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Aging process variability on the human skeleton: artificial network as an appropriate tool for age at death assessment

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Abstract

Adult age-at-death assessment is one of the most difficult problem encountered in paleoanthropology. Many procedures have been proposed using either skeletal remains or dental records, but most show systematic bias. Data processing of current methods are a source of error because they neglect that process of biological ageing is very variable between individuals and populations. The aim of this study is to test the potentiality of artificial neural networks (ANN) as a prediction tool. ANN have been used for a wide variety of applications where statistical methods are traditionally employed. But it performs better to solve linearly non separable patterns. We applied this technique after observation of several features' aging changes of the pubic symphysis and the auricular surface of the ilium.

Although we failed to reduce the size of the intermediate class (30–59 years), the neural network identifies, with better reliability than previous works, the youngest (20–29 years) and the oldest (above 60 years) individuals.

Keywords: Age-at-death; Artificial neural network; Adult; Pubic symphysis; Auricular surface

1. Introduction

Estimation of adult age at death is fundamental for all the studies of human skeletal remains: research on fossils, individual identification in the forensic field, paleobiological studies (health and disease, paleodemography). The validity of age-at-death assessment, one of the most difficult problems encountered by biological anthropologists, is necessary for interpretations to be reliable [1]. Biological anthropologists and forensic specialist frequently ignore that there is no linear relationships between chronological age and indicators or disregard the extremely complex variability of the ageing process. As a consequence, data processing is a great source of error, since predictions are elaborated with inappropriate statistical methods. For instance, most of ageing techniques use linear regression to correlate morphological score of one indicator and chronological age. The equation of this regression line is used to convert unknown values of the age indicators into predicted ages. But, the poorer the correlation, the greater is the bias [2]. There is a systematic trend towards overestimating the age of the young adults and underestimating that of older individuals. Given that the correlation between biological data and age is low [3,4], it represents a fundamental limitation to this predictive technique. We argue that artificial neural networks (ANN) increase the reliability of adult age-at-death assessment, since this tool is appropriate when relationship between variables is difficult to model. We applied ANN on the scoring system elaborated by [5] on the pubic symphysis and the sacropelvic surface of the ilium on 677 individuals from identified dry bone collections. As the use of multiple indicators gives better results than individual criterion [6], we pooled both indicators. We used ANN as a classifier in age range categories.

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2. Materials and methods

We observed 677 individuals, 327 males and 350 females. The mean age is 53.24 years with a minimum of 19 and a maximum of 96, the standard deviation (S.D.) is 18.09, all individuals are within three S.D. from the mean selected from five collections of known age at death. The skeletal sample was selected from five identified collections: the collection of identified skeletons (Departamento de Antropologia, Universita Coimbra, Portugal); the Spitafields collection (Museum of Natural History of London, England); the Gemmerich collection (Département d'Anthropologie et d'Ecologie, Université de Genève, Switzerland); the Alcione collection (Departamento de Medicina Legal, Facultad de Medicina Madrid, Spain) and the Hammann-Todd collection (Museum of Natural History of Cleveland, Ohio, USA). Table 1 shows the number of individuals selected in each collection.

Table 1
Number of individual observed by sex and collections

Collections	Male	Female	*N*
Coimbra	64	73	174
Londres	79	95	137
Geneve	27	19	45
Madrid	33	34	67
USAa[a]	41	44	85
USAe[b]	83	85	168

[a] African origin.
[b] European origin.

2.1. Scoring system

The current methods based on the pubic symphysis and the sacropelvic surface of the ilium have been evaluated on various skeletal collections of known age [7–9]. It has been established that they have poor reliability; moreover the scoring methods they used are rather complex and subjective.

As a consequence, we developed a gradual scale of visual scoring for each character of each criterion [5,10]. We observed three features on the pubic symphysis: posterior plate (billowings, modification, complete); ventral rampart (absent, formation, complete); dorsal lip (absent, present) and four features on the auricular surface of ilium: the transverse organization (striae, absent); the texture and porosity (fine, granulation, coarsening, porosities), the apical activity (absent, present) and the retroarticular activity (absent, present). Short description of the scoring system is given in Table 2. Notice that the label absent does not mean that the feature is missing (i.e. destroyed) but that the feature is not present. The repeatability of this visual scoring between observers is good. Morphological individuals' observations are independent from the observer [5].

2.2. Artificial neural networks (ANN)

ANN is a collective term referring to a variety of highly distributed computational models. Such models are well

Table 2
Brief description of the scoring system for the pubic symphysis and the auricular surface of the ilium

Features	Scoring			
	Score 1	Score 2	Score 3	Score 4
Pubic symphysis				
Posterior plate	Ridges and furrows	Flattening of the surface, dorsal margin begins to appear	Complete	
Ventral plate	Ridges and furrows	Flattening of the surface, rampart expanding	Ventral rampart presents a complete surface	
Dorsal lip	Regular dorsal rim	Lipping of the dorsal rim		
Auricular surface of the ilium				
Transverse organization	Undulations or striae following a transverse organisation	Absent		
Texture and porosity	Dense surface	Uniform or partially coarsening granular texture	Coarse granular texture, distinct signs of bone destruction, porosities	Irregular surface, large bone destruction, deep porosities
Apical activity	Apex sharp and distinct, regular margins	The apex becomes broader, formation of a rim		
Retroauricular activity	Smooth surface	Irregular surface, osteophytes		