JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, March 2011, Vol. 56, No. 2
doi: 10.1111/j.1556-4029.2010.01658.x
Available online at: onlinelibrary.wiley.com

PAPER

ANTHROPOLOGY

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A Re-examination of Cremains Weight: Sex and Age Variation in a Northern California Sample*

ABSTRACT: The reduction of modern commercially cremated remains into a fine powder negates the use of traditional methods of skeletal analysis. The literature on the use of cremains weight for estimating aspects of the biologic profile is limited, often with conflicting results. This study re-evaluates the value of weight in the assessment of biologic parameters from modern cremated remains. A sample of adults was collected in northern California ($n = 756$), with a cremains weight averaging 2737.1 g. Males were significantly heavier than females ($\bar{x} = 3233.2$ g versus $\bar{x} = 2238.3$ g, respectively; $p < 0.001$). Comparison of this sample with other previously reported samples from southern California, Florida, and Tennessee indicates a consistent sex difference, with the most similar mean values to the Tennessee study. Although cremains weight decreases with age as expected, the relationship is weak; thus, cremains weight cannot accurately predict age-at-death. While sex estimation shows considerable accuracy (86.3% for males and 80.9% for females), sectioning points may be population specific.

KEYWORDS: forensic science, forensic anthropology, cremains weight, sex estimation, regional variation

According to the Cremation Association of North America (1), the use of cremation in the U.S. has steadily increased over the last few decades, a trend which is predicted to continue. This highlights the need for a greater understanding of the challenges and limitations faced by forensic researchers when studying modern cremated remains. A plethora of research on burned human bone exists, including the study of fracture patterns (2–4), color changes (2,5,6), assessment of prefire trauma (7,8), and demographic profiles (9,10). While this information is often useful in both archeological and forensic contexts, modern commercially cremated remains (cremains) provide a unique set of challenges because of the practice of pulverization of calcined bone into osteologically unrecognizable fragments.

One useful measure of modern commercially cremated remains is weight. Sonek's (11) unpublished study in southern California calculated average cremains weights to estimate the minimum number of individuals and to assess commingling; the mean values of Sonek's (11) raw data were later reported by Murad (12). Warren and Maples (13) and Bass and Jantz (14) provide the only two published studies that have directly assessed the value of cremains weight in establishing aspects of the biologic profile, each producing different results.

Warren and Maples (13) established equations to predict cremains weight from cadaveric and calculated skeletal weight, as well as stature. This study reported an average cremains weight of 2430 g, with males ($\bar{x} = 2893$ g) weighing significantly more than females ($\bar{x} = 1840$ g); however, there was a degree of overlap between the sexes (13). Using a sample of 90 adults, they were able to determine that stature had the highest correlation with cremains weight and cadaveric weight the lowest (13). Skeletal weight was calculated based on four anthropometric measures, which were influenced by soft tissue thickness differences. Thus, the authors state that weights taken on dry skeletal material alone may produce different results (13). Bass and Jantz (14) conducted a study on cremains weight with data on over 300 individuals. Interestingly, the average cremains weights for males ($\bar{x} = 3379.8$ g) and females ($\bar{x} = 2350.2$ g) were statistically significantly heavier than those found by Sonek (11) and Warren and Maples (13). They equated this finding to differences in the body composition of individuals living within the respective areas of the studies, citing that those in Tennessee may have had greater body mass and thus a higher cremains weight.

This study examines the relationship between average cremains weight, sex, and age-at-death using a large sample from northern California. Additionally, this research compares the data with three previous studies to address differences in cremains weight reported in the literature.

Materials and Methods

Permission was granted from the Newton-Bracewell Chico Funeral Home (NBCFH) in Chico, CA, to conduct research on data collected by staff for cremations performed between December 2003 and October 2006. The sample consists of 384 male and 372 female adults ($n = 756$). Adults were defined as individuals older than 20 years of age to ensure completion of longitudinal bone growth (15). Two individuals were excluded from the study because sex could not be determined from the available records.

