*Original article*

# Association between age and acetabulum morphological changes in dry bones in the Thai population

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Age estimation is one of the essential aspects of biological identification from human skeletal remains. The hip bone is often found at the scene and the acetabular region is usually one of the best preserved parts of the skeleton and can be of use in medico-legal examinations. Rissech (2) in 2006 identified seven features of the acetabulum which were found to be statistically significantly correlated with age at death. The present study investigated the correlation between those seven morphological features in the acetabulum and age in the Thai population. The study was performed using skeletal remains of 48 Thai individuals (34 males and 14 females). We found three of the seven features that were significantly statistically correlated with age at death: the left side of the acetabular groove in females (r = 0.61), acetabular rim porosity (r = 0.59) and apex activity score in left side male acetabulums (r = 0.62). This indicates that morphological changes of the acetabulum may be useful in estimating age at death in the Thai population when a hip bone is available for forensic examination. **Chiang Mai Medical Journal 2017;56(1):21-28.**

**Keywords:** acetabulum, age estimation, forensic anthropology, human aging process, age at death, Thai population sample

## Introduction

Morphological changes can be very useful in estimating age at death in forensic science (1). The paper by Rissech *et al*, "Using the Acetabulum to Estimate Age at Death of Adult Males",(2) describes the relationship between morphological changes of the acetabular head of dry bone and age at death. Similarly, Lovejoy et al.(3) reported on age-related features of the auricular surface. The acetabular head is generally the most well-preserved bone after death, making it potentially very useful in forensic anthropology for estimating the age at death using the dry bone (2). The present study investigated the relationship between age at death and scores of the seven variables identified by Rissech et al. using Thai specimens. The aim of the study was to validate the evaluation methods of Rissech in estimating the age at death in the Thai population.

## Materials and methods

In this study, we selected 50 skeletons (34 male and l4 female) obtained from the Forensic Osteology Research Center (FORC) of the Faculty of Medicine, Chiang Mai University, Thailand. The age at death of individuals in

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the sample ranged from 20 and 89 years. Skeletons with pathologic bone diseases were excluded from the study. Both right and left sides of the acetabulums were used. The imbalance in gender representation in the sample reflects the unequal number of males and females available from the FORC.

The study was conducted in three steps: planning, examination and analysis. During the planning process, we first consulted a statistician to determine the appropriate number of specimens needed. We then examined and collected data on the selected skeletons for each of the seven features identified by Rissech et al (2). The next step was to design a data collection format using 10-year age intervals. Age intervals for males began at 20-29 years with an upper age interval of 80-89 years. Age intervals for female skeletons began at 50-59 years with the oldest interval of 80-89 years. The investigation was conducted as a blind study.

The first of the seven variables in this study, the acetabular groove, appears below and surrounds the internal margin of the acetabular rim. With age, the acetabular groove can become more or less pronounced either along the entire acetabular rim or along only a part of it. Variable 2 was the a etabular rim shape. The rim loses its round, smooth form with age as a consequence of the progressive development of osteophytes, which can form a crest. Variable 3, acetabular rim porosity, increases with age. The porosity appears on the acetabular rim and on the adjacent ilio-ischiatic area of the acetabulum. Two kinds of porosity have been defined: (a) microporosity, which refers to a fine, just optically visible perforation (<1 mm); and (b) macroporosity, which refers to an oval or round perforation larger than 1 mm. Variable 4, apex activity, is bone activity on the apex of the posterior horn of the lunate surface. With aging, this apex loses its rounded form, gradually becoming sharper and finally developing a spicule, which can become quite large. Variable 5, activity of the outer edge of the Acetabular fossa, refers to an osteophytic formation that grows as a mini-crest from the outer edge of the acetabular fossa toward the lunate surface. Usually it can be felt but not seen. When present, the edge is rough to the touch and can be detected by repeatedly moving the finger along the outer edge of the acetabular fossa towards the center of the aetabular fossa surface. Sometimes this osteophytic formation becomes visible and is extensive enough to cover the acetabular fossa. Variable 6 refers to activity of the aceta-bular fossa. The young acetabular fossa appears dense and smooth and is almost level with the lunate surface. With increasing age, the acetabular fossa moves to a more internal position and appears clearly deeper than the lunate surface. This activity also expresses as relief, porosities, and bone production on the fossa.

