Forensic Science International 275 (2017) 315.e1–315.e11

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Forensic Anthropology Population Data

Inaccuracy and bias in adult skeletal age estimation: Assessing the reliability of eight methods on individuals of varying body sizes

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ARTICLE INFO

Article history:
Received 9 January 2017
Received in revised form 6 March 2017
Accepted 10 March 2017
Available online 18 March 2017

Keywords:
Forensic Anthropology Population Data
Skeletal age estimation
Body mass
Stature
Body mass index (BMI)

ABSTRACT

Accurate age estimations are essential for identifying human skeletal remains and narrowing missing persons searches. This study examines how BMI, body mass, and stature influence inaccuracy and bias in adult skeletal age estimations obtained using eight methods. 746 skeletons from the Hamann-Todd and William Bass Collections were used. Underweight BMI, light body mass, and short-stature individuals have the most error associated with their age estimates and are consistently under-aged between 3 to 13 years. Obese BMI, heavy body mass, and tall-stature individuals are consistently over-aged between 3 to 8.5 years. The most reliable methods for smaller-bodied individuals are Kunos et al. (first rib) and Buckberry-Chamberlain (auricular surface); for individuals in the average range, İşcan et al. (fourth ribs) and Passalacqua (sacrum); and for larger-bodied individuals, İşcan et al., Passalacqua, and Rougé-Maillart et al. (auricular surface and acetabulum). Lovejoy et al. (auricular surface) and Suchey-Brooks (pubic symphysis) produce consistent inaccuracy and bias scores across all body size groups. The least reliable method for smaller-bodied individuals is İşcan et al.; for larger-bodied individuals, Buckberry-Chamberlain; and across all body size groups, DiGangi et al. (first rib).

1. Introduction

Accurate age estimations are essential for identifying human skeletal remains and narrowing missing persons searches in forensic contexts. Reliability in adult skeletal age estimations is generally lower than ideal, especially for individuals over the age of 40 years. Validation studies have shown that there are population differences [1–9], sex differences [10,11], socio-economic differences [12–14], and individual variation differences [15–18] that affect the age changes observed on bones.

While a significant body of work has established the uneven reliability of age estimation methods, these studies have not systematically considered body size as one of the key factors affecting the results. Recently, articles by Merritt [19] and Wescott and Drew [20] have shown that the body mass index (BMI) influences age estimations. Merritt [19] demonstrated using transition analysis that the commonly used İşcan et al., Lovejoy et al., Buckberry-Chamberlain, and Suchey-Brooks methods consistently under-age underweight individuals and over-age obese individuals. Similarly, Wescott and Drew [20] presented data showing that the Buckberry-Chamberlain and Suchey-Brooks methods over-age obese BMI individuals compared to normal BMI individuals. Merritt [19] also used stature and body mass as body size variables, and her results showed that short individuals are under-aged compared to tall individuals; lighter-bodied individuals are under-aged compared to heavier individuals; tall individuals are over-aged compared to short individuals; and individuals with a high body mass are over-aged compared to individuals with a low body mass. These findings suggest that obese and tall individuals experience accelerated skeletal aging and underweight and short individuals experience decelerated skeletal aging.

This paper expands on these findings by examining the ways BMI, body mass, and stature affect inaccuracy and bias scores for eight age estimation methods. While the creation of one universally reliable age estimation method may not be possible, this study identifies which methods offer better reliability for small-bodied individuals (i.e., individuals who are in the underweight BMI category, under 55 kg, or under 1.60 m), large-bodied individuals (i.e., individuals in the obese BMI category, over 80 kg, or over 1.81 m), and individuals of an average-range body size (i.e., individuals in the normal and overweight BMI categories, between 56 kg and 79 kg, or between 1.61 m and 1.80m). In this study, small-bodied, average-bodied, and large-bodied individuals were

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http://dx.doi.org/10.1016/j.forsciint.2017.03.003
0379-0738/

