

A Study on the Age Estimation Based on the Adult Acetabulum in Thai Population

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ABSTRACT

Objective: The acetabulum is one of the parts of the os coxa (pelvic bone). It is well preserved in forensic contexts and also a reliable age indicator. The aim of this study was to validate the age estimation from the acetabulum by using the original scoring method of Rissech et al. in a Thai population.

Design: Seven variables on the acetabulum by the scoring method were utilized for age estimation.

Materials and Methods: The present study was carried out on a sample of 200 skeletons (98 males, 102 females) from the Forensic Osteology Research Center (FORC), Faculty of Medicine, Chiang Mai University. The age ranged between 22-90 years for both sexes. Seven variables on the acetabulum were examined.

Results: There were no significant differences between both sexes and sides in age estimation from the acetabulum. Correlation between each variable and the actual age were all significant. The accuracies in Bayes prediction were 66% within 10 years and 71% within 12 years. The inaccuracy of all ages was eight years and tended to underestimate age.

Conclusions: The original scoring method of Rissech et al. was performed fairly well in the Thai sample. The maximum accuracy was 71% in a 12-year interval for age estimation. Our study suggests that in order to apply this method on Thai samples, some variables should be modified or developed for better outcomes.

KEY WORDS

forensic science, forensic anthropology, acetabulum, age estimation, Thailand

INTRODUCTION

The estimation of age from adult human remains is crucial in biological identification. It is one of the more challenging tasks to be developed in forensic anthropology and forensic medicine. When the skeletal remains are only partially recovered, the os coxa is often available. The two parts of the os coxa are the pubic symphysis and the auricular surface which are commonly used for age estimation¹⁻³⁾. Although a study of age estimation using the auricular surface and pubic symphysis in a Thai sample was conducted, the results were inaccurate for age prediction⁴⁾. The auricular surface is preserved longer than the pubis⁵⁾. However, previous studies on age estimation from the auricular surface have found an overestimation of the younger individuals and an underestimation of the older individuals⁶⁻⁸⁾.

The acetabulum is one part of the os coxa. It is frequently preserved due to a robust and durable nature^{9,10)}. Most commonly, the acetabulum was used for sex determination by using metric^{11,12)} and nonmetric analysis¹³⁾. In addition, it can be utilized to estimate stature¹⁴⁾. The acetabulum is also a substantial age prediction. Roug Maillart *et al.*¹⁵⁾ found a significant correlation between the morphological changes of the acetabulum and age. In a study using the Rissech *et al.*¹⁶⁾ scoring method a Portuguese sample was used to describe seven acetabular variables: the acetabular groove, acetabular rim shape, acetabular rim porosity, apex

activity, activity on the outer edge of the acetabular fossa, activity of the acetabular fossa, and porosities of the acetabular fossa. The results showed 89% accuracy in 10-year intervals of the samples. In 2007, the same authors tested their method on four Western European collections. They found that the estimated ages were 83-100% accurate within 10 years¹⁷⁾. Calce and Rogers¹⁸⁾ tested the scoring method developed by Rissech *et al.*¹⁶⁾ in a Canadian sample. They reported an 83% accuracy in 12-year intervals for age estimation.

Previous studies on age estimation from the adult acetabulum by using the original Rissech *et al.*¹⁶⁾ method showed a high accuracy and correlation between the acetabular variables and age. Therefore, the aim of the present study was to test the original scoring method for age estimation by Rissech *et al.*¹⁶⁾ in a modern Thai population. This method can be utilized in forensic anthropology, forensic medicine, and archaeological contexts.

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Table 1. Samples with the absolute difference (|d|) between estimated age and actual age on 5-year age classes.

