Anthropology
ISSN: 2332-0915

Venara et al., Anthropol 2013, 2:1
DOI: 10.4172/2332-0915.1000113

Research Article Open Access

Estimation of skeletal Age at Death in Adults Using the Acetabulum and the Auricular Surface

Venara A[1], Martrille L[3], Godin M[1], Kerdat C[1], Deguette C[1,5], Chapard D[5] and Rouge-maillart C[1,4,5,*]

[1]*Forensic science Department. CHU Angers, 4 Rue Larrey, 49933 ANGERS Cedex 9, France*
[2]*VisceralSurgeryDepartment. CHU Angers, 4 rue Larrey, 49933 ANGERS Cedex 9, France*
[3]*Forensic science Department. CHU Nancy, BP 184 – 54505 VANDOEUVRE-LES-NANCY CEDEX, France*
[4]*LUNAM University ANGERS, France*
[5]*GEROM Groupe Etude Remodelage Osseux et bioMateriaux-LHEA, IRIS-IBS Institut de Biologie en Sante, France*

Abstract

Rougé-Maillart et al proposed a technique to determine the age of a subject using the acetabular surface and the auricular surface of the coxal bone. This technique has been described as promising, particularly in subjects under 50 years of age. The initial aim of this study was to test the technique on a new population with two observers, one of whom had no prior experience of the technique. A second aim was to confirm the utility of using the technique on elderly subjects.

Material and method: We worked on 210 bones (108 male and 102 female) from the Terry Collection. Two observers studied the bones (one was a beginner, one an advanced user of the technique). Age estimation of the skeletons was based on analysis of the auricular surface and the acetabulum as described in the method by Rougé-Maillart et al. Intra- and inter-observer correlations were performed to monitor the reliability and reproducibility of this technique in the overall population, before moving on to subjects aged over 50.

Results: For both observers, the data highlighted a good average correlation between score and real age (overall scores of 0.648 and 0.773) in the overall population. The similarity between the observers' results increases as total scores are used. However, the inter-observer correlation is lower than for the previous study, as some criteria are more difficult to classify for the novice observer. As regards subjects over 50, the results are less reliable than expected, with a higher inter-observer variation than in the overall population.

Conclusion: This study confirms the reproducibility and effectiveness of the method. However, some criteria must be redefined, while others must be weighed. Likewise, a modification to the Bayesian approach with a change to the intervals should be considered.

Keywords: Physical anthropology; Age determination; Acetabulum; Auricular surface

Introduction

Estimation of the age at death of adult subjects has been the focus of numerous studies based specifically on bone degeneration, though this has never achieved as high a degree of reliability as that achieved when estimating sex [1-3].

Lovejoy et al. developed an initial technique to estimate the age at death of adult subjects using the auricular surface of the coxal bones [4,5]. This technique has been reproduced many times, and some authors have highlighted that it underestimates the age of elderly subjects and overestimates the age of younger subjects because of the interdependence of criteria [6]. In 2002, Buckberry and Chamberlain suggested a solution that adjusts the estimated age by making each criterion independent, thus allowing the calculation of a composite score [7]. The composite score then relates to an age group. However, this technique came up against the same errors as those encountered when using Lovejoy's method (over- and under-estimation of age according to age group) [8].

Auricular surface has frequently been assessed and it has been shown to overestimate age under 59 and to underestimate age over 60 [8]. According to Schmitt, this technique should not be used on Asian archaeological series or forensic cases [9].

In addition, use of the technique described by Lovejoy et al., Osborne et al. revealed that only 33% of their sample was allocated the correct age, because of the five-year age ranges provided by Lovejoy et al [10]. Therefore, for Osborne et al. the auricular surface performed as well as any other single skeletal indicator of adult age [10]. For this reason, Rougé-Maillart et al. proposed to link this surface with another one in order to calculate a score [11,12].

Like the auricular surface, the acetabular surface is resistant to deterioration, while the joint is subject to age-related degeneration. This surface was studied by several authors, notably Rissech et al. [13-16]. They concluded that seven variables were potentially useful in estimating age at death [13]. Furthermore, they concluded in another study that this surface could be used to make accurate age estimates for adults of any age [15].