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*Presented at the 59th Annual Meeting of the American Academy of Forensic Sciences, February 19–24, 2007, in San Antonio, TX.

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Received 23 Nov. 2009; and in revised form 2 Feb. 2010; accepted 28 Feb. 2010.

All cremations were completed with a Power-Pak II retort (Industrial Equipment and Engineering Company, Orlando, FL). Average cremation temperatures varied from 871 to 927°C, but may have reached as high as 1150°C. The average duration of a cremation was *c.* 2 h. When complete, the cremains were left to cool within the retort for 30 min. All metal, prosthetics, and other nonosseous materials were removed prior to processing. The only prosthetic device removed prior to cremation was the pacemaker, because of the explosive nature of the batteries upon heating. The cremains were swept into the processing machine, which ground the bone fragments for 30–60 sec until fragments were osteologically unrecognizable and had an ash-like consistency.

After processing, the cremains were placed in a plastic liner within a previously weighed urn. Final cremains weight was calculated by subtracting the urn weight from the filled urn weight. The metal identification tag accompanying each decedent throughout the cremation process was added to the urn after weighing. Weights were originally recorded in 0.25-lb increments by the NBCFH staff. For comparability with previous studies, all weights were converted into grams using the following formula: $g = lbs \times 453.6$.

In the beginning of July 2006, weights were recorded in grams using a standard autopsy hanging scale. The second weighing method was implemented to test the accuracy of the previous weighing method used by NBCFH staff. Both scales were tested using known weights of 295 and 147.5 g and found to be accurate. An independent sample *t*-test found no significant difference between the cremains weights of the two methods ($t = 1.165$, df = 166, $p = 0.246$).

Data collected at the time of cremation by the funeral home staff were recorded following standard operating procedures outlined by NBCFH. Data collection for this study consisted of sex, age-at-death, date of cremation, cremains weight, estimated body weight, cremation start and end times, use of embalming fluids, and the type of cremation container used. The software package SPSS 14.0 (SPSS, Inc., Chicago, IL) was used for statistical analysis, with statistical significance set at $\alpha = 0.05$.

Descriptive statistics were calculated for both cremains weight and age-at-death. Independent sample *t*-tests were used to evaluate sex differences in cremains weight. Additionally, linear regression and correlation were used to assess the relationship between cremains weight and age-at-death. A weighted mean was used to establish a sectioning point in cremains weight values for prediction of sex.

Results

The majority of the NBCFH sample was cremated in cardboard containers (91.8%), with 7.1% in containers composed of other materials. The container used was not recorded for 1.1% of the sample. The cremains weight of decedents cremated in noncardboard containers ($n = 52$) and a subset of those cremated within cardboard containers ($n = 69$) are not significantly different ($t = 0.18$, df = 119, $p = 0.858$), indicating no relationship between container type and cremains weight. The majority of the sample did not involve embalming fluids prior to cremation (93.1%), with only 6.1% embalmed and 0.8% not recorded.

Sex Differences

Descriptive statistics for the NBCFH sample are reported in Tables 1 and 2, and the distribution of cremains weight by sex is shown in Fig. 1. The mean cremains weight for the total sample ($n = 728$) is 2737.1 ± 729.7 g (1 SD). The mean weight for males is 3233.2 ± 581.0 g, and the mean weight for females is 2238.3 ± 482.0 g. The cremains of males weigh 995 g more than those of females, a statistically significant difference ($t = 25.151$, df = 703.396, $p < 0.001$). The mean age of the sample is 73.7 years, with males ($\bar{x} = 71.4$) *c.* 5 years younger than females ($\bar{x} = 76.1$), a statistically significant difference ($t = -4.07$, df = 750.55, $p < 0.001$). The sample was stratified into 10-year categories (20–29 to 100+) to determine whether sex differences in cremains weights are age dependent. Individuals in the 20–29, 30–39, and 100+ age categories were excluded because of small sample size. Comparisons by sex indicate significant differences in cremains weight for all age categories examined ($p < 0.001$).

