

Sex Estimation Based on the Cuboid Bone in a Modern Thai Population

Estimación del Sexo Basada en el Hueso Cuboides en una Población Tailandesa Moderna

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SUMMARY: The determination of sex is a crucial element of forensic anthropology, particularly when attempting to distinguish unidentified skeletal remains. The objective of this research was to assess the cuboid bone's capability for sex determination in a contemporary Thai population. A total of 600 Thai cuboid bones (300 male, 300 female) were used in this study, with the right and left cuboid bones used to obtain ten measurements. To establish sex estimation equations for each measurement, multiple logistic regression analysis was applied. The cuboid height (CubHt) and cuboid width (CubBr) measures showed the greatest classification accuracy, surpassing 80 %. To confirm the models, this study used a test sample of 60 cuboids (30 male, 30 female), with overall precision found to be between 58.3 % and 81.6 %. Especially, when more sexually dimorphic bones are unobtainable, the findings of this study indicate that the cuboid bone could be used as an additional tool for the determination of sex.

KEY WORDS: Sex estimation; Cuboid bone; Tarsals; Forensic anthropology; Thailand.

INTRODUCTION

Bones can still exist after bodies decompose completely. To jointly create a biological profile, In addition to providing specific information like age, ancestry, stature, pathological state, or traumatic injuries, studying bones helps us comprehend human variety and view the past (Corrieri & Márquez-Grant, 2015; Spradley, 2016). For unidentified skeletal remains found in various situations, such as fires, natural disasters, and anonymous burials, the biological profile is indispensable (Corrieri & Márquez-Grant, 2015). To focus the search for missing people who could fit the characteristics of a deceased person, it is essential to accurately estimate sex. Measurements of long bones and the morphology of the skull or pelvis are typically used for determining sex (Tallman & Blanton, 2020).

Numerous bone morphometric analyses have been used for determination of sex in Thailand, such as for the pelvis (Wangdee *et al.*, 2014), sacrum (Naksuwan *et al.*, 2021), calcaneus (Scott *et al.*, 2017), talus (Mahakkanukrauh *et al.*, 2014), radius (Jongmuenwai *et al.*, 2021), maxillary suture (Sinthubua *et al.*, 2017), skull (Mahakkanukrauh *et al.*, 2015),

os coxa (Mahakkanukrauh *et al.*, 2017), navicular (Viwatpinyo, 2014), scapula (Peckmann *et al.*, 2017), upper limb (Duangto & Mahakkanukrauh, 2020), femur (Monum *et al.*, 2017), and carpal bones (Barnes *et al.*, 2019). Despite a large amount of research on the topic, there are situations in which severely damaged or absent bones make sex estimation difficult. The study claims that tarsal bones, which have been maintained effectively in forensic settings, have significant promise for sex determination. Tarsal structures tend to be dense and compact. Compared to other bones, their thick cortices also help to better resist taphonomic processes. Second only to talus height and length among tarsal bones, cuboid breadth displays evident sexual dimorphism (Harris & Case, 2012). Besides, the joints in the lateral column of the foot show more flexibility compared to those in the medial column while in a walking stance (Zhu *et al.*, 2020). Thus, between males and females, the cuboid in the lateral column may possess more morphological variances. Consequently, the purposes of this study are to identify the sexual dimorphism in the cuboids of skeletons from a contemporary Thai population and to create equations for sex estimation in a contemporary forensic setting.

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MATERIAL AND METHOD

The Research Ethics Committee of the Faculty of Medicine, Chiang Mai University authorized this study under research ID ANA-2564-08724. The Osteology Research and Training Center, Faculty of Medicine, Chiang Mai University, Thailand provided 600 Thai cuboid bones (300 male, 300 female) for this study. A left cuboid, a right cuboid, or both were provided by each individual. To rationalize any conceivable bilateral asymmetry, the left and right cuboids were examined independently. Cuboids were excluded if they were fractured, had pathologies, or ambiguous anatomical landmarks. For all cuboids, sex and age at death were documented. Measurements were taken from 540 cuboids (270 male, 270 female) to develop the equations for sex estimation. Among samples, the average age at death was 63 years (an average of 64 years for males

and 62 years for females). Table I details the age distribution of the samples employed in this research.