Rougé-Maillart et al. thus outlined a technique combining the score achieved using the Buckberry et al. method with a score relating to the acetabular surface [11].

***Corresponding author:** Rougé-MaillartClotilde, Professeur, Forensic Science Department, 4 rue Larrey, 49933 Angers Cedex 9, France, Tel: 00-33-2-41-35-59-28; Fax: 00-33-2-4135-39-48; E-mail: ClRouge-maillart@chu-angers.fr

Received October 24, 2013; **Accepted** December 05, 2013; **Published** December 10, 2013

Citation: Venara A, Martrille L, Godin M, Kerdat C, Deguette C, et al. (2013) Estimation of skeletal Age at Death in Adults Using the Acetabulum and the Auricular Surface. Anthropol 2: 113. doi:10.4172/2332-0915.1000113

This technique used 4 auricular surface criteria: [11,12].

(i) Transverse organization: Broad ripples or well-defined grooves located on the surface of the joint. The size of the area occupied by transverse organization is the component taken into consideration.

(ii) Surface texture: The finely granulated aspect which, over time, becomes more polished as the bone becomes denser. Fine granulation is defined as less than 0.5 mm in diameter.

(iii) Porosity: This is the deterioration of the subchondral bone, which may lead to perforations. Microporosity refers to perforations of less than 1 mm; larger perforations are referred to as macroporosity.

(iv) Apical activity: This refers to changes to the edge of the auricular surface in the apex region. With age, the apex becomes more prominent and angular, at which point the edge becomes irregular and begins to resemble thin lips.

In terms of the acetabular surface, three criteria were described, emerging from the study by Rougé-Maillart et al [11,12]:

(i) Appearance of the acetabular roof ('rim'): This is the appearance of the edge of the acetabulum, which may have a foam-like appearance. It disappears with age, giving way to a sharper feature.

(ii) Appearance of the acetabular base: This is the granulated appearance of this part of the acetabulum. Initially, granulations are fine, of less than one millimeter, before becoming coarser.

(iii) Apical activity of the posterior horn of the acetabulum: This refers to the appearance of the end of the posterior horn. In young subjects, it is smooth and regular. Gradually, it becomes irregular due to osteophytic activity. We considered activity to be the presence of osteoarthritic reorganization. It is considered moderate in the event of irregularity, as long as the curvature of the horn is respected. It becomes substantial when osteophytic obstructions are present that break up the curve.

Each surface was given a score. Both scores were then added together, enabling an overall score to be obtained, which pertained to membership of a class, itself associated with an age group [12].

In 2009, research work validated this technique by emphasizing its satisfactory reproducibility and ability to provide a good estimation of age [12]. Rougé-Maillart et al. reported satisfactory discrimination in terms of age for individuals over 50 years of age, something which had not been found in previous works [12].

The aim of our study was to conduct a new assessment of this technique with two observers, one of whom was unfamiliar with the method, in another population sample. We wanted to confirm the reproducibility and reliability of the technique, and its specific utility in subjects over 50 years of age.

Materials and Methods

We worked on 210 coxal bones from a series of identified skeletons (age and sex) belonging to the Terry Collection of the Smithsonian National Museum of Natural History in Washington, D.C. in the United States. This collection, open to researchers from around the world, includes 1,728 specimens aged between 16 and 102, whose dates of birth range between 1822 and 1943. We randomly selected the left pelvises of 210 individuals (108 men and 102 women). This was based on the fact that Lovejoy and Buckberry and Chamberlain showed that their technique could be applied independently of the side chosen [4,5,7]. Observers selected skeletons with knowledge of gender, in order to have an approximately equal number of bones from male and female subjects. Age was not known, and was checked only after observation of the bones.

Two observers performed age estimation; one of whom had received a half-day's training (Observer 1), while the other was familiar with the technique (Observer 2). This system then allowed inter-observer analysis reflecting the reproducibility of the method used.