When this activity is extreme, the aceta-bular fossa may be obliterated. The seventh and last variable is porosities of the acetabular fossa. Through the aging process, microporosities first become macroporosities, then trabecular bone, and finally destructively invading the entire fossa. There are two types of macroporosities. Smaller (<1.5 mm) macroporosities occur as a transitional form of microporosities in trabecular bone. They have a blunt perime-ter; with continued destruction, will become small macroporosities. Larger (>1.5 mm) macroporosities have a sharp perimeter due to destruction of the fossa. They are conspicuous because of their size and can be either round or less regular. They can become macroporosities with continued destruction. These characteristics are summarized in Table 1.

In the last step of data analysis process, we used the statistical methods to analyze:

1. The association between the seven variables in the same subject using the Wilcoxon Signed Rank Test.

2. Differences in the seven variables between males and females on the same side (right or left) acetabulum using the Mann-Whitney U Test.

3. The correlation between actual age at death and the predicted age based on the variable scores using Spearman's rho.

## Results

### Difference in evaluation scores for the right and left side acetabulums

To analyze differences in evaluation scores between right and left sides in individuals of the same age and sex, the Wilcoxon Signed Ranks Test was used. No significant differences in evaluation scores between left and right acetabulums was found.

### Difference in evaluation scores between males and females

To analyze differences in evaluation scores between males and females of the same age and the same side acetabulum, the Wilcoxon Signed Ranks Test and the Mann-Whitney U test were used. No significant difference in evaluation scores between males and females was found.

**Table 1.** Description of the variables.

| Variables | Alternative states of the variables | Characteristic of the alternative states |
|---|---|---|
| (1) Acetabular groove | No groove | There is no groove below the acetabular rim. There is no anatomical interruption between the lunate surface and the acetabular rim. |
| | Groove | An anatomical interruption is observed between the lunate surface and the acetabular rim. Although it might be short or shallow, it surrounds some or much of the acetabular rim. |
| | Pronounced | A deeper groove surrounds a large part of the acetabular rim. |
| | Very pronounced groove | An extremely pronounced groove surrounds nearly all the acetabular rim. In some specimens, extreme growth of the rim has obscured the groove so that only a tissue discontinuity between the lunate surface and the acetabular rim can be observed. |
| (2) Acetabular rim shape | Rounded Acetabular rim | The acetabular rim is dense, round and smooth, typical of young specimens. |
| | Partially narrow acetabular rim | The acetabular rim keeps its round and smooth form in some areas but is narrower in others. There are two variations: (a) the iliac part of the acetabular rim narrows but not the ischial part; or (b) the external part of the acetabulum retains its rounded form but its internal part has an upright form. In all of these cases, the acetabular rim is smooth to the touch. |
| | Narrow or rough acetabular rim | There are two variations: (a) the whole acetabular rim is narrow, or (b) some part of the acetabular rim might be rough to the touch due to the presence of little grooves. In both cases, there is no osteophytic development. |
| | Partially crested rim | Osteophytic constructions (development) form a small chain (< 1 mm in height) on some small part of rim; a larger osteophyte, either linked or not linked to the chain, might be observed. |
| | Crested rim | An osteophytic formation makes either (a) a low crest (< 1 mm in height) along the entire acetabular rim or (b) a high crest (2–4 mm in height) along only part of the rim. This crest appears dense. |
| | Very high crested rim | A very high crest (44 mm in height) has developed as a consequence of bone construction and destruction. This crest is thin and sharp or rounded with a spongy appearance. |
| | Destructured rim | An extremely high crest (<8 mm in height) has developed. It may be either thin, sharp and leaning slightly toward the lunate surface or rounded, spongy and fragile with swollen and hollow bone. |
| (3) Acetabular rim porosity | Normal porosity | The acetabular rim is smooth without porosities and roughness. The area adjacent to the acetabular rim also has normal porosity. |
| | External porosity | In the area around the acetabulum, microporosity is slightly increased on the anterior inferior iliac spine, on the posterior wall of the acetabulum and on the area below the two extremities of the lunate surface. There is no porosity on the acetabular rim, which is dense and smooth. |
| | Rim porosities | Some microporosities on the acetabular rim may be large (51 mm) but the acetabular rim always has a round and dense appearance. There is no bone destruction. |
| | Rough rim | The acetabular rim is not smooth to the touch and there may be some macroporosity on the rim. |
| | Destructured rim | Newly constructed bone has become very porous with many micro- and macroporosites, or it has suffered subsequent destruction. |
| | Extremely destructured rim | Macro- and microporosities of the destructured acetabular rim have partially invaded the lunate surface. Usually this invasion occurs on the superior area of the lunate surface below the anterior inferior iliac spine. |

