariadas directas mostraron tasas de precisión de 91,1 % a 92,3 % (rango de validación cruzada de 90,3 % a 91,5 %). De manera similar, tres funciones discriminantes multivariadas mostraron tasas de precisión de 90,7 % a 92,7 % (rango de validación cruzada de 90,7 % a 92,7 %). Además, el grupo de prueba mostró del 86,67 % al 100 % de precisión en la determinación del sexo en seis funciones discriminantes. Como recomendación para la determinación del sexo mediante el uso de la combinación de los parámetros escapulares y claviculares, se obtiene una precisión estadísticamente alta para la determinación del sexo. Por lo tanto, las precisiones de estas ecuaciones de funciones discriminantes multivariadas obtenidas de la escápula y la clavícula se pueden aplicar para la determinación forense del sexo, especialmente en los tailandeses modernos.

PALABRAS CLAVE: Antropología forense; Determinación del sexo; Escápula; Clavícula.

REFERENCES

Akhlaghi, M.; Moradi, B. & Hajibeygi, M. Sex determination using anthropometric dimensions of the clavicle in Iranian population. *J. Forensic Leg. Med., 19(7)*:381-5, 2012.

Barnes, A. E.; Case, D. T.; Burnett, S. E. & Mahakkanukrauh, P. Sex estimation from the carpal bones in a Thai population. *Aust. J. Forensic Sci., 52(6)*:665-80, 2020.

Dabbs, G. R. & Moore-Jansen, P. H. A method for estimating sex using metric analysis of the scapula. *J. Forensic Sci., 55(1)*:149-52, 2010.

Frutos, L. R. Determination of Sex from the clavicle and scapula in a Guatemalan contemporary rural indigenous population. *Am. J. Forensic Med. Pathol., 23(3)*:284-8, 2002.

Hudson, A.; Peckmann, T. R.; Logar, C. J. & Meek, S. Sex determination in a contemporary Mexican population using the scapula. *J. Forensic Leg. Med., 37*:91-96, 2016.

Jongmuenwai, W.; Boonpim, M.; Monum, T.; Sintubua, A.; Prasitwattanaseree, S. & Mahakkanukrauh, P. Sex estimation using radius in a Thai population. *Anat. Cell Biol., 54(3)*:321-31, 2021.

Kaewma, A.; Sampannang, A.; Tuamsuk, P. & Iamsaard, S. Morphometry of Isan-Thai clavicles as a guide for sex determination. *Int. J. Morphol., 35(1)*:172-7, 2017.

Koukiasa, A. E.; Eliopoulos, C. & Manolis, S. K. Biometric sex estimation using the scapula and clavicle in a modern Greek population. *Anthropol. Anz., 74(3)*:241-6, 2017.

Krishan, K.; Chatterjee, P. M.; Kanchan, T.; Kaur, S.; Baryah, N. & Singh, R. K. A review of sex estimation techniques during examination of skeletal remains in forensic anthropology casework. *Forensic Sci. Int., 261*:165.e161-65, 2016.

Mahakkanukrauh, P.; Khanpetch, P.; Prasitwattanseree, S. & Case, D. T. Determination of sex from the proximal hand phalanges in a Thai population. *Forensic Sci. Int., 226(1)*:208-15, 2013.

Mahakkanukrauh, P.; Sinthubua, A.; Prasitwattanaseree, S.; Ruengdit, S.; Singsuwan, P.; Praneatpolgran, S. & Duangto, P. Craniometric study for sex determination in a Thai population. *Anat. Cell Biol., 48(4)*:275-83, 2016.

Math, S.; Math, S. C.; Jatti, V. B. & Murthy, C. R. V. Identification of sex of human clavicles from North Karnataka zone. *Anthropologist, 17(3)*:917-20, 2014.

Myint tun, S.; Das, S.; Ruengdit, S.; Singsuwan, P. & Mahakkanukrauh, P. Sex determination from different sternal measurements: A study in a Thai population. *J. Anat. Soc. India, 64(2)*:155-61, 2015.

Papaioannou, V. A.; Kranioti, E. F.; Joveneaux, P.; Nathena, D. & Michalodimitrakis, M. Sexual dimorphism of the scapula and the clavicle in a contemporary Greek population: Applications in forensic identification. *Forensic Sci. Int., 217(1-3)*:231.e1-7, 2012.

Peckmann, T. R.; Scott, S.; Meek, S. & Mahakkanukrauh, P. Sex estimation from the scapula in a contemporary Thai population: Applications for forensic anthropology. *Sci. Justice, 57(4)*:270-5, 2017.

Sarkar, N. & Mukhopadhyay, P. P. Determination of sex from the morphometry of orbits in adult skull of contemporary eastern Indian population. *Egypt. J. Forensic Sci., 8(1)*:61, 2018.

Sehrawat, J. S. & Pathak, R. K. Variability in anatomical features of human clavicle: Its forensic anthropological and clinical significance. *Transl. Res. Anat., 3-4*:5-14, 2016.

Steele, D. G. The estimation of sex on the basis of the talus and calcaneus. *Am. J. Phys. Anthropol., 45(3 pt. 2)*:581-8, 1976.

Ungchittrakool, S. & Sinloyma, P. Gender determination of Thai populations by measurements of clavicle. *Suan Dusit Grad. Sch. Acad. J., 14*:243-57, 2018

Corresponding author:
Prof. Pasuk Mahakkanukrauh, MD
Research Cluster in Osteology Research and Training Center (ORTC) Chiang Mai University
Chiang Mai
THAILAND

E-mail: pasuk034@gmail.com