Age estimation of the skeletons was based on analysis of the auricular surface and acetabulum as described in the method outlined by Rougé-Maillart et al. [11]. This technique was described in the introduction above. However, during our work, in order to improve the sensitivity of the technique, we modified one criterion, in specific regard to the apical activities of the auricular and acetabular surfaces. This change was made on the advice of the beginner, who observed that there were too many differences between stages 2 and 3. The change was made to enable a better approximation of age at death.

In comparison to the Rougé-Maillart method [12], one point was added:

In terms of the apical activity of the auricular surface, we set out four stages. Stages 1 and 2 were identical to those used in the original technique. Any medium-mean irregularity in the contours of the auricular surface was defined as Stage 3, while any irregularity in the overall contours of the auricular surface, whereby the apex shape was no a longer smooth arc was defined as Stage 4. In terms of apical activity of the acetabular surface, we also set out four stages. Stages 1 and 2 were identical to the original technique. Moderate activity was defined as Stage 3 and pronounced activity was defined as Stage 4. Statistics were created using SPSS 17 software. The correlation test used in the study was the non-parametric Spearman test, with a significance level of 1%. The best correlation coefficient is 1. Graphical representation was based primarily on results in box plot form. The variable analysis method took account of the multivariate variable. Initially, we carried out one correlation based on the selected criteria with actual age, and another based on the score obtained by different observers with actual age. Afterwards, we conducted an inter-observer comparison in order to assess the reproducibility of the method. This gave rise to correlations between scores, classes and the various criteria obtained by each of the two observers. Finally, we specifically studied those subjects who died aged over 50, so as to assess the reliability of this technique for this age class.

Results

We studied a sample of 210 left pelvises composed of 108 men and 102 women aged 18 to 94 at the time of death.

In terms of assessing the technique, data from both observers was analyzed individually, and the summary revealed an average correlation (overall score 0.648) between age and overall score for the first observer, and a better correlation (overall score 0.773) for the second. The results are reported in Table 1.

It was also observed that when the score (Figures 1 and 2) was:

(i) less than 13, 85% of the individuals were aged under 40

(ii) less than 17, 85% of the individuals were aged under 50

(iii) greater than 17, 95% of the individuals were aged over 40

	Observer 1	Observer 2
Transverse organization	0.446	0.682
Texture	0.549	0.600
Porosity	0.427	0.538
Apical activity	0.456	0.558
Total auricular surface	0.609	0.724
Rim	0.511	0.673
Base	0.428	0.611
Apical activity	0.492	0.623
Total acetabulum	0.490	0.721
Overall score	0.648	0.773

Table 1: Correlation between actual age and criteria studied: Spearman's correlation coefficient.

