

Morphometry of Isan-Thai Clavicles as a Guide for Sex Determination

Morfometría de las Clavículas en una Población Isan-Thai
como Guía para la Determinación del Sexo

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SUMMARY: The dried clavicles have been well documented to determine individual sex and age in many races. Such morphometric investigations in Isan (Northeastern) Thais have never been reported. Therefore, this study aimed to estimate the sex from dried clavicles of Isan-Thais using morphometric analysis. The identified 454 dried clavicles (254 males and 200 females), averaged age (60.69±14.36 years) were measured and analyzed for identification point (IP) and the demarking point (DP) values. The results showed that the identified-bone percentages by IP of the maximum clavicular lengths in males and females were 90.55 % (>139.9 mm) and 89 % (<140.6 mm). In addition, such percentages of the mid shaft circumference measured in male clavicles was 83.46 % (>37.7 mm) and in females was 75 % (<37.0 mm). However, percentages of the DP in all parameters were less than 50%. The highest DP values of maximum length of male clavicles was 43.31% (>152.5). In conclusion, the maximum length and mid shaft circumference investigated from this study can be used as basic data of Isan – Thais for applying as a guide in forensic sciences for sex determination from dried clavicle remains.

KEY WORDS: Clavicle; Morphometry; Isan Thais; Sex determination.

INTRODUCTION

Sex determination from bony remains is important in individual identification. In previous studies, many skeletal human bones have been used to determine and distinguish the sexes, including patella (Dayal & Bidmos, 2005), sternum (Is_{can}, 1985), and foot bones (Bidmos & Dayal, 2003). Particularly, the basic morphometry of clavicles has been reported in many races (Olivier, 1951; Jit & Singht, 1966; Kaur *et al.*, 2002). In addition, the appearance of rhomboid fossa on inferior clavicular surface could be used to distinguish the males from the females (Jit & Kaur, 1986; Rogers *et al.*, 2000; Prado *et al.*, 2009). Moreover, the medial articular surface of clavicle could be used to estimate age of Europeans (Kreitner *et al.*, 1998; Falys & Prangle, 2015). In Thailand, there was only a report investigated about the age estimation based on length measurements by using computed tomography (CT) images of clavicles in North - Thais (Pattamapasong *et al.*, 2015). However, both sex and age estimations including morphometric analysis using CT or dried clavicles in the Isan (Northeastern)-Thai population have never been systemically observed. Therefore, this study aimed to primarily evaluate the morphometry on dried

clavicles of Isan Thais using measurement parameters to be hopefully used as a guide for individual sex determination.

MATERIALS AND METHOD

The 476 identified clavicles (left and right sides) were provided from Isan (Northeastern) Thai skeletons (270 males and 206 females) from KKU Osteological Collection Unit, Department of Anatomy, Faculty of Medicine, Khon Kaen University. The ages were ranged from 19 to 100 years. The incomplete clavicles such as fractured and plate fixation clavicles were excluded. In this study, the lengths of clavicular parameters (Figs. 1 and 2) were measured by digital Vernier caliper in triplicates. These morphometric parameters included C1 (maximum length), C2 (mid shaft circumference), C3 (mid shaft maximum diameter), C4 (mid shaft minimum diameter), C5 (maximum breadth of acromial end) and C6 (maximum breadth of sternal end), respectively (Fig. 1).

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In addition, the FL (maximum length of fossa), FW (maximum width of fossa), medial articular surface; ML (maximum length of medial articular surface) and MW (maximum width of medial articular surface), acromial surface; AL (maximum length of acromial surface), and AW (maximum width of acromial surface), respectively, were triplicate measured (Fig. 2). This study was approved from the Office of The Khon Kaen University Ethics Committee for human research (the human ethic number HE581460 to Miss Ailadda Kaewma).

Statistical Analysis. Statistical analyses were performed using the SPSS software version 17.0. The student t-test was used to compare the differences between groups whereas Mann-Whitney U Test was used to analyze the data with non-normal distribution. The p-value < 0.05 was determined as statistical significance. Identification point (IP) was represented as mean ± 1SD (Udoaka & Nwokediuko, 2013). To gain more accuracy in sex determinations, the demarking point (DP) based on mean ± 3SD differences of all parameters were analyzed (Singh & Grangrade, 1968).