To assess the precision of equations for sex measurements, an additional 60 cuboids (30 male, 30 female) were used. Among samples, the average age at death was 71 years (69 years for males and 72.5 years for females).

Measurement. Utilizing both right and left cuboid bones, ten measurements were taken. Obtained via a digital Vernier caliper, seven measurements (Measurements 1-7) were constructed for this study. A mini-osteometric board was used to take three measurements (Measurements 8-10) according to the method described by Harris & Case (2012). Figure 1 illustrates the cuboid parameters, while Table II describes each cuboid bone measurement.

Table I. Age distribution of the sample concerning to sex.

Sample		Male (n=270)		Female (n=270)		Total (n=540)	
Age range (years)	Frequency	Age (years)	Frequency	Age (years)	Frequency	Age (yr)	
10-19	0	0	6	16.33±2.06	6	16.33±2.06	
20-29	4	25.50±4.04	6	25.33±2.73	10	25.40±3.09	
30-39	14	36.86±1.40	10	35.50±2.75	24	36.29±2.13	
40-49	33	45.73±2.58	30	46.10±2.92	63	45.90±2.74	
50-59	62	54.71±2.71	48	54.98±3.03	110	54.82±2.85	
60-69	49	64.51±3.07	81	64.52±2.85	130	64.52±2.93	
70-79	58	74.93±2.64	51	74.92±2.95	109	74.93±2.78	
80-89	41	83.98±3.10	34	83.82±3.22	75	83.91±3.14	
90-99	9	92.33±1.22	4	93.50±0.57	13	92.69±1.18	

Table II. Description of each cuboid bone measurement.

No	Parameter	Ab breviation	Description
1	Metatarsal facet length	MetLg	The maximal dimension regarding the transverse plane of the metatarsal facet on the cuboid bone
2	Metatarsal facet breadth	MetBr	The minimal dimension regarding the sagittal plane of the metatarsal facet on the cuboid bone
3	Calcaneal facet length	CalLg	The maximal dimension regarding the transverse plane of the calcaneal facet on the cuboid bone
4	Calcaneal facet breadth	CalBr	The minimal dimension regarding the sagittal plane of the calcaneal facet on the cuboid bone
5	Medial dorsal length	MedDorLg	Linear distances between the most medial dorsal point of the metatarsal facet on the cuboid bone and the most medial dorsal point of the calcaneal facet on the cuboid bone
6	Medial plantar length	MedPlaLg	Linear distances between the most medial plantar point of the metatarsal facet on the cuboid bone and the most medial plantar point of the calcaneal facet on the cuboid bone
7	Lateral length	LatLg	Linear distances between the metatarsal facet of the cuboid bone and the calcaneal facet of the cuboid bone measured on the lateral side
8	Cuboid Length	CubLg	Place the distal end of the cuboid against the vertical end board and press the movable upright against the most proximal point of the cuboid beak.
9	Cuboid Breadth	CubBr	Place the medial side of the cuboid against the vertical end board and press the movable upright against the most lateral point on the lateral side of the cuboid.
10	Cuboid Height	CubHt	Place the superior surface of the cuboid against the vertical end board and press the movable upright against the inferior surface.

