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Sex Determination by Patella Measurements in Thais

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Abstract

Sex determination is an important step for personal identification of an individual from skeletal remains. Various bones have been studied for sex determination using both morphological and metrical methods, as well as the discriminant function analysis. However, there is no proper discriminant function equation of the patella for the Thai population. Therefore, the aim of this study was to derive a discriminant function equation for sex determination by measuring the patella of Northern Thais collected in the Department of Anatomy, Faculty of Medicine, Chiang Mai University, Thailand. A total of 191 pairs of normal patellae (137 males and 54 females) aged between 15 and 96 years, were examined using six measurements, including the volumetric method. Univariate, stepwise, and direct discriminant analyses were performed. One function from univariate measurements (Left LAFB = left max width of lateral articular facet) yielded the highest value of correct sex determination with an average accuracy of 85.3% (male 82.5%, female 92.6%), and the highest rate of classification from direct discriminant analysis with an average accuracy of 90.5% (male 89.0%, female 94.4%) including all 6 parameters of the left patella. Our results demonstrated that, the patella is useful for forensic purposes as it yielded a high accuracy for sex determination.

Keywords: Forensic, Patella, Sex determination, Discriminant function analysis, Thai population

Introduction

The identification of human remains is one of the most essential aspects of forensic medicine (Kahana, 1997). Beyond the humanitarian considerations of such a task, identification is essential for the completion and certification of official documents such as death certificates, probates of will and disbursements of benefits and insurance. Scientific identification of human remains might be accomplished by fingerprint, dental, anthropological, genetic or radiological examinations. Consequently, the best strategy in forensic laboratories is to use morphology first, then molecular systems are added if necessary or confirmation is needed.

Sex determination is a major goal of the forensic anthropologist for the process of individuation from unidentified skeletal remains (Introna, 1998).

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The estimation of sex is more reliable if the complete skeleton is available but in forensic cases human skeletal remains are often incomplete or damaged, depending on their taphonomic history (Haglund, 1997), as a result of animal activity, preservation circumstances or recovery proficiency.

The kneecap (patella) is a solid element of the human skeleton with no discernible morphological features for determining sex and no significant differences attributed to race. However, as a sesamoid bone that forms within the tendon of the quadriceps muscle, it is very resistant to postmortem changes and so available for personal identification purposes.

In previous studies, the equations are specific for each studied regional populations then it should be derived from a local region. Introna and co-workers (1998) studied on 80 patellae of a known contemporary South Italian population to discriminate function analysis and gained the highest classification rate of 83.3%. Bidmos and co-workers (2005) conducted the same methods in South Africa by using 120 patellae of South African whites. Dayal and Bidmos (2005) studied in South African Blacks by using 120 patellae and gained the highest rate of classification of 85%. Kemkes-Grottenthaler (2005) also used the same method on 82 samples and gained 85% average accuracy (when sample size was not taken into consideration). Mahfouz and his co-workers (2007) used nonlinear classification methods on 228 samples and gained 90.9% overall accuracy. In addition, Akhlaghi and his co-workers (2010) using 113 patellae from the fresh cadavers of Iranian population found the highest average accuracy of 92.9%.

Many researches on sex determination using skeletal remains have been studied so far in Thailand such as sternum (Mahakkanukrauh, 2001), vertebral column (Sinthubau and Mahakkanukrauh, 2001), radius (Suwanlikhid and Mahakkanukrauh, 2004), calcaneus (Wanpradub et al., 2011) and Mastoid process (Sujarittham et al., 2011)

The aim of this study was to determine sex using multivariate analysis on patella measurements from a skeletal collection of Northern Thai population from Chiang Mai University whose sex, age and time of death were known. This leads to the possible that this method is useful for future sex estimation in Thailand.

Methodology

Six metrical characteristics were measured by sliding vernier caliper, from a total of 191 pairs of normal patellae (137 males and 54 females) of Northern Thai population, aged between 15 and 96 years. These specimens were obtained from the Department of Anatomy, Chiang Mai University. Both left and right sides of each individual patellae were used. The bones present pathological conditions, such as fracture with or without malunion, pin and plates, bad erosion or loss of bone density, were excluded. The particular measurements have been modified from KnuXmann (1988) as follows (Fig.1):

1.1 Maximum height of articulating facet (HAF): maximum distance between the most superior and the most inferior points on the articular facet on the posterior surface.

1.2 Maximum width of medial articulating facet (MAFB): linear distance between the medial border of the patella and the median ridge of the articular facet.