A sectioning point between the sexes for cremains weight was set at 2737.1 g using the weighted mean. Weights above this value are classified as male and weights below are classified as female. Within the sample, sex estimation using cremains weight had an overall accuracy rate of 83.7% (Table 3). Females classified correctly in 87.3% of cases (317/363), while males classified correctly in 79.5% of cases (290/365). To accurately predict sex for a single

TABLE 1—*Sex and age-at-death distribution of the Newton-Bracewell Chico Funeral Home sample.*

Sex	*N*	Mean Age-at-Death	Minimum	Maximum	Standard Deviation	Standard Error of the Mean
Females	372	76.1	20	106	15.3	0.8
Males	384	71.4	20	102	16.9	0.9
Total	756	73.7	20	106	16.3	0.6

TABLE 2—*Descriptive statistics for cremains weight (in grams) for the Newton-Bracewell Chico Funeral Home sample.*

Sex	*N*	Mean Weight (g)	Minimum	Maximum	Standard Deviation	Standard Error of Mean
Females	363	2238.3	1057	4309	482.0	25.3
Males	365	3233.2	1701	4990	581.0	30.4
Total	728	2737.1	1057	4990	729.7	27.0

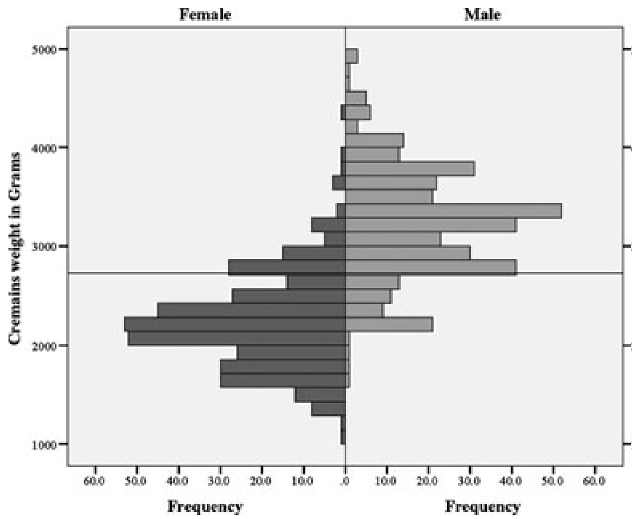

FIG. 1—*Cremains weight distribution of the sexes with a reference line illustrating the sectioning point.*

TABLE 3—*Sex classification of cremains weight in the Newton-Bracewell Chico Funeral Home (NBCFH) sample using a sectioning point (SP) of 2737.1 g.*

NBCFH sample	*N*	# Correct	# Incorrect	% Correct	% Incorrect
Overall accuracy rate					
Females	363	317	46	87.3	12.7
Males	365	290	75	79.5	20.5
Total	728	607	121	83.4	16.6
Single case accuracy rate*					
Below SP (<2737.1 g)	392	317	75	80.9	19.1
Above SP (>2737.1 g)	336	290	46	86.3	13.7

*Following method of Klepinger and Giles (16).

case, the true error rate formula outlined by Klepinger and Giles (16) was used. This provides an accuracy rate of 86.3% in predicting male sex if the value falls above the sectioning point and an accuracy rate of 80.9% in predicting female sex if the value falls below the sectioning point.

Age Differences

As expected, the age distribution for both males and females is skewed toward the older age categories. Regression and correlation statistics indicate a significant negative relationship between age and cremains weight ($r = -0.354$, $p < 0.001$, Table 4). Examination of the sexes separately produced results similar to the total sample, although females show a slightly higher correlation ($r = -0.392$) than males ($r = -0.319$) as expected. The amount of variation in cremains weight explained by age is low, as seen in the r^2 values for each subgroup in Table 4. Figure 2 illustrates the negative relationship between age and cremains weight for both males and females and shows considerable overlap between the distributions.

