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Reliability of age estimation from iliac auricular surface in a subactual Chilean sample

María José Herrera[a,*], Rodrigo Retamal[b]

[a] Departamento de Arqueología, Facultad de Ciencias Sociales, Universidad Alberto Hurtado, Almirante Barroso 10, Santiago, Chile
[b] Departamento de Antropología, Facultad de Ciencias Sociales, Universidad de Chile, Av. Ignacio Carrera Pinto 1045, Santiago, Chile

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ABSTRACT

The aim of this study was to test the reliability of Osborne et al. (2004) [8] age estimation based on the iliac auricular surface of the ilium. We selected 172 skeletons with documented sex and age-at-death and established six uniformly distributed age intervals for analysis. ANOVA was employed to assess the association of the documented age with sex and the auricular surface classification. We employed Bonferroni post-hoc tests to find any statistical differences across documented ages within each phase of Osborne's criteria. While the ANOVA showed a significant association between the documented age and the auricular surface classification, post-hoc tests found that phases 2 and 3 were the only consecutive phases with significant differences. We argue that a lack of statistical significance between consecutive phases undermines the reliability of this method for forensic purposes especially in middle adults. It may be possible that the collapse of intermediate phases would increase the accuracy of this method.

1. Introduction

Age estimation is a fundamental step in the reconstruction of a biological profile from skeletal remains. However, the reliability of age estimation has become controversial, especially in adult individuals, since it is based on the observation of skeletal traits sensitive to developmental and degenerative factors, which have lack close precision with chronological age [1–4]. As a consequence, individuals with similar chronological ages may present distinct traits. Furthermore, individual and population-level biocultural variability may affect the relationship between chronological and developmental age, undermining the reliability of methods based on different temporal and geographical samples compared to the target population [3,5].

Two of the most often employed techniques for age estimation are the pubic symphysis and the iliac auricular surface morphologies due to their higher precision based on categories of degeneration compared with other skeletal traits [5]. In particular, the auricular surface normally displays better preservation compared to the pubic symphysis, making it more suitable for forensic purposes [2]. The age estimation method based on the auricular surface was originally developed by Lovejoy et al. [6] (see Lovejoy et al. [6], Işcan and Steyn [7], and Osborne et al. [8] for a historical review of this method), who proposed eight phases for adults, starting from 20–24 to 60+ years old, divided into 5 and 10 years [2]. Osborne et al. [8] tested this method and reduced it to six phases with broader age intervals and discarded the sex and ancestry effect. According to Osborne et al. [8] their new method is preferable for forensic purposes since the broadening of the age intervals should be in agreement with the true age variation. However, this modification carries a high overlap among phases, which may hamper the distinction among phases and consequently the age estimation [5].

In Chile, the Servicio Médico Legal is the only institution in charge of all forensic cases involving the identification of human remains. Practitioners of forensic anthropology at this institution exclusively employ the method proposed by Osborne et al. [8] on the auricular surface as part of their protocol, although its accuracy has not yet been evaluated against the local population. Therefore, the objective of our study was to test the Osborne et al. [8] method within a Chilean population sample of known age-at-death. We hope that our assessments can contribute towards a more efficient positive identification process for investigations of Human Rights violations committed during the Chilean military dictatorship period (1973–1990).

* Corresponding author.
E-mail addresses: majo.hersot@gmail.com, mjherrera@antropologiafisica.cl (M.J. Herrera), roretama@uchile.cl (R. Retamal).

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2. Material and methods

For this study, we employed the Cementerio General skeletal collection. The collection is composed of Chilean individuals who died between 1960 and 1980 [9], with documented sex, age-at-death, and cause of death. The remains are currently curated at the Department of Anthropology, University of Chile. We selected a sample of 172 (84 females, 88 males) well-preserved skeletons, uniformly split into six 10-year age intervals for analyses [10,11] (Table 1). Both auricular surfaces for each individual, whenever present and well preserved, were classified was classified into 6 phases according to Osborne et al. [8]. We performed an intra-observer error test in a subsample of 20 individuals, utilizing Cohen's Kappa. Right and left auricular surfaces were also compared utilizing Cohen's Kappa, showing 87% agreement of an average score. In case of disagreement between sides, the youngest phase was selected. Descriptive statistics were calculated including confidence intervals at 95% by each phase. We tested normality using a Shapiro–Wilk test. Osborne et al. [8] means were compared at each phase of the analysis with what was obtained within the current study utilizing a Student T-test. In addition, we calculated the percentage of each age interval by each phase in order to know their distribution. We ran an ANOVA to know the association between documented age with sex, the auricular surface classification, and the interaction between both variables. Finally, we performed Bonferroni post-hoc tests to know the statistical difference of the distribution among phases. We carried out all analyses utilizing R v 3.2.3 (2015) statistical package.