1.3 Maximum width of lateral articulating facet (LAFB): linear distance between the lateral border of the patella and the median ridge of the articular facet

1.4 Maximum breadth (MAXB): maximum linear distance between the medial and lateral borders.

1.5 Maximum height (MAXH): maximum linear distance between the tip of the apex and the base.

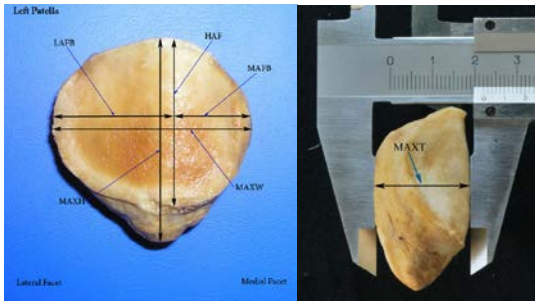

Fig. 1 Six metrical characteristics

1.6 Maximum thickness (MAXT): maximum distance between the anterior and posterior surfaces.

In addition, a water displacement technique was used as volumetric method (Najjar and Williams, 1978).

Each sample was submerged into a container of water and the displacement method was used to calculate the volume of the bone (Fig.2).

SPSS Version 11.5 was used to analyze all the data.

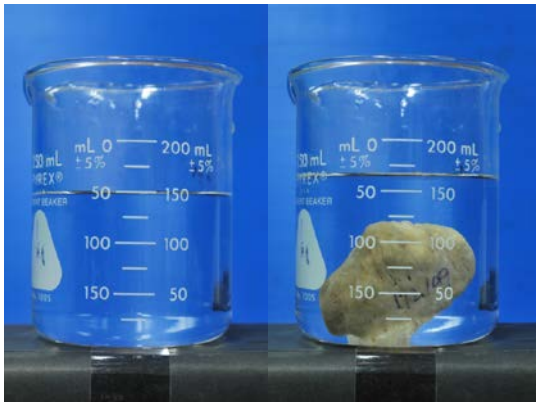

Fig. 2 Volumetric method

Results

Descriptive statistics of all variables were presented for both sexes and both sides of patella. The results of all 7 parameters in the present study showed that the average size of left and right male patella bones were larger than those of the female, which was statistically significant difference at *p*-value < 0.05 (Table 1). From univariate, all 7 parameters can be used to determine sex. The highest average accuracies were LAFB (L) and MAXH (L) with 85.3% and 84.8%, respectively.

Stepwise analysis was performed from all 7 parameters, 3 variables (Left MAFB, LAFB, and MAXH) were selected (function 1,Table 2). A discriminant function equation can be formulated from these variables using the Classification Function Coefficients and constant (Table 2). The percentage average accuracy in correct classification using this equation is 88.5% (86.9% male, 92.6% female)

Direct discriminant function analyses

A combination of all variables (left patella) showed the highest average accuracy of 90.5% (Function 4, Table 2). The other functions which include a combination either, one function obtained from combination of 3 variables (Right LAFB, MAXB and MAXH) with percentage average accuracy of 86.9% higher than those 3 variables generated from stepwise analysis (Right MAFB, LAFB and MAXH) from right side, which obtained only 85.9% average accuracy. Last function was combination of 6 geodesic measurements with volumetric measurement, with average accuracy of 90.5% (89.7% males, 92.6% females).

Discussion

There are several things had to be considered if patella bone was used to determine sex:

First, the side of the bone (right or left): Set the flatter side (articular surface) down on the table with the point (Apex) away from the investigator. The side it falls to is usually to the outside.

Compare each variable by univariate analysis, the more variables the greater value of corrected classification

from left patella (side). They were HAF, MAFB, LAFB and MAXH.

Second, for stepwise analysis, the left side of patella gained a greater value than the right side from the same variables selected which were MAFB, LAFB and MAXH.

Third, from direct discriminant analysis, the equation derived which had the most accuracy was from the combination of 6 morphometric measurements (HAF, MAFB, LAFB, MAXB, MAXH and MAXT)

Table 1. Descriptive statistics of patella measurements of Northern Thais with % average accuracy of each individual variable function analysis.

	Variable	Male (N = 137)		Female (N = 54)		*p-value	% Average accuracy
		Mean	SD	Mean	SD		
1	HAF (R)	3.06	.24	2.82	.19	0.000	69.1
2	MAFB (R)	2.06	.19	1.82	.17	0.000	69.6
3	LAFB (R)	2.66	.16	2.36	.15	0.000	80.1
4	MAXB (R)	4.46	.28	3.96	.26	0.000	82.7
5	MAXH (R)	4.21	.27	3.75	.22	0.000	82.7
6	MAXT (R)	2.09	.16	1.86	.13	0.000	77.0
7	VOLUME (R)	15.29	2.81	11.01	1.83	0.000	80.6
8	HAF (L)	3.08	.24	2.82	.16	0.000	73.3
9	MAFB (L)	2.06	.18	1.82	.19	0.000	72.8
10	LAFB (L)	2.67	.17	2.34	.14	0.000	85.3
11	MAXB (L)	4.44	.29	3.95	.26	0.000	81.2
12	MAXH (L)	4.25	.27	3.75	.21	0.000	84.8
13	MAXT (L)	2.09	.17	1.91	.30	0.000	74.7
14	VOLUME (L)	15.38	2.88	10.79	1.95	0.000	78.5

**All Significant at $p < 0.05$*

Compared to combination of morphometrical methods, when volumetric variable was added to direct function analysis, lower classification rate was obtained.