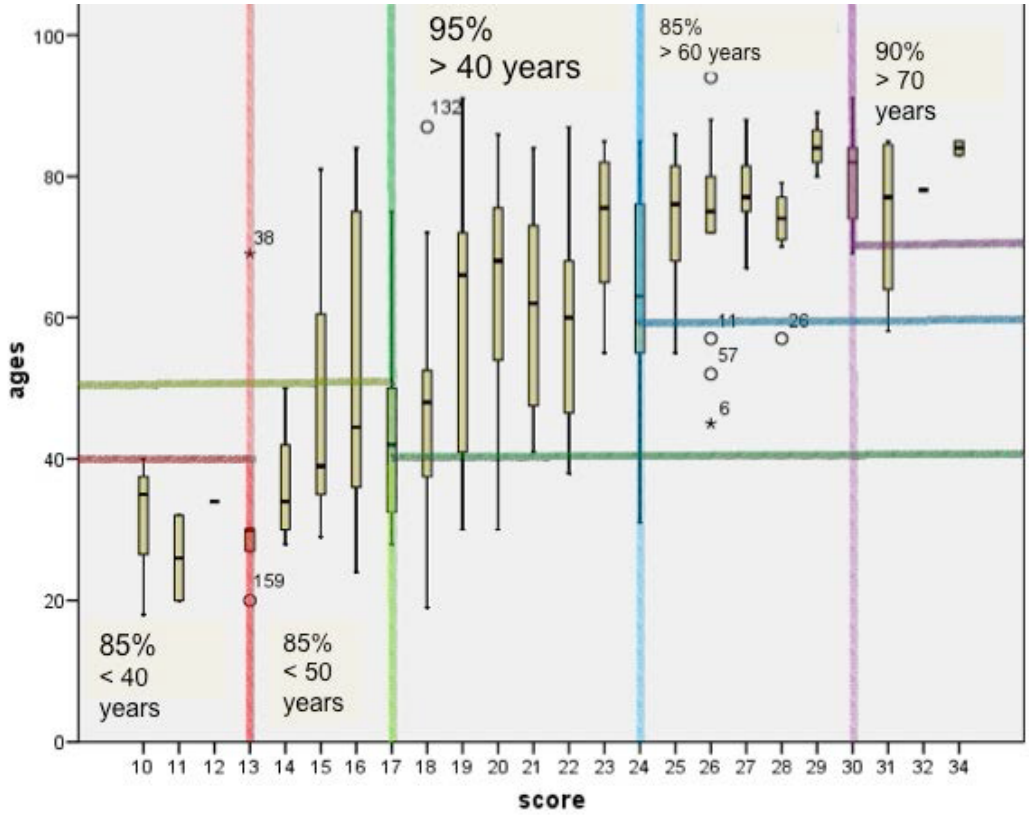

Figure 1: Box plot of the actual age of subjects according to overall score: Observer 1.

(iv) greater than 24, at least 85% of the individuals were aged over 60

(v) greater than 30, 90% of the individuals were aged over 70

Figures 1 and 2 show that the overall score enables several groups to be identified: those aged over 40, those aged over 60 and those aged over 70.

In terms of analyzing reproducibility, inter-observer variations were verified by means of the inter-class coefficient. In Table 2, a similarity can be noted between the observers, which increases as more total scores are used, along with a better correlation with the overall score (CC = 0.775).

The technique can thus be reproduced, and we can see the benefit of using an overall score compared to using the score for the acetabular or auricular surface alone.

Finally, in terms of assessing the study in individuals aged over 50, we selected 147 individuals in our sample, of whom 73 were men and 74 were women, aged 50 to 94. For this age class, comparison of the overall score and the actual age revealed large margins of error, with a Spearman coefficient of 0.325 and 0.555 (Figures 3 and 4).

The inter-class correlation made between the listed results for each result ranges from 0.325 with a confidence interval of 0.166 ; 0.497 for the texture of the auricular surface to 0.695 with a confidence interval of 0.601 ; 0.770 for the activity of the acetabular base (Table 3). However, the overall score evens out large variations, and the intra-class correlation coefficient then reaches 0.643 0.536; 0.729. The population distribution over the study is considered to be 1% below the limit of fifty, while 53% of this population is assigned the correct age class for Observer 1, with 3% and 63% respectively for Observer 2. Overall, the actual age of the sample is underestimated by both observers (Tables 4 and 5).