Comparative Analysis

The average cremains weight of the NBCFH sample is higher than predicted based on available comparative data. When compared to the average weights reported by Murad (12) from Sonek's (11) data and Warren and Maples (13), the NBCFH sample mean weights are substantially higher; however, the NBCFH weights are comparable to those published by Bass and Jantz (14). To statistically assess the four samples, raw data were obtained for the three other studies (Sonek [11] data from TA Murad; R. Jantz, personal communication; Warren and Maples [13]). Because Sonek's (11) study was not published, all values reported here were recalculated from Sonek's raw data provided to one of the authors (TAM). To minimize a sample size bias, a subset of 100 males and females were randomly sampled within the larger NBCFH sample, with nonadults and cases with missing cremains weight information excluded. To maintain consistency between the studies, adulthood was established at 20 years of age and individuals considered to be subadults (<20 years of age) from all studies were excluded from the comparative analysis. All reported statistics were calculated from the new data sets. When the pooled sex samples were compared (Table 5), a significant difference was found in the mean cremains weights (analysis of variance [ANOVA], $p < 0.001$). A *post hoc* Bonferroni test revealed no significant differences between the Sonek (11) and Warren and Maples (13) studies, while the NBCFH sample showed no significant differences from the Bass and Jantz (14) sample. This relationship also holds when males and females from each sample are compared separately (Table 5). Two prior cremation studies from southern California and Florida (11,13) reported similar mean cremains weight values, which significantly differed from the data reported by Bass and Jantz (14) from Tennessee. Thus, the similar average weight for the NBCFH and the Bass and Jantz (14) data sets was somewhat unexpected.

Discussion

A number of factors may account for the high cremains weight within the NBCFH sample. One possible source of error is the weighing methodology. Although this was a concern because of the lack of direct involvement by the authors in the weighing and recording process, the consistency with which the NBCFH staff recorded the data suggests that sample weights are accurate. Another possibility is the influence of cremation container. As stated in Warren and Maples (13), cremation containers were cardboard, while in the present study and that of Bass and Jantz (14) some containers were made of other materials. The relationship between cremation container and cremains weight was found to be insignificant, indicating other factors are contributing to the difference in the cremains weight between studies.

Other possible contributing factors to the higher cremains weight are a younger age distribution, an uneven sex distribution, regional genetic differences, diet, activity levels, or a combination of these factors. However, the average age of the NBCFH sample is higher than in the other studies, which should have resulted in a lower cremains weight. Additionally, a bias in the sex distribution of the NBCFH sample is not the cause because of a nearly perfect 50/50 representation of the sexes (49.9% female vs. 50.1% male). This suggests that other factors, such as variation in diet, activity, and/or bone mineral density, may be contributing to the differences in average cremains weight between the regions included within the samples.

The sex difference in average cremains weight conformed to expectations, with males weighing more than females. The difference of *c*. 1000 g is consistent with the two other published studies (13,14), thus providing support for significant sex differences in cremains weight. This difference reflects the well-established sex difference in body size (15,17,18), as well as known sex differences in bone mineral density (19,20). The consistent and significant difference in cremains weight between the sexes within each age category indicates that these differences are real and not an artifact of an age–sex bias in the sample.

Because studies have shown that only hydroxyapatite persists in calcined remains heated beyond 800°C (21–23), cremains weights

TABLE 4—*Regression and correlation coefficients for cremains weight and age in the Newton-Bracewell Chico Funeral Home sample.*

	r	r^2	df	*F*-Ratio	*p*-Value	Regression Equation (y=)	Standard Error of Estimate
Total	−0.354	0.125	1.726	104.103	<0.001	95.402 ± 0.008 (CW)	15.321
Females	−0.392	0.153	1.361	65.412	<0.001	103.896 ± 0.012 (CW)	14.087
Males	−0.319	0.102	1.363	41.262	<0.001	101.570 ± 0.009 (CW)	16.190

CW, cremains weight.