3. Results

The intra-observer error test showed a weak Kappa between the first and second classifications (Table 2), even though the Kappa test showed that the agreement between both classifications was statistically significant. Table 3 shows the descriptive statistics of the current study and those obtained using the Osborne et al. [8] method, including the comparison utilizing Student T-test. Results of the current study show that phases 1, 2, and 6 had a low variation, while phases 3–5 had a high variation (Fig. 1). Confidence intervals showed that all consecutive phases overlap, excepting phases 2 and 3. The comparison between the present study and the Osborne et al. [8] method showed that phases 1 and 6 had significant differences and higher means within the sample of Cementerio General.

Table 4 shows the frequencies for each phase at each age interval. Phase 1 was observed only between 20 and 34 years, while phase 2 was observed between 20 and 44 years of age. Phases 3 and 4 were present between 30 and 64 years, although younger and older individuals also presented this phase. Phase 5 was mainly present between 40 and 79 years of age, although individuals aged between 20 and 29 years also presented this phase. Finally, phase 6 was present between 50 and 79 years of age.

The ANOVA model is presented in Table 5. The model shows an adjusted R^2 of 0.52 and a mean squared error of 12.20 years. The auricular phase classification shows a significant association with the documented age, while sex and the interaction between sex and the auricular classification were not significant. A Bonferroni post-hoc test (Table 6) shows that consecutive phases display no significant differences, except the transition between phases 2 and 3.

Table 1
Age and sex composition of the sample tested within this study.

Age	Female	Male	Total
20–29	12	24	36
30–39	11	18	29
40–49	12	12	24
50–59	13	14	27
60–69	21	12	33
70–79	15	8	23
Total	84	88	172

Table 2
Results of intra-observer tests.

Sides	Kappa	Agreement	Expected agreement	p-Value
Right	0.3563	50%	22.32%	<0.05
Left	0.2956	42.86%	18.88%	<0.05
Combined	0.3	44.12%	19.29%	<0.05

4. Discussion

The results of this study showed that the auricular phase classification proposed by Osborne et al. [8] was statistically associated with the documented ages from the Cementerio General sample, indicating an association between chronological and the biological age expressed in the auricular surface morphology. In our current study, the skeletal sample was uniformly selected aiming to avoid sample bias [4]. While this sampling procedure has been recently criticized since target populations would not have uniform age-at-death distributions [10,11], our work is not focused on age estimation of populations but rather, on age estimation of individuals.

The high scattering and overlapping observed among phases 2–5 undermine the reliability of this method in the Chilean population. We posit that the high variation of these intermediate phases may be due to their low correlation between the chronological age and the gradual nature of some traits utilized in the phase definition of the Osborne et al. [8] method. Furthermore, some individuals would display characteristics of older age ranges than others [4], which may be associated with nutritional, biomechanical, physiological, and developmental factors [12–14], reflecting some aspects of the social age [4], which is consistent with our sample, since it belongs to middle and low social classes.

While there is high variation present in the intermediate phases, this phenomenon was not observed in phases 1 and 6, possibly due to these phases having traits constrained to narrower age ranges. Although Buckberry [4] argued that narrow age ranges are associated with earlier phases, in this study we observed that the oldest phase also displayed a narrow age range. This would indicate that some traits observed in this phase are not present in younger individuals. Therefore, the intermediate phases need a re-evaluation in order to find morphological traits delimited to a range of 35–50 years of age. It is possible that the coalescence of intermediate phases into only one phase may result in higher accuracy in spite of losing precision. Once it is possible to divide the adult age range in three clear and distinguishable categories (young adult, middle adult, and old adult) it may be possible to subdivide them to secure higher precision.

The current study obtained statistical differences of mean documented ages in phases 1 and 6 compared with those estimated by the Osborne et al. [8] method. It is possible that the different means between this age estimation method and the current study in phase 1 may be due to different age sampling. The study by Osborne et al. [8] utilized a sample of individuals starting at 16 years of age onwards, while our study utilized individuals starting at 20 years of age onwards. However, for phase 6, the contrasting means were not due to sampling design but were the result of different age distributions. In this case, the Cementerio