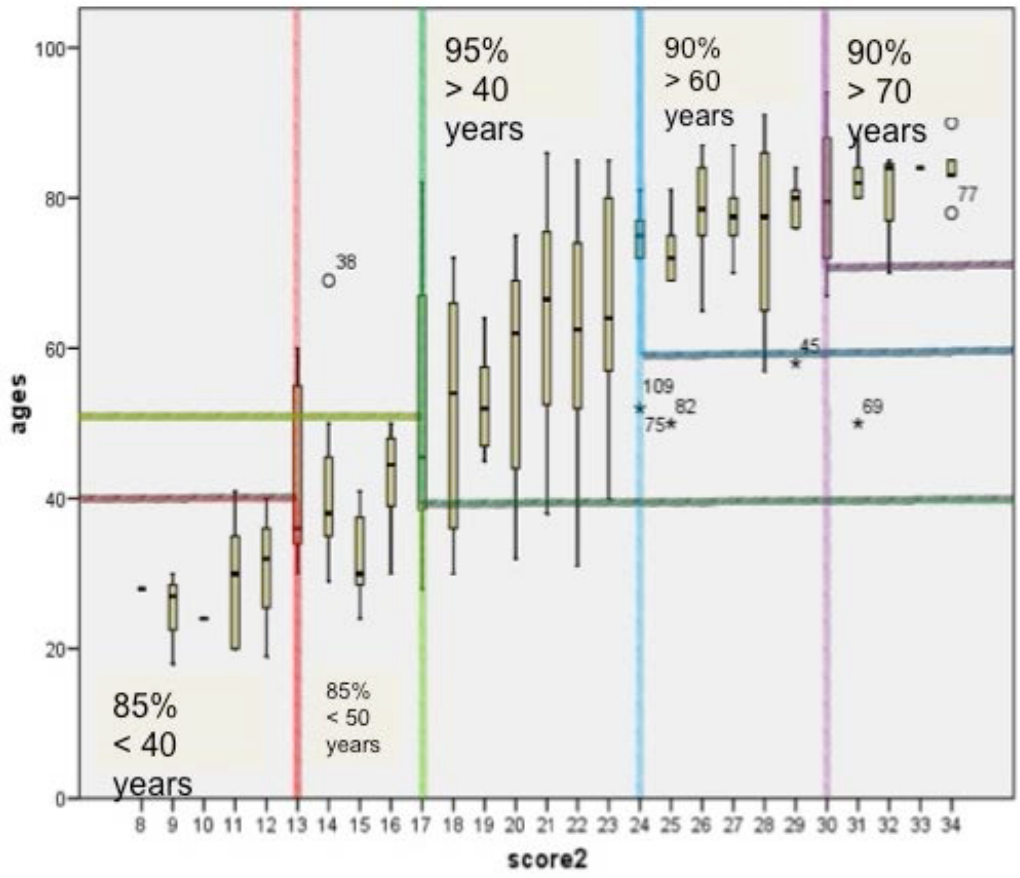

Figure 2: Box plot of the actual age of subjects according to overall score: Observer 2.

Criteria	Intraclass correlation coefficient	Confidence interval 95%
Auricular surface organized transversally	0.557	0.456 – 0.644
Auricular surface has granular texture	0.520	0.399 – 0.621
Porosity of auricular surface	0.718	0.640 – 0.781
Apical activity of auricular surface	0.490	0.273 – 0.639
Total score for auricular surface	0.729	0.658 – 0.786
Acetabular rim	0.647	0.561-0.719
Acetabular base	0.537	0.413 – 0.637
Apical activity of posterior Acetabulum horn	0.737	0.668-0.793
Total acetabulum score	0.743	0.675-0.798
Overall score	0.775	0.714-0.824

Table 2: Inter-observer variability: Intra class correlation in the overall population.

Discussion

Rougé-Maillart et al proposed a method using the acetabulum and the auricular surface. This technique is based on the development of a score established using seven criteria (each criterion is associated with a different stage). In 2009, the technique was tested on a Portuguese population. This study showed the criteria were correlated with age. It also showed that establishing a score allows a better correlation with age with lower intra-/inter-observer variability. The other benefit is its ability to distinguish elderly people. We tested this technique on a new population. We wanted to show the method's utility in terms of distinguishing the oldest subjects, and its feasibility for a novice observer. This study confirms the correlation between overall score and age in both observers. It is worth classifying subjects achieving a score of 85%: those aged over 40; those over 60 and those over 70. As such, this method has good feasibility and can be used by a novice observer. Inter-observer reproducibility is relatively satisfactory. These results are in line with the previous study. In fact, the calculation of a total score allows the smoothing of some of the slight variations intrinsic to a scoring system, which will always be subjective and as such, will entail differences in score. The results obtained clearly show that these inter-observer variations in the scores allocated to the same bone are smoothed thanks to the diversity of the assessment criteria. Disparities linked to personal bias are limited and as a result, margins of error are reduced.