Age range	d < 1			d < 5			d < 10			d < 12			d > 12			Total				
	0	-	+	0	-	+	0	-	+	0	-	+	-	+						
21-25	0	0	0	0	0	3	3	0	0	3	3	0	0	3	3	0	0	0	3	
26-30	1	0	0	1	1	2	1	4	1	2	1	4	1	2	1	4	0	1	1	5
31-35	0	1	0	1	0	1	1	2	0	1	1	2	0	1	1	2	0	0	0	2
36-40	0	0	0	0	0	2	2	4	0	2	4	6	0	2	4	6	0	1	1	7
41-45	2	2	0	4	2	4	2	8	2	5	2	9	2	5	3	10	1	2	3	13
46-50	0	0	2	2	0	3	6	9	0	4	8	12	0	4	9	13	0	4	4	17
51-55	0	3	2	5	0	4	2	6	0	5	6	11	0	5	8	13	1	4	5	18
56-60	0	0	0	0	0	2	3	5	0	2	7	9	0	2	7	9	4	8	12	21
61-65	0	0	0	0	0	2	6	8	0	4	10	14	0	5	11	16	1	6	7	23
66-70	0	0	1	1	0	1	2	3	0	4	7	11	0	4	8	12	3	0	3	15
71-75	0	0	4	4	0	5	9	14	0	7	12	19	0	7	13	20	5	0	5	25
76-80	0	2	0	2	0	3	0	3	0	6	1	7	0	8	1	9	4	0	4	13
81-85	0	2	2	4	0	9	3	12	0	14	3	17	0	14	3	17	7	0	7	24
86-90	0	0	0	0	0	1	0	1	0	8	0	8	0	8	0	8	6	0	6	14
Total	3	10	11	24	3	39	40	82	3	64	65	132	3	67	72	142	32	26	58	200

Table 2. Bias and inaccuracy.

Age Range	N	Bias	Inaccuracy
21-25	3	2.7	2.7
26-30	5	3.02	6.74
31-35	2	0.35	1.25
36-40	7	4.03	5.46
41-45	13	1.97	6.28
46-50	17	7.03	8.91
51-55	18	6.24	9.13
56-60	21	6.02	11.93
61-65	23	4.42	8.38
66-70	15	-2.24	8.71
71-75	25	-3.76	7.57
76-80	13	-7.86	9.09
81-85	24	-7.64	7.92
86-90	14	-11.38	11.38
All Ages	200	-0.17	8.55

MATERIALS AND METHODS

Preliminary study for testing both acetabulums of an individual

A preliminary sample consisted of 88 individuals of known sex and age at death for 48 males and 40 females from the Forensic Osteology Research Center (FORC), Faculty of Medicine, Chiang Mai University. The acetabulum of both sides of each individual was examined according to seven variables. All data were analyzed using the Wilcoxon test to compare both left and right acetabulum. The results showed no significant differences between the sides ($p > 0.05$). Consequently, the left acetabulum was observed when available, the right side was used when the left side was absent or damaged.

Study for age estimation from the acetabulum

The Thai sample of this study consisted of 200 left os coxae with

fused acetabulum of each adult skeleton (98 males, 102 females) of known sex and age at death from the Forensic Osteology Research Center (FORC), Faculty of Medicine, Chiang Mai University. The age ranged between 22-90 years for both sexes. For males, the mean age and standard deviation were 62.90 years and 16.61, respectively. For females, the mean age and standard deviation were 63.18 years and 15.86, respectively. The damage, fracture, trauma or pathology of the acetabulum were excluded, while non-inflammatory osteoarthritis or diffuse idiopathic skeletal hyperostosis (DISH) were included.

All investigations were blinded regarding the known age of an individual. The acetabulum of each individual was examined with scores from seven variables of the acetabular region proposed by Rissech *et al.*¹⁶: (i) acetabular groove, (ii) acetabular rim shape, (iii) acetabular rim porosity, (iv) apex activity, (v) activity on the outer edge of the acetabular fossa, (vi) activity of acetabular fossa, and (vii) porosities of the acetabular fossa. The description of all seven traits and variable states can be studied in Rissech *et al.*¹⁶ original scoring method.

The study examined the data using descriptive statistics and inferential statistics. Descriptive statistics included mean and standard deviation. The Mann-Whitney *U* test was used to compare both sexes. A Kruskal-Wallis test was conducted on the correlation between each variable and age. Box plots for each variable were examined to display the age range, mean, standard error, and standard deviation. These data were analyzed using the SPSS software package (SPSS for Windows, Version 15, Chicago, IL, USA).

Age estimation was conducted in the IDADE2 program using Bayesian inference, following the original article of Rissech *et al.*¹⁶ IDADE2 analyses a sample of known age of the reference population to calculate the likelihood distributions to estimate ages at death for unknown samples.

Bias was calculated from Σ (estimated age - actual age)/N to determine the result in overestimating or underestimating age. Inaccuracy was calculated from Σ |estimated age - actual age|/N to present the average absolute error of age, without overestimating or underestimating age. These analyses were performed using Microsoft Office Excel.