Comparing individual variables (univariate) and direct DA to previous study

The best variable to determine sex was the maximum thickness with average accuracy of 78.75% (Introna et al., 1998), while the highest individual variable yielded 85.3% LAFB (L) in the present study. With multivariate discriminant analysis, the best function of their study was a combination of maximum of thickness and width with 83.8% accuracy. While the best function of the present study was a combination of 6 morphometric measurements, excluding volumetric method, with 90.5% accuracy of sex determination.

The maximum height was the highest variable with 80.8% accuracy. Then the combination of height of facies articularis interior and height of facies articularis exterior gained 100% of accuracy in sex determination (Kemkes-Grottenthaler, 2005)

Then compared to Bidmos et al. (2005) study, the variable that gained the highest average accuracy rate of sex determination was the maximum height with 85%. A combination of all measurements was the best function for sex determination with average accuracy of 85%.

Compared with the study of Dayal and Bidmos (2005), the maximum width (80%) was the highest individual variable analysis, with a combination of 3 variables (MAXB, MAXH and MAXT) with 85% of classification rate. Mahfouz et al. (2007) used computerized diagnosis then analyzes

the classification problem in a nonlinear approach using neural networks and gained classification rate of 93.5% which could not be compared with the results of the present study.

Finally, Akhlaghi et al. (2010) studied only 3 measurements: max height, max width and thickness with the average accuracy of 92.9% for sex classification.

Table 2. Stepwise and direct discriminant analyses

	Variables	Classification Function Coefficients		Corrected classification (%)	Average accuracy (%)
		Male	Female		
Stepwise 1	MAFB (L)	35.415	31.088	88.5%	88.5%
	LAFB (L)	65.470	57.079		
	MAXH (L)	32.992	29.383		
	Constant	-194.795	-150.920		
Stepwise 2	MAFB (R)	27.051	23.681	85.9%	84.8%
	LAFB (R)	65.292	58.146		
	MAXH (R)	35.022	31.145		
	Constant	-189.193	-149.278		
Direct 3	LAFB (R)	55.604	49.542	86.9%	85.9%
	MAXB (R)	13.155	11.651		
	MAXH (R)	36.296	32.209		
	Constant	-180.429	-142.609		
Direct 4	HAF (L)	18.766	20.059	90.5%	88.9%
	MAFB (L)	29.761	23.452		
	LAFB (L)	63.005	52.536		
	MAXB (L)	0.178	1.759		
	MAXH (L)	26.122	21.405		
	MAXT (L)	-.036	1.864		
	Constant	-200.322	-157.216		
Direct 5	HAF (L)	65.189	66.205	90.5%	88.4%
	MAFB (L)	27.312	21.017		
	LAFB (L)	89.199	78.573		
	MAXB (L)	87.538	88.600		
	MAXH (L)	78.567	73.538		
	MAXT (L)	41.730	43.381		
	Volume (L)	-20.499	-20.377		
	Constant	-495.976	-449.362		

***Example discriminant function 1*:** Ym = 35.415 MAFB (L) + 65.470 LAFB (L) + 32.992 MAXH (L) -194.795, Yf = 31.088 MAFB (L) + 57.079 LAFB (L) + 29.383 MAXH (L) -150.920; (where Ym for male, Yf for female) the result with greater value would be allocated to that sex.

The average accuracy of all functions obtained from the present study were 69.1% - 88.9% in Thais which were higher than those in sternum (74.2%, Mahakkanukrauh 2001), vertebral column (70-86.5%, Sinthubau & Mahakkanukrauh, 2001), and mastoid process (66-78%, Sujarittham et al., 2011), but lower than those in radius (86.9-89.4%, Suwanlikhid & Mahakanukrauh, 2004) and calcaneus (90.5.91%, Wanpradub et al., 2011). Therefore, the equation obtained from the present study is useful for sex determination but should be used with caution.

Compared to Juenkajornkiati's study (100 samples, 65 males and 35 females), the range of average accuracy was 77.1-100% which was obtained from single analysis. The means of all variables were higher than those in the present study. This might be due to the maceration technique.

Conclusion

From the present study, it has shown that mean values for males were higher than those for females. The equations derived can be used for sex determination in Thais with the highest average accuracy of 90.5% (89.0% male, 94.4% female).

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