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The Anthropometry of Contemporary Commercial Cremation*

REFERENCE: Warren MW, Maples WR. The anthropometry of contemporary commercial cremation. J Forensic Sci 1997; 42(3):417–423.

ABSTRACT: This study establishes baseline parameters and examines those variables thought to influence cremains weights. Data were collected during the cremation of 100 individuals. A series of measurements was taken to determine relative skeletal robusticity. The weight, stature, sex, and age of each cadaver was recorded prior to cremation. The average cremains weight for the fully developed adults (n = 91) was 2430 g and ranged from 876 g to 3784 g. Male and female means were separated by 1053 g, but there was considerable overlap in the distribution. All cremains weights above 2750 g were male and all cremains weights below 1887 g were female. Five amputees and one long bone donor produced cremains weights below the means for their respective groups, reflecting the relative contribution of the thick cortical bone of the limbs to total skeletal weight, and thus to total cremains weight. Cremains weight represented approximately 3.5% of total body weight in adults, 2.5% of total body weight in children, and approximately 1% of total body weight in fetuses. The most accurate predictor of cremains weight was cadaver stature ($r = .8473$; $p < .01$). Calculated skeletal weight was also highly correlated with cremains weight ($r = .7986$; $p < .01$). Cadaveric weight was least correlated with cremains weight ($r = .5470$; $p < .01$). Regression formulae were calculated for each of the variables.

KEYWORDS: forensic science, forensic anthropology, physical anthropology, cremation, anthropometry, human identification

Physical anthropologists have often dealt with burned or cremated bone in their investigation of human skeletal remains. Although inhumation is still the most common means of disposal of human remains in the United States, cremation has played a role in the burial customs of many different peoples in North America since the Late Archaic period (1). Physical anthropologists have traditionally directed their research toward interpreting prehistoric and historic cremation practices. Analysis of cremation data have been used in population and ecology studies, as well as answering questions about early cremation techniques.

The increasing incidence of commercial cremation in contemporary society is posing new questions for anthropologists. Improper disposal of cremated remains (cremains), disputed identity of cremains, and cremation as a means of destroying forensic evidence are issues that are increasingly being brought to the attention of forensic anthropologists. The thorough job of reduction accomplished by commercial crematoria presents a formidable challenge. The reduction process is made complete by, not only the incineration of the body, but mechanical reduction in a processor that renders the cremains to small particles and ash suitable for inurnment or "scattering." The investigator may be asked to find evidence among the cremains that can help to establish the decedent's identity, refute the claimed origin of the cremains, or show that the incinerated remains are from a commercial crematory and therefore represent a death that has already been investigated by the authorities.

This study examines the distribution of normal cremains weights and explores the gross factors affecting cremains weight. The relationship of cremains weight to three variables, cadaver stature, cadaver weight and calculated skeletal weight, is examined with the purpose of establishing correlation coefficients for predicting cremains weight.

The literature of cremation may be broken down into four primary categories: The attempt to classify burned bone by analysis and experimentation (1–4); the study of early cremation practices (2,5–7); histological studies of burned bone (8–12); and the analysis of contemporary commercial cremation (13–16). Case studies in the forensic literature have focused on inappropriate disposal of cremains and the incineration of remains in an attempt to conceal evidence (17–22).

Methods

Permission was obtained from a crematorium to conduct research during the cremation of 100 cadavers. The sex and, when possible, the age were recorded for each cadaver. A series of four anthropometric measurements were taken on each cadaver utilizing a spreading caliper: The maximum epicondylar diameter of the humerus; the bistyloid diameter of the articulated radius and ulna; the bicondylar diameter of the femur; and the bimalleolar diameter of the articulated tibia and fibula (after Matiegka and Trotter)(23,24). Skeletal weight was calculated based on Matiegka's formula: Skeletal mass (g) = $1.2D^2H$ (where D is the average of the four measurements and H is standing height). Matiegka's suggested coefficient of 1.2 has been discarded in this study because the variable "calculated skeletal weight" is not intended by the authors to represent actual skeletal weight, but simply relative skeletal robusticity. Also, the present study, like Matiegka, does not correct for tissue thickness, because it may be considered a function of total body weight and therefore possibly a component of cremains weight.

The four measurements were chosen because of their established correlation with skeletal weight ($r = .7007$, significant at the .01 level)(24). They are also among the least invasive measurements for predicting skeletal weight in the literature. It should be noted

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*Partially funded by a Forensic Sciences Foundation Lucas Research Grant, 1994.

Received 28 May 1996; and in revised form 26 Sept. 1996; accepted 30 Sept. 1996.

that research involving mortuary practices is of a highly sensitive nature and certain constraints were placed on this project that were unavoidable.

Each cadaver was weighed prior to being placed in the cremation retort. The weight was determined by placing the cadaver, within its cardboard container, on a medical spinal immobilization board. The board, container and cadaver were weighed on a digital platform scale and the weight of the board and container subtracted to arrive at a cadaveric weight. The stature was recorded by pulling the cadaver up in the container until the head was touching the top, then measuring from the container top to the sole of the left foot on a coronal plane through the medial malleolus (25).

The remains were cremated following the standard operating procedure used by the crematorium. Cremation temperatures and duration were recorded in each case. The data were analyzed and formulae for predicting cremains weights were derived.