RESULTS

A Mann-Whitney *U* test was performed on the sexes and each state of the variables. There were no significant differences between the sexes ($p > 0.05$). Additionally, the relationship between the distribution of actual age and sex groups indicated no significant differences by the same statistical test. Hence, the data of males and females were combined. All significances between each variable and chronological age ($p < 0.05$) by using Kruskal-Wallis test. Box plots of seven variables

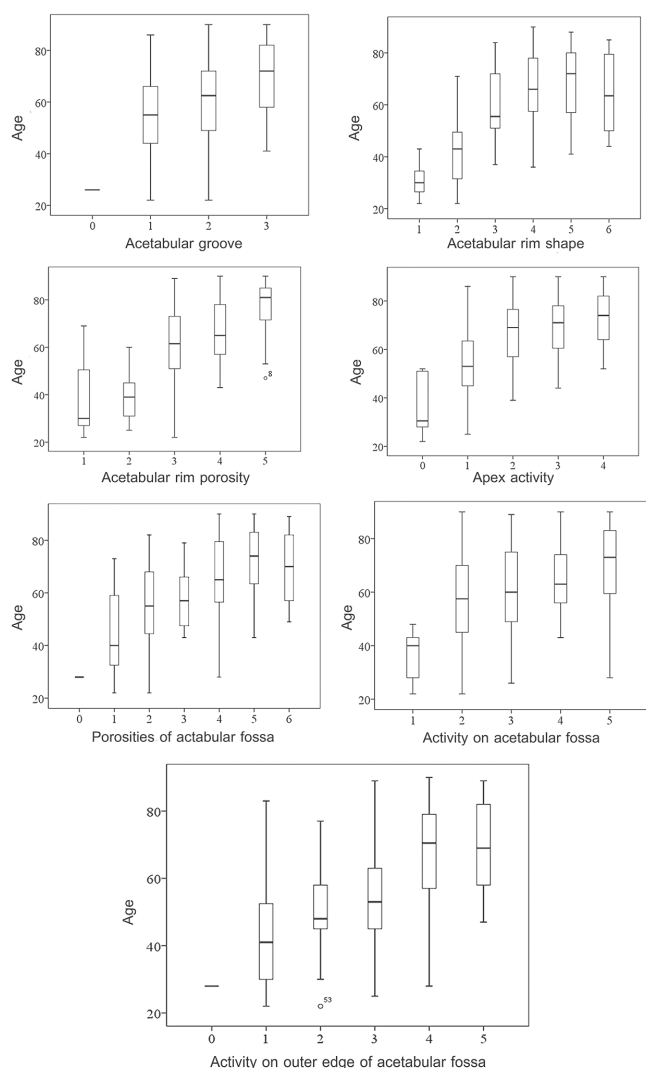


Figure 1. Box plot between the age at death and each state of seven variables.

showed the age ranges of each state of variable including median, first and third quartiles, and maximum and minimum. The majority of box plots showed that the median states of each variable were progressing with age (Figure 1).

The differences between estimated age and actual age in five-year age classes is presented in Table 1 and Figure 2. The results of the accuracy in Bayes prediction within 10 and 12 years were 66% and 71% of the samples, respectively.

Table 2 reports the bias and inaccuracy of estimated age. Ages of individuals under 66 years were overestimated and the lowest bias was the age range of 31-35 years. Individuals 66 years and older were underestimated and the 66-70 year age category was found with the lowest bias. The average of inaccuracy for all ages of individuals was approximately eight years and the bias of overall ages indicated underestimation.

DISCUSSION AND CONCLUSION

The acetabular region is more often available and well preserved in forensic cases due to its concave shape; it is also surrounded by a soft tissue that protects it from destruction^{16,19,20}. The acetabulum is used for the substantial estimation of age. It has morphological characteristics and degenerative changes, including osteoarthritis and diffuse idiopathic skeletal hyperostosis (DISH) that could be associated with the age of an adult skeleton¹⁵⁻¹⁷.