However, the results fell short of expectations. This inter-observer correlation was lower than in the previous study [12]. Disparities in

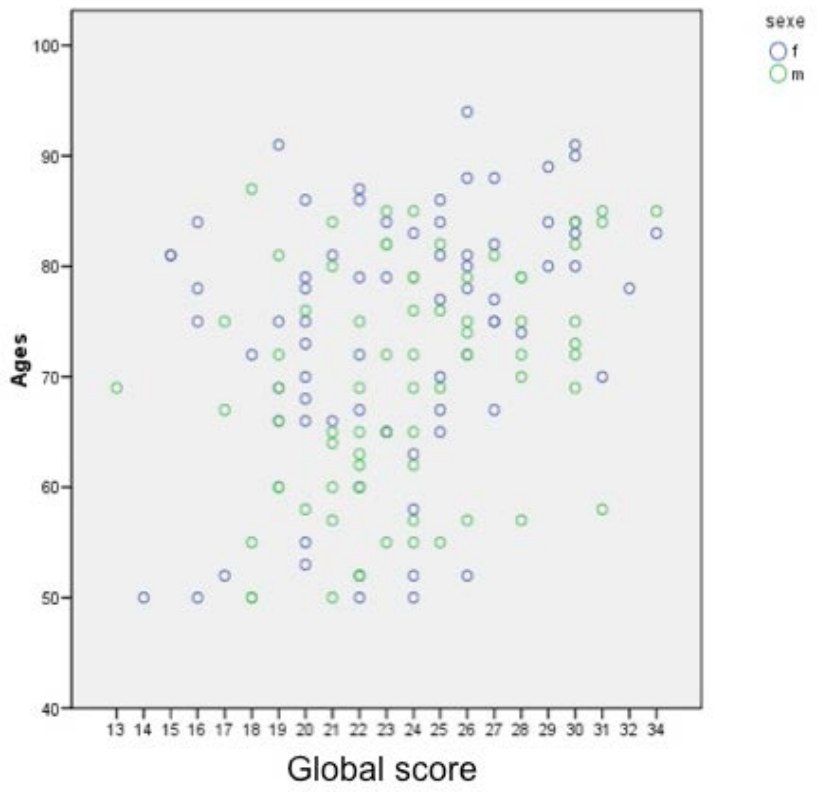

Figure 3: Scatter graph showing distribution of scores for subjects aged over 50: Observer 1.