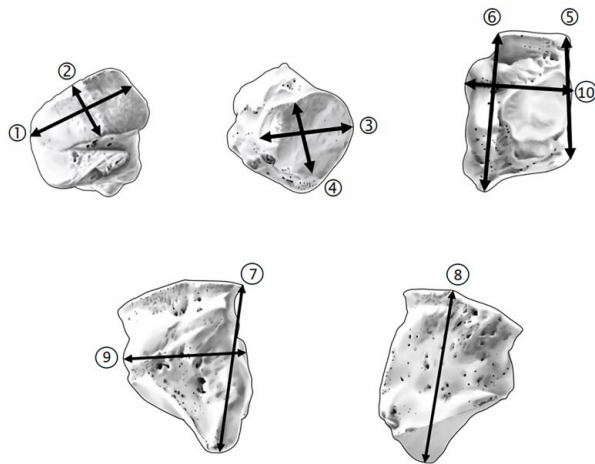


Fig. 1. Ten measurements of cuboid bone. 1: Metatarsal facet length (MetLg), 2: Metatarsal facet breadth (MetBr), 3: Calcaneal facet length (CalLg), 4: Calcaneal facet breadth (CalBr), 5: Medial dorsal length (MedDorLg), 6: Medial plantar length (MedPlaLg), 7: Lateral length (LatLg), 8: Cuboid Length (CubLg), 9: Cuboid Breadth (CubBr), 10: Cuboid Height (CubHt). Description of ten measurements of the cuboid bone are written in Table II.

To create the equation, authors KT, NM, LS, and WN measured five hundred and forty cuboids. LS repeatedly measured 60 cuboids that were randomly chosen three times to assess intra-observer reliability. LS, KT, and NM repeatedly measured 60 cuboids chosen randomly to estimate inter-observer reliability.

Statistical analysis. A random selection of 60 samples is used to do repeated measurements to assess intra-observer error. One week after the initial observation, the second evaluation is conducted. By choosing 60 samples at random, repeated measurements are made for the inter-observer error test. The technical error of measure (TEM), relative TEM (rTEM), and coefficient of reliability (R) (Harris & Case, 2012) are used to assess the relationship between inter-observer and intra-observer errors.

For investigating sex, descriptive statistics, including mean, standard deviation, and range of all values were used. For the accuracy prediction % used to the sex discrimination formula, multiple logistic regression analysis was conducted on each parameter for both the right and left sides, and a sex estimate equation of contemporary Thai people was developed. A significant value was determined at $p < 0.05$. SPSS version 25.0 was utilized to assess all data.

RESULTS

Table III illustrates descriptive statistics for the ten measurements of the cuboid bone, while Table IV indicates the results of intra- and inter-observer errors. These results revealed that errors were lower for CubLg, CubBr, and CubHt, all of which were acquired with a mini-osteometric board than for MetLg, MetBr, CalLg, CalBr, MedDorLg, MedPlaLg, LatLg that were obtained with sliding calipers.

Table III. Descriptive statistics for ten cuboid measurements by sexing (mm).

Measurement	N	Male				Female				
		Min.	Max.	Mean	SD	N	Min	Max	Mean	SD
MetLg	270	19.97	28.96	24.1161	1.79031	270	16.95	26.55	21.8879	1.58653
MetBr	270	10.36	20.83	14.6986	1.37785	270	9.50	16.02	13.0557	1.23500
CalLg	270	21.06	31.39	25.8873	1.64658	270	13.97	28.31	23.1754	1.81714
CalBr	270	11.88	21.00	16.9494	1.49563	270	10.91	19.48	14.9570	1.38481
MedDorLg	270	24.47	34.16	29.7054	1.95325	270	19.00	33.56	26.7471	1.94416
MedPlaLg	270	27.94	42.23	35.0713	2.48479	270	22.38	38.84	31.8693	2.27213
LatLg	270	31.29	41.21	35.7191	2.06269	270	25.45	37.88	32.4924	2.05966
CubLg	270	30.97	44.40	36.9766	2.22795	270	24.36	38.89	33.1973	2.27173
CubBr	270	22.85	32.48	27.5538	1.68097	270	20.99	29.12	24.7566	1.48347
CubHt	270	21.07	29.71	24.9749	1.56439	270	19.18	28.92	22.5948	1.50132

Table IV. Results of intra- and inter-observer error analyses.