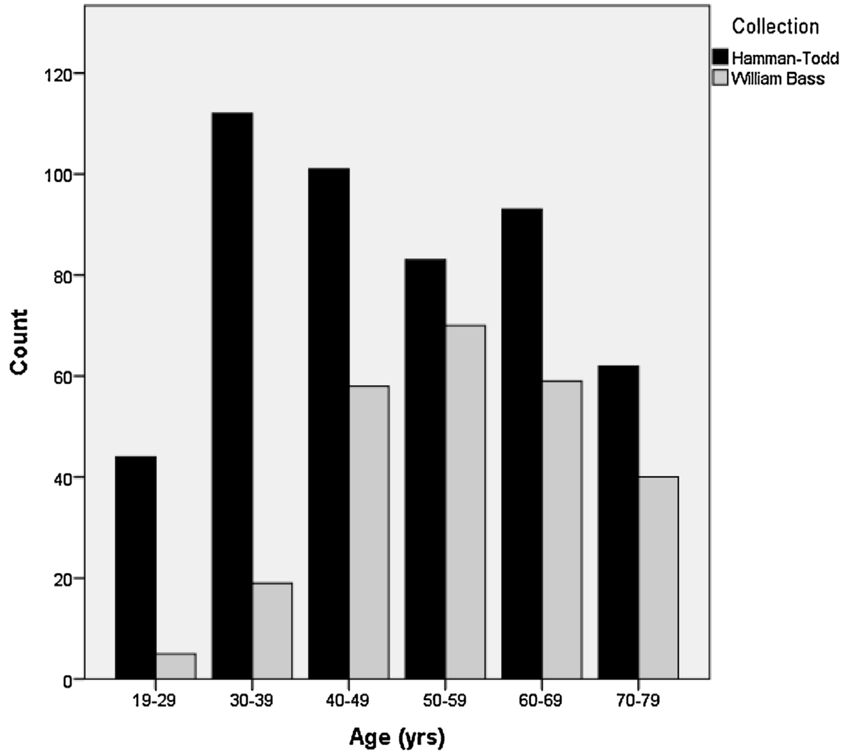

Fig. 1. Age structure for the Hamman-Todd and William Bass Collections.

identified through a cluster analysis where individuals were assigned to equal, unbiased groups based on the stature and body mass of this sample.

2. Materials

746 individuals from the Hamann-Todd and William Bass collections were used for this project (see Fig. 1 for the age structure from each collection). The individuals ranged in age from 19 to 79 years, with a mean age of 51.4 years. Though the sample comes from two different collections, there are no significant differences for the inaccuracy and bias scores between the collections for BMI (inaccuracy $F[1, 1.4] = 0.070$, $p = 0.791$; bias $F[1, 0] = 0.003$, $p = 0.957$), body mass (inaccuracy $F[1, 0] = 0.001$, $p = 0.984$; bias $F[1, 36] = 0.447$, $p = 0.504$), and stature (inaccuracy $F[1,28.2] = 1.443$, $p = 0.230$; bias $F[1, 4] = 0.048$, $p = 0.827$). Therefore, the sample was combined to form one large dataset. Table 1 displays the distribution of age, sex, ancestry, and body size statistics for the combined sample. Stature and body mass are cadaver measurements that were taken at the time of autopsy.

The sample was selected in order to include a wide range of body sizes, and was not random. Exclusion criteria included: individuals where the age at death was estimated from soft tissue; individuals who died of a wasting disease (for example, cancer, tuberculosis); individuals shorter than 1.40 m and individuals taller than 1.95m, due to small sample sizes; and individuals who weighed less than 40.14 kg, to reflect modern population parameters. For the specific criteria used in the selection of the specimens used in this study and the study limitations in using these collections, refer to Merritt [19].

3. Methods

Age assessments were performed on each skeleton without knowledge of the recorded age, BMI, body mass, or stature. Sex was known for all individuals as the İşcan et al. and Suchey-Brooks methods have sex-specific criteria. The mean age at death within each phase for each method was then compared to the recorded age at death from the Hamann-Todd and William Bass collection documentation, and inaccuracy and bias scores were calculated.

Table 1
Descriptive statistics for total sample.

Sex, ancestry, and age categories	n	Mean age	Average stature (m)	Stature range (m)	Average body mass (kg)	Body mass range (kg)
Males	554	51.5	1.75	1.42–1.95	71.74	40.14–190.51
Females	201	51.2	1.61	1.42–1.83	60.17	40.37–99.79
European ancestry	540	53.9	1.71	1.50–1.95	70.30	40.37–190.51
African–American Ancestry	206	44.8	1.72	1.42–1.92	64.22	40.14–99.79
19–29 years	49	24.6	1.72	1.50–1.90	63.46	40.14–89.81
30–39 years	131	35.0	1.73	1.42–1.92	69.30	40.82–136.08
40–49 years	159	44.5	1.71	1.44–1.93	70.29	40.37–181.44
50–59 years	153	53.7	1.72	1.45–1.95	73.26	41.50–190.51
60–69 years	152	64.0	1.71	1.49–1.93	67.17	40.82–129.27
70–79 years	102	73.9	1.67	1.47–1.86	62.83	40.37–99.79
Total	746	51.4	1.71	1.42–1.95	68.62	40.14–190.51