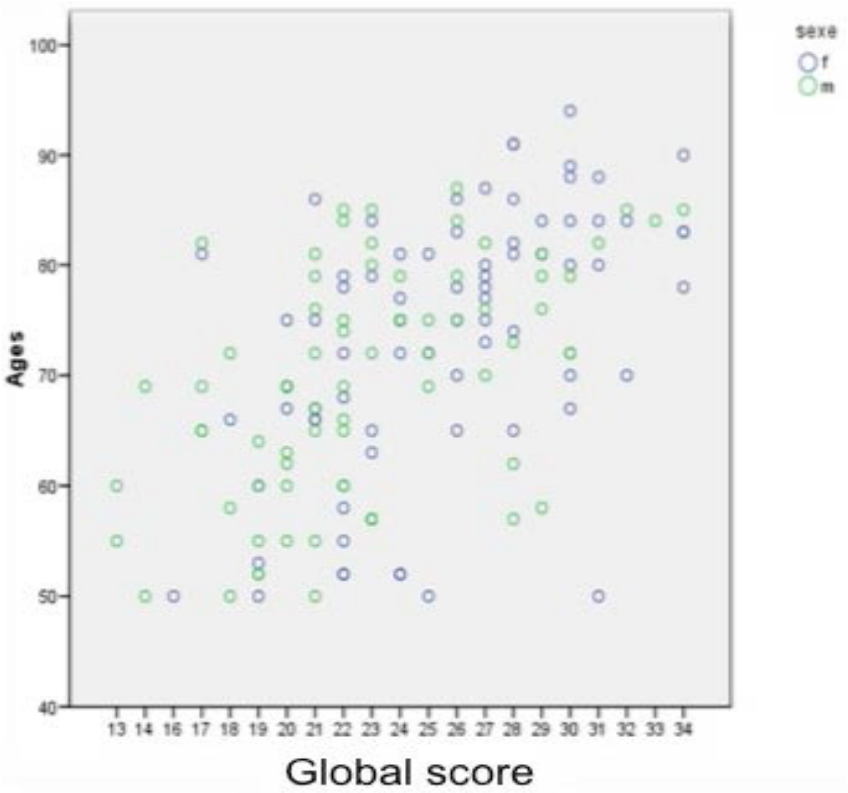

Figure 4: Scatter graph showing distribution of scores for subjects aged over 50: Observer 2.

Criteria	Intra class correlation coefficient	Confidence interval 95%
Auricular surface organized transversally	0.379	0.233 - 0.509
Auricular surface has granular texture	0.325	0.166 - 0.467
Porosity of auricular surface	0.689	0.594- 0.766
Apical activity of auricular surface	0.437	0.240 - 0.587
Total score for auricular surface	0.582	0.464 - 0.680
Acetabular rim	0.570	0.451 - 0.670
Acetabular base	0.435	0.253 - 0.578
Apical activity of posterior Acetabulum horn	0.695	0.601 - 0.770
Total acetabulum score	0.652	0.525 - 0.746
Overall score	0.643	0.536 - 0.729

Table 3: Inter-observer variability: Intraclass correlation coefficient for subjects over 50.

Subjects	Score class							
Actual age-class	1	2	3	4	5	6	7	Total
4		1	4	6	3			14
5			1	12	8	1	1	23
6		1	2	15	14	7	1	40
7			6	11	19	15	3	54
8			1	4	5	4	2	16
Total		2	14	48	49	27	7	147

Table 4: Distribution of subjects aged over 50 according to the score class: Observer 1. (Gray box = poorly classified).

Subjects	Score class							
Actual age-class	1	2	3	4	5	6	7	Total
4		1	2	7	3		1	14
5		2	1	13	4	3		23
6		1	5	16	8	9	1	40
7			2	9	18	16	9	54
8				2	3	7	4	16
Total		4	10	47	36	35	15	147

Table 5: Distribution of subjects aged over 50 according to the score class: Observer 2. (Gray box = poorly classified).

the results observed could most likely be explained by the conditions in which the study was conducted. A serious lack of time meant that double viewing of each bone could not be undertaken, though this would have allowed its score to be further refined, and to enable observations to be backed up.

The second point to note is that definition of the criteria was not fully hermetic, thus giving rise to a number of variations. In line with research previously undertaken, the Rougé-Maillart method benefited both from an opinion external to the team in charge of its development, and an example of new user training as regards the method used. During the study, this gave rise to the modification of a criterion, that of apical activity of the posterior horn of the acetabulum and apical activity of the auricular surface. Bone condition definitions were reviewed and the classification was modified accordingly during the study.

The third observation is that such criteria are complex and difficult to assess for novice observers; for instance, criteria such as the transverse organization of the auricular surface. The allotment of scores under this criterion, particularly in subjects aged over 50 (CC=0.379), and in the rest of the study (CC=0.557), could be based more on subjectivity and practice than the other criteria, which would go some way to explaining the marked differences between the results observed.

As regards the population aged over 50, the results are less relevant than for the overall population, with a correlation coefficient between 0.325 and 0.555. Classification was undertaken using a Bayesian approach, with regular and fixed intervals. According to Osborne et al, intervals predefined in this way are most likely not suitable for all ages [10], requiring a change in the scope of the score classes, meaning that results may not be regular, but will be more accurate. Furthermore, it is noted that the correlation coefficient is clearly higher in the experienced observer, which would tend to suggest that the learning curve is slower when determining this age group. Thus, in both nature and definition, the criteria do not seem to require review. It may be possible to suggest a weighting of the various points observed according to their relevance and their capacity for discrimination. This could be done so as to further refine the results obtained and allow a wider sample size. Likewise, a modification to the Bayesian approach with a change to the intervals should be considered in a subsequent assessment of the technique, with a view to improving it.