**Table 1.** (continune)

| Variables | Alternative states of the variables | Characteristic of the alternative states |
|---|---|---|
| (4) Apex activity | No activity | The apex is round and smooth to the touch. There is no spicule. |
| | Apex activity | The apex has become longer and is sharp to the touch, or a small spicule can be felt. |
| | Osteophytic Activity (<1 mm) | A developed and conspicuous osteophyte larger than 1mm can be seen with the naked eye. |
| | Much osteophytic Activity (<3 mm) | The apex has an osteophyte larger than 3 mm, which may cover the entire horn of the lunate surface. |
| | Very much osteophytic activity (<5 mm) | An osteophyte is so large (45 mm) that it enters the acetabular notch and may completely cross it, in which case the anterior horn of the lunate surface also has activity. |
| (5) Activity on 1the outer edge of the Acetabular fossa | No activity on the outer edge | The outer edge feels smooth, or at least not rough, and the finger moves smoothly over it towards the fossa. |
| | Slight activity (<1/4) on the outer edge | A mini-crest can be felt (but not seen) on less than one quarter of the outer edge of the acetabular fossa. It is usually found on only one of the two horns of the lunate surface, near the apex. |
| | Medium activity (<1/2) on the outer edge | Bone growth can be felt (but not seen) on between a quarter and half of the outer edge of the acetabular fossa. Usually, this bone growth is not continuous; therefore, all the active parts must be considered to estimate the proportion. |
| | Much activity (<3/4) on the outer edge | Bone growth can be felt on between one half and three quarters of the outer edge of the acetabular fossa. |
| | Extreme activity (<3/4) on the outer edge | Bone growth can be felt and sometimes it can be seen on more than three quarters of the outer edge. |
| | Destructured outer edge | There is so much visible bone growth on the outer edge towards the fossa that it partially covers the fossa parallel to the outer edge. |
| (6) Activity of the acetabular fossa | No activity | The lunate surface is level with the acetabular fossa, which appears dense and smooth. |
| | Slight activity | The lunate surface is clearly no longer level with the acetabular fossa, which still appears dense and smooth. |
| | Peripheral activity | The acetabular fossa shows activity on between a quarter and a half of its surface. This activity is usually located on the posterior area of the fossa or sometimes on peripheral areas, but never on the center. This activity results in relief, porosities and spongy bone, which grows toward the lunate surface from small parts of the external border of the fossa. Areas of the acetabular fossa without activity appear dense and smooth. |
| | Central activity | There is activity on about half of the fossa. It is usually found on the posterior half and always extends to the center. Activity on the center of the acetabular fossa usually produces a relief that is similar to the trabeculae. Peripheral activity is usually expressed by porosities. There may be some growth of spongy bone toward the lunate surface. |

**Table 1.** (Continoue)

| Variables | Alternative states of the variables | Characteristic of the alternative states |
|---|---|---|
| | Major activity | Activity is observed on more than three quarters of the fossa. This activity produces relief and porosities, but the fossa does not lose its consistency and density. |
| | Generalized activity | The entire fossa, or nearly all of it, is covered by extensive formation. There are two possibilities: (a) the fossa is not consistent nor dense or (b) the fossa is partially or totally obliterated. |
| **(7) Porosities of the acetabular fossa** | Major activity | Activity is observed on more than three quarters of the fossa. This activity produces relief and porosities, but the fossa does not lose its consistency and density. |
| | Generalized activity | The entire fossa, or nearly all of it, is covered by extensive formation. There are two possibilities: (a) the fossa is not consistent nor dense or (b) the fossa is partially or totally obliterated. |
| | Dense acetabular fossa | The acetabular fossa is dense and smooth, but it may have a few normal peripheral microporosities. |
| | Acetabular fossa with microporosities | The acetabular fossa appears dense but there are small areas with some microporosities. These areas look like “orange peel,” usually on the superior lobe of the fossa, but sometimes elsewhere. |
| | Microporosities or peripheral trabecular bone | Part of the fossa is covered with microporosities and smaller macroporosities. These porosities occur on about one half of the fossa, which can include the center, but not on all three lobes. Some trabecular bone may occur on the peripheral area of the fossa. |
| | Microporosities on the three lobes | Porosities occur on about three quarters of the fossa. The three lobes and the center of the fossa are covered with smaller macroporosities and microporosities, but not the area of the acetabular notch. Trabecular bone may occur on the peripheral area of the fossa. |
| | Microporosities with destruction | Macroporisities with destruction occur on a base of microporosities and smaller macroporosities. This may be observed over most of the fossa or only over a restricted area. |
| | Bone destruction on most of the fossa | Most of the fossa is covered with trabecular bone. There are no microporosities. There is much destruction evidenced by large irregular macroporosities with destruction. The bone of the fossa is swollen and has lost consistency as a result of bone destruction. |
| | Bone proliferation | Bone proliferation on the acetabular fossa obliterates the fossa. |

Modified from American Academy of Forensic Sciences (2006), pages 215-217.