Measure	Intraobserver			Interobserver		
	Median error (mm)	Median % error	TEM (mm)	Median error (mm)	Median % error	TEM (mm)
MedLg	0.21	0.87	0.30	0.26	1.14	0.34
MedBr	0.26	1.83	0.52	0.39	2.55	0.66
CalLg	0.37	1.30	0.54	0.50	2.15	0.60
CalBr	0.32	1.98	0.56	0.41	2.60	0.59
MedDorLg	0.18	0.57	0.52	0.41	1.41	0.55
MedPlaLg	0.23	0.60	0.57	0.75	2.15	0.89
LatLg	0.23	0.56	0.31	0.40	1.19	0.59
CubLg	0.02	0.05	0.04	0.02	0.06	0.04
CubBr	0.05	0.20	0.18	0.04	0.13	0.17
CubHt	0.04	0.15	0.14	0.04	0.17	0.18

Table V. Logistic regression equations.

Measure	N	Logistic equation	Logistic regression result (N = 540)			Test sample result (N = 60)		
			Female	Male	Overall	Female	Male	Overall
			%	%	%	%	%	%
MetLg	540	0.791*MetLg – 18.139	77.4	72.6	75	90	66.6	78.3
MetBr	540	0.992*MetBr – 13.762	73.7	73.3	73.5	76.6	63.3	70
CalLg	540	0.906*CalLg – 22.254	80.4	78.5	79.4	86.6	76.6	81.6
CalBr	540	1.024*CalBr – 16.317	77	75.6	76.3	83.3	56.6	70
MedDorLg	540	0.812*MedDorLg – 22.892	81.1	78.1	79.6	63.3	76.6	70
MedPlaLg	540	0.580*MedPlaLg – 19.409	77	74.4	75.7	66.6	50	58.3
LatLg	540	0.794*LatLg – 27.062	77.4	78.9	78.1	90	60	75
CubLg	540	0.749*CubLg – 26.310	77.8	80	78.9	83.3	73.3	78.3
CubBr	540	1.174*CubBr – 30.647	83	83	83	86.6	73.3	80
CubHt	540	1.086*CubHt – 25.743	81.9	78.5	80.2	80	76.6	78.3

Assessed by either the median difference or TEM, variations in the intraobserver measurement were less than 0.2 mm for all dimensions, with the average percent divergence being less than 2 %. Consistently, intraobserver errors were lower than interobserver errors. Still, the average percentage variance for interobserver error values for measurements made with the mini-osteometric board was less than 0.18 %. Except for MetBr, CalLg, CalBr, and MedPlaLg, all of the caliper measures had average percent variations of less than 1.5 %. All had values that exceeded 2 %. CubBr and CubHt had the greatest overall anticipated precision values, both of which produced sex determinations exceeding 80 % accuracy, as shown in Table V, with MedDorLg showing the next highest precision at 79.6 %.

DISCUSSION

Harris & Case (2012) studied a modern European-American sample and included the measurement of the cuboid. Males were found to have considerably bigger mean length, width, and height dimensions for each tarsal than females, according to their findings. Out of the three cuboid measures, CubBr was shown to have the greatest sexual dimorphism (86.4 %). Cuboid bones from four distinct human subgroups, including Victorian British, Romano-British, Southern Chinese from Hong Kong, and Zulu tribespeople from the Republic of South Africa, were used in different research (Kidd & Oxnard, 2002). Medial plantar length (variable 6), short metatarsal facet dimension (variable 2), and lateral length (variable 7) make up the most notable dimensions of the cuboid. Medial plantar length (cuboid variable 6) is the primary cuboid measurement that promotes detection in the first canonical variate. Only the British groups are afforded distinction by the second canonical variate. The long calcaneal dimension (cuboid variable 3) is the measurement that reinforces distinction. All measurements in research on Portuguese samples (Navega *et al.*, 2015) were higher among males

than females. For the determination of sex, CubHt was revealed to be significant.