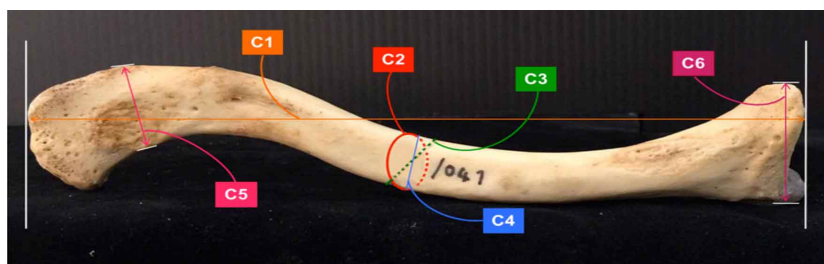


Fig. 1. Photograph showing 6 clavicular parameters measured: C1 (maximum length), C2 (mid shaft circumference), C3 (mid shaft maximum diameter), C4 (midshaft minimum diameter), C5 (maximum breadth of acromial end) and C6 (maximum breadth of sternal end).

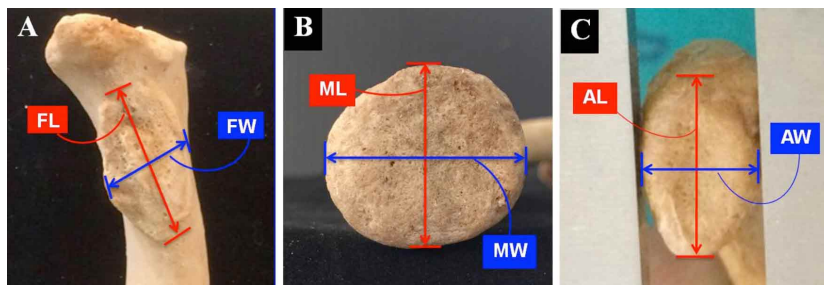


Fig. 2. Photographs showing 6 clavicular parameters measured: A) rhomboid fossa; FL (maximum length of fossa) and FW (maximum width of fossa), B) medial articular surface; ML (maximum length of medial articular surface) and MW (maximum width of medial articular surface), and C) acromial surface; AL (maximum length of acromial surface) and AW (maximum width of acromial surface).

RESULTS

The results showed that lengths of C1, C2, C3, C4, C5 and C6 were 141.85 ± 0.8 , 37.8 ± 0.33 , 10.91 ± 1.26 , 10.47 ± 1.34 , 21.31 ± 5.79 and 23.51 ± 2.73 mm, respectively. In addition, the lengths of FL, FW, SL, SW,

AL and AW were 22.82 ± 4.33 , 9.81 ± 1.96 , 23.33 ± 2.71 , 23.16 ± 2.83 , 17.12 ± 3.46 and 11.12 ± 2.24 , respectively (Table I). Interestingly, all parameters in males were higher than those of females (Table I).

Table II shows the identification point (IP) values; percentage bone identified, and test of significance from 454 Isan Thai clavicles. It was found that the percentage bone identified of the C1 of both sexes and C2 of only males is greater than 80 % as compared to the rest parameters (Table II). Significantly, the IPs of C1 in males and females were >139.9 mm and <140.6 mm. In addition, the IP of C2 in males was >37.7 mm (Table II). The percentage bones identified were composed of C2 in females (75 %; IP = <37.0 mm), C3 in males (74.80 %; IP = >10.94) and females (76.50 %; IP = <10.59), C4 in both sexes (60.24 %; IP = >10.88, 57.50 %; IP = <9.81), C5 in males (64.57 %; IP = >21.88), MW in males (57.87 %; IP = >24.45) and AL in males (52.36 %; IP = >18.36) (Table II). In this study, the percentage bones identified that were lower than 50 % were composed of C5 in females, C6, maximum FL, FW, ML, SW in females, AL in females and maximum width of AW (Table II). However, all results showed significant differences ($P < 0.001$) between males and females (Table II).

For further analysis, the demarking point (DP) (mean ± 3SD) and percentages of identification bone by DP in both sexes were shown in Table III. It was found that no parameter has the percentages of identification bone by DP more than 50 %. However, the highest percentage of that of C1 in males was 43.31 % (DP = >152.5 mm) (Table III). As greater than 10 %, the percentages of identification bone by DPs of C2, C3, C4 and C5 in males were 25.98 % (DP = >43.3), 18.90 % (DP = >13.17), 10.24 % (DP = >13.31) and 10.24 % (DP = >27.07), respectively (Table III).

Table I. The lengths of C1 - C6, FL, FW, SL, SW, AL and AW measured in Isan Thais.