**Correlation between evaluation scores and age at death in the Thai population**

The specimens were divided into four groups: right and left side male acetabulums and right and left side female acetabulums. Variable 1 (acetabular groove) exhibited a statistically significant correlation with age at death in all four groups. The highest correlation (r = 0.61) was in left side female specimens. Variables 3 (acetabular rim porosity) and 4 (apex activity)were found to be associated with age at death (r=0.59 and 0.62, respectively), in left side male specimens. There was also a significant correlation with age at death in the other groups of specimens with the exception of left side female specimens. Significant correlation between age and variable 5 (activity on the outer edge of the acetabular fossa) was found in the right side male specimens, but not in the other 3 groups. Finally, there was signifi-

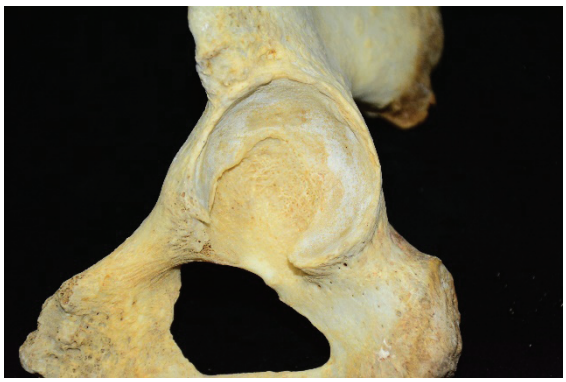

**Figure 1.** Acetabulum

cant correlation between age and variable 6 (activity of the acetabular fossa), but only in right side female specimens.

The same methods were used to evaluate the correlation between the evaluation scores of variable 6 (activity of the acetabular fossa) and variable 7 (porosities of the acetabular fossa), including dividing the specimens into the same 4 groups. All the correlations were statistically significant, with the highest (r= 0.75) for right side male specimens.

For both sides of male specimens, correlations were found between variable 1 and variable 2, variable 1 and variable 3, variable 1 and

variable 6, variable 1 and variable 7, and variable 3 and variable 7. In the female specimens, no correlations were found between any of the pairs of variables.

In the right side specimens of both sexes, correlations were found between variables 1 and 3 and between variables 1 and 6. In the left side specimens of both sexes, no correlations were found between any of the pairs of variables.

There were many correlations between two variables that were found in only one group of specimens, e.g., in right side male specimens (variables 1 and 5, variables 2 and 3, variables 2 and 4, variables 2 and 5, variables 2 and 6, and variables 3 and 5). Similarly, in left side male specimens, there were correlations between variables 1 and 4 as well as between variables 3 and 4. In left side female specimens, correlations were found between variables 2 and 3.

## Discussion

Among the seven acetabular variables described by Rissech and his colleagues, three variables 1 (acetabular groove), 3 (acetabular rim porosity), and 4 (apex activity) demonstrated moderate to strong correlations with age at death in almost all specimen groups (2). According to these results, it can be inferred that Thai and Portuguese people undergo similar forms of morphological changes as they age, especially in the areas involved in variables 1, 3, and 4. Moreover, for all seven variables there are no significant differences between males and females or between left and right sides of individuals. In addition, variable 1 has a moderate to strong correlation with variable 3, indicating that those variables are similarly affected by the aging process in terms of morphological change.

The other four variables, variable 2 (acetabular rim shape), variable 5 (activity on the outer edge of the acetabular fossa), variable 6 (activity of the acetabular fossa), and variable 7 (porosities of the acetabular fossa), are only weakly correlated with age at death(4). These results suggest that Thai and Portuguese individuals may have some degree of difference in the pattern of morphological changes in the acetabular region. Variable 6 (activity of the acetabular fossa) and variable 7 (porosities of the acetabular fossa) have the strongest correlation to each other. This appears to be because they are involved in the same area, the acetabular fossa, indicating some level of morphological overlap.