CubBrd had the greatest overall projected accuracy measurement in this analysis, which is consistent with research by Harris & Case (2012). The current study indicated that both CubBrd and CubHt were applicable for the determination of sex, while the study by David showed that only CubHt was significant for discrimination of sex. Three cuboid measurements, including CubLg, CubBrd, and CubHt, were employed in the studies by both Harris and David. All three metrics have the same definitions as in this study, meaning sexual dimorphism was influenced by many ethnic groupings. Kidd & Oxnard (2002) employed nine cuboid metrics in their research. Measurement definitions differed slightly compared to this study. Still, sexual discrimination was presented by the long calcaneal dimension (cuboid variable 3) in this research, or CalLg in this research.

Overall precision rates from 58.3 % to 81.6 % are shown in this study. The detection of sex in the Thai population can be done using various morphometric studies. For example, the pelvis (Wangdee *et al.*, 2014) exhibited sex determination precision between 72.5 % and 98.7 %. Multivariate analyses of the calcaneus (Scott *et al.*, 2017) revealed accuracy ranging between 81.5 % and 87.7 % for males and between 84.0 % and 87.7 % for females, while univariate analyses showed accuracy ranging between 71.6 % and 84.0 % for males and between 67.9 % and 85.2 % for females. The present research demonstrated a wide range of accuracy when compared to prior studies. Compared to another study, the lowest accuracy % of the test sample is lower. Therefore, in comparison to other bones, the cuboid had a decreased capacity for identification of sex. It is suggested to employ more than one measurement to generate equations, which boosts the precision of the discriminant functions in this analysis.

CONCLUSIONS

When other bones are unusable or inaccessible, the cuboid bone has been shown to be beneficial for determining the sex of unknown skeletal remains among the contemporary Thai population. As shown in Table V, ten equations were created by using ten measurements of the cuboid bone, which could be utilized to reveal the sex of unknown remains. The greatest overall predicted accuracy for the determination of sex was shown by the CubBrd and CubHt measurements, with precise allocation rates of 83 % and 80.2 %, respectively. When individual metrics were tested on a sample of 60 skeletons, most of them scored either as good as or worse than what logistic regression algorithms projected. In comparison to prior research, overall precision rates were between 58.3 % and 81.6 %, which is a significant range with a reduced minimum precision. Nonetheless, the CubBrd rates had up to 80 % overall precision.

In conclusion, it is recommended to initially use CubBrd measurements when single dimensions are being analyzed and include the equations gained from this study in forensic applications in Thailand. It is also suggested that multiple measurements be linked to obtain the equations, which enhances the precision of discriminant functions.

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RESUMEN: La determinación del sexo es un elemento crucial de la antropología forense, en particular al intentar distinguir restos óseos no identificados. El objetivo de esta investigación fue evaluar la capacidad del hueso cuboides para la determinación del sexo en una población tailandesa contemporánea. En este estudio se utilizaron 600 huesos cuboides tailandeses (300 masculinos y 300 femeninos), utilizando los huesos cuboides derecho e izquierdo para obtener diez mediciones. Para establecer ecuaciones de estimación del sexo para cada medición, se aplicó un análisis de regresión logística múltiple. Las medidas de altura cuboidea (CubHt) y anchura cuboidea (CubBr) mostraron la mayor precisión de clasificación, superando el 80 %. Para confirmar los modelos, este estudio utilizó una muestra de 60 cuboides (30 de hombres y 30 de mujeres), con

una precisión general de entre el 58,3 % y el 81,6 %. En particular, cuando no es posible obtener huesos con mayor dimorfismo sexual, los hallazgos de este estudio indican que el hueso cuboide podría utilizarse como herramienta adicional para la determinación del sexo.

PALABRAS CLAVE: Estimación del sexo; Hueso cuboide; Huess tarsianos; Antropología forense, Tailandia.

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