N	Parameters	Sex	Rang (mm)	Mean(mm)	SD
1	Maximum length (C1)	M	119 - 180	150.2	0.97
		F	115 - 152	133.5	0.63
			Averaged	141.85	0.8
2	Mid shaft circumference (C2)	M	31 - 48	40.7	0.37
		F	30 - 44	34.9	0.28
			Averaged	37.8	0.33
3	Mid shaft maximum diameter (C3)	M	7.89 - 15.44	11.99	1.41
		F	7.74 - 13.2	9.82	1.11
			Averaged	10.91	1.26
4	Mid shaft minimum diameter (C4)	M	8.17 - 16.45	11.26	1.46
		F	6.84 - 14.01	9.67	1.22
			Averaged	10.47	1.34
5	Maximum breadth of acromial end (C5)	M	15.99 - 31.92	23.32	3.20
		F	9.97 - 27.55	19.29	2.59
			Averaged	21.31	5.79
6	Maximum breadth of sternal end (C6)	M	17.48 - 33.7	24.38	2.88
		F	16.02 - 28.86	22.64	2.57
			Averaged	23.51	2.73
7	Maximum length of fossa (FL)	M	13.31 - 32.7	23.46	4.32
		F	10.58 - 33.19	22.18	4.34
			Averaged	22.82	4.33
8	Maximum width of fossa (FW)	M	4.43 - 16.89	10.39	2.28
		F	4.6 - 14.08	9.22	1.63
			Averaged	9.81	1.96
9	Maximum length of medial articular surface (ML)	M	17.98 - 34.29	24.21	2.89
		F	16.34 - 28.9	22.45	2.52
			Averaged	23.33	2.71
10	Maximum width of medial articular surface (MW)	M	16.25 - 35.38	24.29	3.22
		F	16.67 - 31.22	22.02	2.44
			Averaged	23.16	2.83
11	Maximum length of acromial surface (AL)	M	9.7 - 36.15	18.76	4.04
		F	9.05 - 25.35	15.48	2.88
			Averaged	17.12	3.46
12	Maximum width of acromial surface (AW)	M	5.74 - 18.66	12.05	2.57
		F	5.59 - 16.62	10.18	1.91
			Averaged	11.12	2.24

DISCUSSION

The mean lengths of C1 have been also used for sex determination in many populations including English (Parsons, 1961), French (Olivier), Amritsar-zone Indians (Jit & Singht), USA Negroes (Singh & Singh, 1972), North America (McCormick *et al.*, 1991), Northwest Indians (Kaur *et al.*), North Indians (Padeyappanavr *et al.*, 2009), Gujarat-zone Indians (Patel *et al.*, 2009), Iranians (Akhlaghi *et al.*, 2012), and Greeks (Papaioannou *et al.*, 2012). In Isan Thais, the mean length of C in males (150.2 mm) was longer than that of females (133.5 mm). Compared to others, the C1 of males in all populations previously reported was longer than that of

females (Table IV). The difference in this length between males and females may be caused from genetic variations and direct alterations from growth and sex hormones. It might be resulted from the environmental influences such as nutrition, life style activities and occupational stresses (Charisi *et al.*, 2011). It is possible that the estrogen hormone in females can inhibit bone growths as previously explained (Khosla *et al.*, 2012; Cohen *et al.*, 2014; Polur *et al.*, 2015; Nicks *et al.*, 2016). Therefore, this hormone may also affect the long growth of female clavicles as reported in various populations including Isan Thais (Table IV).

Table II. The identification point (IP), percentage bone identified and test of significance in both sexes (N=454).