Conclusion

This work thus enabled the reproducibility and effectiveness of the Rougé-Maillart method to be confirmed. The combination of the various criteria reduces the margin of error, making the method more reliable. Furthermore, this method is easy to use, even after only a few hours' training. Nevertheless, some criteria must be revised. The apical activity of the auricular surface and of the acetabulum must be defined using four stages. Additionally, some criteria are too complex to be distinguished by an inexperienced observer. We suggest that the technique be redefined, with the weighting of criteria. Likewise a modification to the Bayesian approach with a change to the intervals should be considered, because the predefined intervals are not suitable for all ages.

Acknowledgement

The authors would like to thank Prof. David R. Hunt at the Department of Physical Anthropology who welcomed us to the Smithsonian Institution National Museum of Natural History and allowed us to work on the Robert J. Terry Anatomical Skeletal Collection.

References

1. Bruzek J (2002) A method for visual determination of sex, using the human hip bone. Am J Phys Anthropol 117: 157-168.
2. Dar G, Hershkovitz I (2006) Sacroiliac joint bridging: simple and reliable criteria for sexing the skeleton. J Forensic Sci 51: 480-483.
3. Boldsen JL, Milner GR (2002) Transition analysis: a new method for estimating age from skeletons. In Hoppa R.D., Vaupel J.W. editors. Paleodemography. Age distributions from skeletal samples. Cambridge: Cambridge University Press 73-106.
4. Lovejoy CO, Meindl RS, Mensforth RP, Barton TJ (1985) Multifactorial determination of skeletal age at death: a method and blind tests of its accuracy. Am J Phys Anthropol 68: 1-14.
5. Lovejoy CO, Meindl RS, Pryzbeck TR, Mensforth TJ (1985) Chronological metamorphosis of the auricular surface of the ilium: A new method for the determination of age at death. Am J Phys Anthropol 68: 15-28.
6. Murray KA, Murray T (1991) A test of the auricular surface aging technique. J Forensic Sci 36: 1162-1169.
7. Buckberry JL, Chamberlain AT (2002) Age estimation from the auricular surface of the ilium: A revised method. Am J Anthropol 119: 231-239.
8. Hens SM, Belcastro MG (2012) Auricular surface aging: a blind test of the revised method on historic Italians from Sardinia. Forensic Sci Int 214: e1-e5.

9. Schmitt A (2004) Age-at-death assessment using the os pubis and the auricular surface of the ilium: a test on an identified Asian sample. Int J Osteoarchaeol 14: 1-6.

10. Osborne DL, Simmons TL, Nawrocki SP (2004) Reconsidering the auricular surface as an indicator of age at death. J Forensic Sci 49: 905-911.

11. Rougé-Maillart C, Jousset N, Vielle B, Gaudin A, Telmon N (2007) Contribution of the study of the acetabulum for age estimation in adult subjects. Foresic Sci Int 171: 103-110.

12. Rougé-Maillart C, Vielle B, Jousset N, Chappard D, Telmon N, et al. (2009) Development of a method to estimate skeletal age at death in adults using the acetabulum and the auricular surface on a Portuguese population. Forensic Sci Int 188: 191-195.

13. Rissech C, Estabrook GF, Cunha E, Malgosa A (2006) Using the acetabulum to estimate age at death of adult males. J Forensic Sci 51: 213-229.

14. Calce S, Rogers T (2011) Evaluating of age estimation technique: testing traits of the acetabulum to estimate age at death in adult males. J Forensic Sci 56: 302-311.

15. Rissech C, Estabrook GF, Cunha E, Malgosa A (2007) Estimation of age-at-death for adult males using the acetabulum, applied to four Western European populations. J Forensci Sci 52: 774-778.

16. Rougé-Maillart C, Telmon N, Rissech C, Malgosa A, Rougé D (2004) The determination of male adult age at death by central and posterior coxal analysis-A preliminary study. J Forensic Sci 49: 208-214.