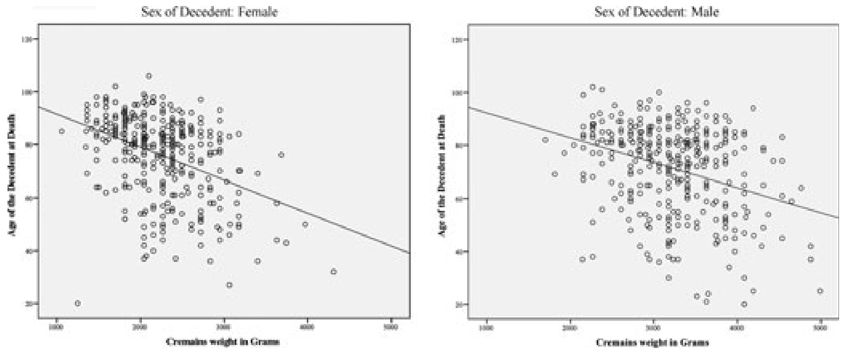

FIG. 2—*Linear regression plot of the relationship between cremains weight and age for both sexes.*

TABLE 5—*Average cremains weight and ANOVA results of the selected Newton-Bracewell Chico Funeral Home (NBCFH), Sonek (11), Warren and Maples (13), and Bass and Jantz (14) samples.*

Sample	*N*	Mean	Standard Deviation	df	*F*	*p*-Value
Females						
Sonek	91	1928.7	581.8	3.376	17.856	<0.001*
Warren and Maples	37	1834.5	397.9			
Bass and Jantz	154	2350.3	538.2			
NBCFH	98	2246.4	508.5			
Males						
Sonek	94	2822.0	587.4	3.375	21.376	<0.001*
Warren and Maples	47	2909.6	499.0			
Bass and Jantz	150	3394.5	625.6			
NBCFH	88	3258.7	601.0			
Total sample						
Sonek	185	2382.6	735.2	3.755	18.762	<0.001*
Warren and Maples	84	2436.1	703.5			
Bass and Jantz	304	2865.6	782.4			
NBCFH	186	2725.3	749.8			

**Post hoc* Bonferroni test shows no significant differences between the Sonek and Warren and Maples data sets and between the Bass and Jantz and NBCFH data sets.

appear to be measuring the remaining bone mineral fraction. Thus, factors that affect bone mineral density *in vivo* should also be reflected in cremains weight. Brown et al. (24) and Deng et al. (25) examined the effects of genetics and environmental factors on bone mineral density and found a high level of heritability, although they did not identify the specific genes involved. This indicates that the genetic makeup of an individual may influence bone mineral density and thus cremains weight. Genetic variation between populations may potentially contribute to differences in cremains weight between the regions sampled in this and other studies (11,13,14).

Warren and Maples (13) found that stature is highly correlated with cremains weight. This may partially explain the cremains weight difference between males and females. The later onset of the adolescent growth spurt in males allows more time for growth prior to the spurt, resulting in a taller adult statures (26). The greater skeletal mass because of taller statures and higher bone mineral density in males may contribute to their heavier cremains weight. The strong relationship with stature reported by Warren and Maples (13) may also be a factor in the differences between the regional studies. A well-established secular trend of increasing stature overtime within the population of the U.S. has been documented (27,28). With increased stature, there is greater bone mass and thus increased cremains weight. Initially, secular trend in stature was thought to be a contributing factor in the differences between the cremains weight groupings of the four studies, because the data from Sonek (11) and Warren and Maples (13) were collected earlier than the more contemporaneous data of the current sample and those of Bass and Jantz (14). Examination of the data reported by Meadows and Jantz (27) indicates that most of the secular trend of increased stature in the U.S. had already occurred by the time decedents within the NBCFH sample reached adulthood, suggesting secular trends are not a primary factor influencing differences in cremains weight. Because of limitations of the available data within the NBCFH sample, stature could not be assessed but this variable warrants further investigation.