N	Parameters	Sex	Range (mm)	IP (mm; mean±SD)	N	%bone identified by IP	P Value
1	Maximum length (C1)	M	119 – 180	>139.9	230	90.55	Z=15.76
		F	115 - 152	<140.6	178	89.00	P<0.0001
2	Mid shaft circumference (C2)	M	31 - 48	>37.7	212	83.46	Z=14.90
		F	30 - 44	<37.0	150	75.00	P<0.0001
3	Mid shaft maximum diameter (C3)	M	7.89 - 15.44	>10.94	190	74.80	Z=13.99
		F	7.74 - 13.2	<10.59	153	76.50	P<0.0001
4	Mid shaft minimum diameter (C4)	M	8.17 - 16.45	>10.88	153	60.24	Z=11.81
		F	6.84 - 14.01	<9.81	115	57.50	P<0.0001
5	Maximum breadth of acromial end (C5)	M	15.99 - 31.92	>21.88	164	64.57	Z=11.50
		F	9.97 - 27.55	<16.69	27	13.50	P<0.0001
6	Maximum breadth of sternal end (C6)	M	17.48 - 33.7	>25.21	84	33.07	T=6.36
		F	16.02 - 28.86	<21.50	69	34.50	P<0.0001
7	Maximum length of fossa (FL)	M	13.31 - 32.7	>26.52	96	37.80	Z=5.57
		F	10.58 - 33.19	<19.14	50	25.00	P<0.0001
8	Maximum width of fossa (FW)	M	4.43 - 16.89	>10.85	115	45.28	T=6.49
		F	4.6 - 14.08	<8.11	50	19.69	P<0.0001
9	Maximum length of medial articular surface (ML)	M	17.98 - 34.29	>24.97	95	37.40	T=6.61
		F	16.34 - 28.9	<21.32	65	32.50	P<0.0001
10	Maximum width of medial articular surface (MW)	M	16.25 - 35.38	>24.45	147	57.87	Z=9.76
		F	16.67 - 31.22	<21.07	73	28.74	P<0.0001
11	Maximum length of acromial surface (AL)	M	9.7 - 36.15	>18.36	133	52.36	Z=8.70
		F	9.05 - 25.35	<14.72	80	40.00	P<0.0001
12	Maximum width of acromial surface (AW)	M	5.74 - 18.66	>12.09	120	47.24	T=8.66
		F	5.59 - 16.62	<9.48	66	33.00	P<0.0001

Table III. The demarking point (DP) and percentage bone identified by the demarking point in both sexes (N=454).

Parameters	Sex	Calculated mean±3SD	DP (mm; mean±3SD)	N	%bone identified by DP
1 Maximum length (C1)	M	121.2-179.3	>152.5	110	43.31
	F	114.6-152.5	<121.2	5	2.50
2 Mid shaft circumference (C2)	M	29.7-51.8	>43.3	66	25.98
	F	26.5-43.3	<29.7	0	0
3 Mid shaft maximum diameter (C3)	M	7.77-16.21	>13.17	48	18.90
	F	6.48-13.17	<7.77	1	0.50
4 Mid shaft minimum diameter (C4)	M	6.89-15.64	>13.31	26	10.24
	F	6.02-13.31	<6.89	1	0.50
5 Maximum breadth of acromial end (C5)	M	13.73-32.91	>27.07	26	10.24
	F	11.50-27.07	<13.73	3	1.50
6 Maximum breadth of sternal end (C6)	M	15.75-33.02	>30.35	6	2.36
	F	14.93-30.35	<15.75	0	0
7 Maximum length of fossa (FL)	M	10.50-36.41	>35.19	1	0.39
	F	9.16-35.19	<10.50	0	0
8 Maximum width of fossa (FW)	M	3.55-17.22	>14.12	9	3.54
	F	4.32-14.12	<3.55	0	0
9 Maximum length of medial articular surface (ML)	M	15.53-32.89	>30.00	7	2.76
	F	15.53-30.00	<15.53	0	0
10 Maximum width of medial articular surface (MW)	M	14.63-33.95	>29.33	17	6.69
	F	14.71-29.33	<14.63	0	0
11 Maximum length of acromial surface (AL)	M	6.65-30.88	>24.12	16	6.30
	F	6.84-24.12	<6.65	0	0
12 Maximum width of acromial surface (AW)	M	4.33-19.77	>15.90	19	7.48
	F	4.46-15.90	<4.33	0	0

The percentage of bone identified by IP of C1 in Isan Thais was more than 80 %, suggesting for excellent accuracy to be used for sex determination. We concludes that the length of Northeastern - Thai male C1 must be >139.9 mm while of females must be <140.6 mm. In contrast to Southern Nigerians (Udoaka & Nwokediuko, 2013), C1’s IP was very low in both sexes (male 38.6 % and females 0% accuracy) as compared with Isan Thais. Similar to others, (Udoaka & Nwokediuko, 2013; Patel *et al.*; Padeyappanavr *et al.*), this study used the DP analysis to increase the accuracy in sex determination. Although the DP of C1 of Thais was highest as compared to Southern Nigerians, Gujarat zone Indians, Karnataka Indians (Patel *et al.*; Padeyappanavr *et al.*; Udoaka & Nwokediuko, 2013), its accuracy is still lesser than 50%. In this study, the C2 was also used as a parameter to determine the sexes. In previous investigations (Table V), the means of C2 of males in many populations were longer than that of females which was similar to Isan Thais. This difference may be affected from estrogen hormone like C1 growths as described above.