Several studies have developed scoring systems with variables and ages^{3,10,15,16}. Each feature was assigned to a series of numerical scores by

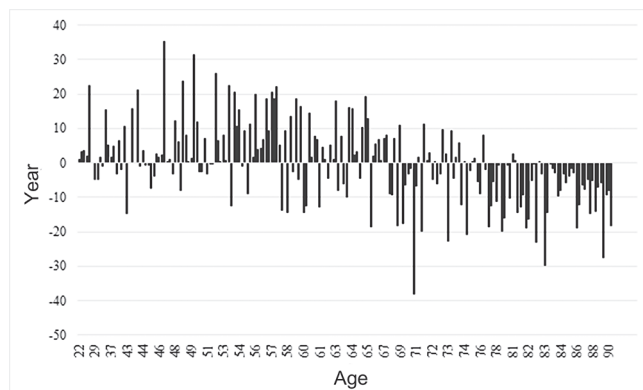


Figure 2. Difference between estimated age and chronological age for each individual.

the degree change of the feature. The scoring method has more objective features and it is easier to categorize.^{21,22} Buckberry and Chamberlain³ studied age estimation from the auricular surface by using the scoring system which was developed from the original Lovejoy *et al.*² method. They mentioned that a quantitative scoring system for each feature is easier to apply and to adjust the often-observed overlapping between different phases. Mulhern and Jones²³ examined auricular surfaces by using the method of Buckberry and Chamberlain³ to compare with the Lovejoy *et al.*² method for age estimation. The results indicated that the scoring method was more accurate than the phase method for older individuals.

The results of this study showed that there were no differences between sides and sexes. Roug Maillart *et al.*²¹ revealed no significant differences for the left and the right sides, as well as for the male and female groups. They suggested examining samples independent of sex or side. However, Mays²³ found that there was a sex difference with age on the Rissech *et al.*¹⁶ methodology. San-Millán *et al.*¹⁰ reported similar results for the differences between sexes in middle-aged groups on the revised method of the Rissech *et al.*¹⁶ method.

The current study found that correlation between the known age at death and each of the seven variables were all significant. The lowest and highest values of variables were the acetabular groove and apex activity, respectively. These results were in accordance with box plots of acetabulum groove which showed no progression with age of state 0, including that each state covers all ages with high overlap, especially states 1 and 2. For box plot of apex activity, there was a progression with age. On the other hand, the original study of Portuguese skeletons by Rissech *et al.*¹⁶ found that the correlations were significant between the actual age and seven variables. The Rissech *et al.* method had higher values of more than 120 of all seven traits from Kruskal-Wallis test. Although the correlations of the present study were significant for all seven variables and ages, the values from Kruskal-Wallis test were not compared to the original study. This could possibly indicate that the developing variables in European individuals are not the same as in Asian individuals. In a study of modern Thai skeletons, some acetabular criteria should be revised. State 2 of the acetabular groove (variable 1) should define the fraction of a deeper groove surrounding a part of the rim and state 3 of the same variable should separate the criteria for the bone growth of the rim that has obscured the groove into another state as state 4. In addition, we primarily found that state 5 of the activity of the acetabular fossa (variable 6) is not consistent nor dense which is not covered by the entire fossa. We suggest adding another state of this variable.

Estimation of age is different from sex determination because there are only two sexes, but age can continue to 90 or more years. It cannot indicate the age of death but can estimate the age ranges. The original Rissech *et al.*¹⁶ study reported 89% accuracy in 10-year intervals and 67% in 5-year intervals. In 2007, the same authors tested four Western European collections using the original method. They found an 83-100% accuracy in 10-year intervals¹⁷. In 2011, Calce and Rogers¹⁸ tested Canadian skeletons by the Rissech *et al.*¹⁶ method. They reported 83% accuracy in 12-year intervals and 79% in 10-year intervals. In our study, the accuracies were 66% and 71% within 10 and 12 years of the known age, respectively. The inaccuracy of all ages was eight years and tended to underestimate age, which was similar to the results of Calce and Rogers¹⁸. However, our limitation of this study was the small sample sizes of a young age group contribution to low bias and inaccuracy.

The age range of 31 to 35 showed the smallest bias and inaccuracy according to the sample size. Furthermore, the specific population differences may relate to morphological changes of the acetabulum for age estimation^{17,18,20,23}. In a study of Thai skeletons for age estimation from pubic symphysis by the Suchey-Brooks¹ method and auricular surface by the Lovejoy *et al.*² method, Schmitt⁴ found overestimation and underestimation of age. The author mentioned these two methods should be avoided in Asian populations and the method using the reference groups of European populations are not appropriate for Thai people. Morphological and degenerative changes of different geographical regions are associated with many factors; genes, health care, nutrition, physical activity types, and environment. All these contribute to the aging process²⁴.

Estimation of age from the acetabulum in a Thai population by using Rissech *et al.*'s¹⁶ original scoring method appears to be the first to report in an Asian sample. In a study of age estimation, the population should be considered because of population differences. Therefore, the method for age estimation should be developed or some variables modified according to the population.

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