Sex estimation using cremains weight shows considerable accuracy within this sample. There are a number of factors that negatively influence bone mineral density (e.g., disease, malnutrition, and lack of activity), which may result in reduced cremains weights. This increases the likelihood of misclassifying a male as a female. Conversely, females may be misclassified as males in cases of taller statures or larger skeletal frames. Given the similar degree of correct classification for both sexes, the sectioning point of 2737.1 g is the most appropriate value for sex estimation. Although there is a reasonably high level of accuracy in sex estimation using cremains weight, the closer the value is to the sectioning point the greater the chance of error. However, the effect of age on cremains weight also needs to be considered. This may result in increased misclassification of older males as females;

young females may also be more easily misclassified as males than older females.

When the sectioning point value established for the NBCFH sample is applied to the other studies to determine the general applicability of the value, accuracy decreases. In both the Sonek (11) and Warren and Maples (13) samples, the prediction rate for females was extremely high (92.4% and 97.3%, respectively); however, the rate for males was only slightly better than guessing (56.4% and 68.1%, respectively). This indicates that the sectioning point is too high for the Sonek (11) and Warren and Maples (13) studies, lending support for the population-dependent nature of this value. When applied to the Bass and Jantz (14) data, the sectioning point correctly classifies males in 86% of cases and females in 77.9% of cases. The poor predictive value of the NBCFH sectioning point for the two earliest studies shows the need for a more appropriate value applicable across a broader range of populations.

The four samples were pooled to calculate a more broadly applicable sectioning point, which was established at 2697.3 g. This resulted in the correct classification of males in 80.2% and females in 82.1% of cases. When Klepinger and Giles' (16) method is applied, the correct classification of a single case was 82.6% for males and 80.4% for females. This indicates that the sectioning point based on the pooled cremains sample is valid for sex estimation.

The negative relationship between cremains weight and age also met expectations because of the well-documented loss of bone mineral density with age. Earlier research by Trotter and Hixon (29) addressed changes in bone weight, density, and ash percentage weight in dry bone from the fetal period through old age. Their study showed an increase in all three values throughout the subadult years, with a steady decrease beginning in the late 20s to early 30s. As expected, the rate of cremains weight loss with age in females is higher than in males within the NBCFH sample. Numerous studies in the clinical literature have shown a greater loss of bone mineral density in females associated with the onset of menopause and accompanying hormonal changes (30,31). The change in cremains weight with age may highlight the relationship between cremains weight and age-dependent loss in bone mineral density, which affects females to a greater degree than males.

Prior to this study, the authors hypothesized that cremains weight may also be useful in narrowing age-at-death. However, the large standard error of prediction and the low amount of variation in cremains weight explained by age (r^2 = 0.102–0.153) produced age estimates that are considerably broad. Thus, the relationship between age of the decedent and cremains weight should only be considered in relation to its effect on sex estimation.

Conclusions

Cremains weight is a useful measure for sex estimation in instances when other biologic information is otherwise unavailable. The use of a sectioning point for discriminating between the sexes based on cremains weight provides an initial line of evidence for establishing aspects of the biologic profile. The relationship between cremains weight and age is weak, and thus, age should only be considered in light of its influence on sex estimation. Regional variation in cremains weight cannot be directly attributed to an age–sex bias in the samples, secular trend, or the use of different cremation containers, thus raising additional questions that need further research. By pooling the four available data sets, a sectioning point more applicable across regions was established and provided considerable accuracy in the correct prediction of sex. While there are many factors, such as stature and body weight, that need further exploration, the consistent relationship between cremains weight and biologic sex has been firmly established.

Acknowledgments

Thank you to the anonymous reviewers of *JFS* for their comments and suggestions. We would like to acknowledge Ric Newton, Bob Bracewell, and the staff at Newton-Bracewell Chico Funeral Home for their permission and willingness to work with us on this project. Thank you also to Dr. Richard Jantz for providing raw and Dr. Michael Warren for contributing published data.

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