Other unknown factors or variables factors or variables, some of which may not yet have been identified may result in different acetabular morphology, e.g., body weight, bone density, physical activity, throughout the bone preserving process. Additionally, taphonomic factors may also affect the morphology of the acetabulum, e.g., humidity can increase the porosity of dry bone (5). These factors can affect the osteological texture of the remaining acetabula, which may result in some degree of distinctness among individuals within a population as well as among different populations.

The results of this study indicate that correlations between variable scores and age at death are significant, especially variables 1, 3, and 4 which can potentially be effective age predictors in the Thai population. However, we suggest further research be conducted to try to improve the accuracy of age prediction (6). Specifically, studies using a larger sample of acetabulums to estimate of age at death in Thais are needed to better understand the nature of acetabular morphological changes during the aging process in the Thai population compared to populations of other countries and to evaluate the population-based age prediction accuracy of the seven acetabular variables described by Rissech and colleagues.

Three variables demonstrated a moderate to strong correlation with age at death in almost all specimen groups: variable 1 (acetabular groove), variable 3 (acetabular rim porosity), and variable 4 (apex activity). Based on this result, it can be inferred that Thais and Portuguese populations undergo similar forms of morphological change during the aging process, especially in those three areas. Additionally, for all seven variables there were no significant differences among males and females or between the left and right side acetabulum.

The results of this study indicate that many variables are significantly correlated with age at death, including variable 1 (acetabular groove) where the highest correlation with age at death was found in the left side of female specimens. Variable 3 (acetabular rim porosity) and variable 4 (apex activity) also have a significant correlation with age at death in the left side for both males and females. The correlation between age at death and variable 5 (activity on the outer edge of the acetabular fossa) was found in right side male specimens. Correlation between age at death and variable 6 (activity of the acetabular fossa) was found in right side female specimens. There were no significant differences between males and females or between left and right sides.

Further studies should include a test of intra and inter-observer errors to increase the validity and reliability of findings.

## Conclusions

At least five of the seven variables identified by Rissech et al. (2007) can be used to estimate age at death in Thai dry bone acetabula (2). These results help establish guidelines for estimating age at death using dry hip bones in the Thai population. As the acetabular region is often one of the best preserved parts of the skeleton after death, the hip bone can be useful in forensic science. There are differences in morphological changes of dry bone throughout the aging process. Lastly, the authors found that changes in the acetabulum are not solely the result of diet, lifestyle, or culture, but are multifactorial in development and expression.

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## Conflicts of interest

The authors have no conflicts of interest.

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## การศึกษาความสัมพันธ์ระหว่างอายุและการเปลี่ยนแปลงทางสัณฐานวิทยาของกระดูกสะโพกในประชากรไทยจากอาจารย์ใหญ่โครงกระดูก

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จากการศึกษาของ Rissech C. และคณะ เรื่อง “Using the Acetabulum to Estimate Age at Death of Adult Males” ในปี ค.ศ. 2006 โดยการศึกษาตัวแปรจำนวน 7 ตัวแปรในกระดูกสะโพกเพื่อใช้ในการประเมินอายุเมื่อเสียชีวิตจากกระดูกแห้ง ในการศึกษาครั้งนี้ได้นำตัวแปรเหล่านั้นมาใช้ประเมินอายุในตัวอย่างกระดูกสะโพกของประชากรไทยทั้งหมด 50 ตัวอย่าง โดยผลการศึกษาพบว่าตัวแปร acetabular groove acetabular rim porosity และ apex activity มีความสัมพันธ์อย่างมีนัยสำคัญกับอายุมากที่สุด ซึ่งมีค่า correlation coefficient เท่ากับ 0.61 0.59 และ 0.62 ตามลำดับ โดยคำนวณจาก Spearman’s Rho Calculator จากผลการศึกษา พบว่า acetabular groove acetabular rim porosity และ apex activity เป็นตัวแปรที่สามารถใช้ประเมินอายุเมื่อเสียชีวิตจากกระดูกสะโพกในประชากรไทยได้ **เชียงใหม่เวชสาร 2560;56(1):21-28.**

**คำสำคัญ:** เบ้าสะโพก การประมาณอายุ มานุษยวิทยานิติเวช ขบวนการเปลี่ยนแปลงเมื่ออายุมากขึ้นในมนุษย์ อายุขณะเสียชีวิต กลุ่มประชากรไทย