Compared to others, the accuracy of C2*IP to determine males was 83.46 % (>37.7 mm) and female was 75 % (<37 mm). However, percentage of DP of C2 in Isan Thais was lowest compared to that of Gujarat zone Indians (Patel *et al.*) and Karnataka Indians (Padeyappanavr *et al.*). It seemed that the DP of C2 is not good parameter to be used in sex determination for Isan Thais. Compared to Greeks (Papaioannou *et al.*), the C4 and C5 in Isan Thais was higher. In contrast, the C3 and C6 of Greek were higher than that of this study. In contrast to Southern Nigerians (Udoaka & Nwokediuko, 2013), the percentages of C5 and C6’s IP were very low in both sexes. The percentage of DP of C5 in this study were higher than that DP investigated in Southern Nigerians (Udoaka & Nwokediuko). However, the accuracy for using C5 and C6 is still not good enough in sex determinations. For the first investigation, the clavicular parameters including FL, FW, ML, MW, AL, and AW were systemically analyzed for sex determination. Unfortunately, although the percentages of all parameters in Isan -Thais were more than 60 % accuracy, their DPs were lesser than 10 %. These results suggest that some lengths of Isan clavicle can be used as parameters for sex determination by using IP instead of DP values. .

Table IV. Comparisons of the mean length of clavicle (C1) in both sexes of Isan Thais to other populations

Races	N	Mean (mm)		Reference
		Males	Females	
English	183	154	139	Parsons, 1961
French	170	155	138.70	Olivier, 1951
USA Negroes	100	157.32	140.80	Singh & Singh, 1972
India (Amritsar zone)	236	147.59	129.80	Jit & Singht, 1966
North America	724	159	141	McCormick <i>et al.</i> , 1991
Northwest Indians	1000	150.27	135.37	Kaur <i>et al.</i> , 2002
India (North Interior Karnataka)	333	142.7	127.8	Padeyappanavr <i>et al.</i> , 2009
India (Gujarat zone)	216	142.08	126.39	Patel <i>et al.</i> , 2009
Iran	120	147.21	130.38	Akhlaghi <i>et al.</i> , 2012
Greek	147	153.9	137.0	Papaioannou <i>et al.</i> , 2012
Northeastern (Isan) – Thais	454	150.2	133.5	Kaewma <i>et al.</i> (present study)

Table V. Comparisons of the mean circumference of clavicle (C2) in both sexes of Northeastern (Isan)–Thais to other populations.

Races	N	Mean (mm)		References
		Males	Females	
Guatemala	97	34.5	29.34	Frutos, 2002
India (North Interior Kamataka)	333	38.15	32.11	Padeyappanavr <i>et al.</i> , 2009
India (Gujarat zone)	216	36.77	30.16	Patel <i>et al.</i> , 2009
Iran	120	44.07	38.38	Akhlaghi <i>et al.</i> , 2012
Greek	147	38.22	32.27	Papaioannou <i>et al.</i> , 2012
Northeastern (Isan)– Thais	454	40.7	34.9	Kaewma <i>et al.</i> , (present study)

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RESUMEN: Las clavículas secas han sido bien documentadas en muchas razas para determinar el sexo y la edad individuales. Tales investigaciones morfométricas en Isan (Noreste de Tailandia) nunca han sido reportadas. Por lo tanto, este estudio tuvo como objetivo estimar el sexo de clavículas secas de Isais-Thais utilizando un análisis morfométrico. Se midieron 454 clavículas secas (254 varones y 200 hembras), con una edad media de $60,69 \pm 14,36$ años, y fueron analizadas para los puntos de identificación (IP) y de demarcación (DP). Los resultados mostraron que los porcentajes de hueso identificados por IP en relación a la longitud clavicular máxima en hombres y mujeres fueron 90,55 % ($> 139,9$ mm) y 89 % ($< 140,6$ mm), respectivamente. Además, tales porcentajes de circunferencia media del eje, medido en las clavículas de los hombres, fue 83,46 % ($> 37,7$ mm) y en las de mujeres fue 75 % ($< 37,0$ mm). Sin embargo, los porcentajes de la DP en todos los parámetros fueron menores al 50 %. Los valores más altos de DP de longitud máxima de las clavículas de los hombres fue 43,31 % ($> 152,5$). En conclusión, la longitud máxima y la circunferencia media del eje investigados a partir de este estudio se pueden utilizar como datos básicos en Isan - Thais para aplicar como guía en las ciencias forenses para la determinación del sexo a partir de restos de clavícula secas.

PALABRAS CLAVE: Clavícula; Morfometría; Isan Thai; Determinación del sexo.

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