The sample was composed of the cadavers of 100 individuals which ranged from the fetal development stage to age 102. The sample included four anatomical cadavers that had been prepared for use by the Florida State Anatomical Board, and then rejected as useful specimens. None of the anatomical specimens had been dissected. The remaining samples were individuals whose families had requested cremation under contract with a funeral director. Seven of these individuals had been autopsied by the district medical examiner.

A fetus and two children were excluded from the general sample in order to prevent the statistics on cremains weights and anthropometrics from being skewed by the small body weights of these individuals. One adult cadaver (a bone-marrow donor from which the long bones had been harvested) and five individuals with lower leg amputations were also excluded for this reason. These nine cases will be discussed separately.

The remaining 91 were fully developed adults and will be referred to as the study sample. Seventy had been refrigerated for 48 h prior to their cremation and the remainder had been embalmed for presentation to family or prepared as anatomical specimens prior to cremation. Age was known for the majority of the sample (n = 80) and ranged from 14 to 102, with a mean age of 69 years. Those individuals for which an age could not be determined from mortuary records were elderly adults (c. 60–80 years of age). Fifty-one of the study sample were males and 40 were females.

Cadaveric weight was highly variable. Although information concerning cause of death was unavailable, it was apparent that several emaciated individuals in the sample had expired from a chronic metabolic disease process. Others in the sample had expired from trauma or acute disease. The weights ranged from 25.3 kg for an elderly female to approximately 170 kg for an obese male (the latter individual was too large to be safely lifted onto the scales by two people. The weight of 170 kg was reported to the funeral director by hospital staff, who used a hydraulic lift to weigh the patient prior to his death).

Anthropometry and Calculated Skeletal Weight

The four anthropometric measurements were heavily skewed by highly variable soft tissue thicknesses. The epicondylar and bicondylar diameters were particularly skewed by obesity and therefore yielded increased skeletal weights for those individuals of greater cadaveric weight. Moreover, the skin turgor of the cadavers varied widely depending on the method of preservation and/or the presence of peripheral edema. Embalming hardens the soft tissues relative to refrigeration. The anatomical specimens had been embalmed, then given additional chemicals to enhance the preservation of the cadaver and render it suitable for dissection. The bistyloid and bimalleolar diameters were less effected. (See Table 1 for descriptive statistics and Table 2 for the raw data of the total sample)

Calculated skeletal weight ranged from 4.79 kg to 12.98 kg and comprised from 6.72% to 25.47% of body weight. The calculated skeletal weight was, of course, a greater percentage of body weight in the emaciated cadavers and a lesser percentage of body weight in the obese cadavers. The average calculated skeletal weight was 8.386 kg, or 13.79% of total body weight.

The variable "calculated skeletal weight," as used in this study should not be considered an accurate estimation of actual skeletal weight, but simply an expression of the expected relationship between skeletal weight, the four anthropometric measurements, and cadaveric stature. Again, because of the influence of soft tissue thicknesses on the anthropometric measurements, calculated skeletal weight also includes some unknown component of cadaveric weight.

Results

Cremains weights for the 91 fully developed adults ranged from 876 to 3784 g. The average cremains weight was 2430 g. The ranges and means of each sex were:

	Males	*Females*	*Total*
Minimum cremains weight	1887	876	876
Maximum cremains weight	3784	2750	3784
Mean cremains weight	2893	1840	2430

The distribution is shown in Fig. 1. Although the means for each sex show a fairly good separation, there is considerable overlap between the sexes. Cremains weights above 2750 g were male and cremains weights below 1887 g were female.

The mean cremains weight for the study sample is .0368% of the mean cadaver weight. Among the two infants and fetus excluded from the study sample, cremains weight was .0253% of body weight for the four-year-old; .0215% of body weight for the two-year-old; and .0103% of body weight for the fetus.

It is significant that all five of the amputees and the individual from whom the long bones had been harvested fell below the mean cremains weight for their respective sex. The male with the least cremains weight was the long-bone donor, a fairly large-framed 47-year-old, who produced only 1798 g of cremains. The lesser cremains weights among the amputees and the long-bone donor suggest that a significant portion of cremains weight is derived from the thick cortices of the long bones. The figures for the amputees and the long-bone donor are shown below in Table 3.

It proved impossible to record cremains volume with consistency. Different volume figures could be obtained from the same set of cremains depending on how tightly the cremains were packed. Because each type of processor produces fragments of different size, it was determined that statements pertaining to cremains volume would be of limited utility. It was generally noted, however, that with the exception of four or five cases, almost all cremains could be packed into the 3750 cm^3 temporary urn used by the crematory.

Correlation with Calculated Skeletal Weight and Other Variables

It is evident from the examination of remains still in the retort after incineration that cremains are almost exclusively derived

TABLE 1—*Descriptive statistics for the total sample.*

Variable	N	Min	Max	Mean	Std. Error	Std. Dev
Age (years)	80	14	97	69.1	1.661	14.86
Stature (cm.)	91	142	191	168.7	1.126	10.737
Weight (kg.)	91	25.3	175	65.9	2.789	26.608
Calc Skel. Wgt. (g.)	91	4790	13,140	8386.6	208.4	987.9
Sum of 4 diameters	91	221	342	279.5	2.795	26.659
Epicondylar breadth	91	49	87	66	0.849	8.1
Bistyloid breadth	91	43	65	53.3	0.548	5.231
Bicondylar breadth	91	67	132	94.1	1.252	11.942
Bimalleolar breadth	91	52	79	65.9	0.614	5.856

from the skeleton. Soft tissue contributes little to total cremains weight. Emaciated cadavers often yielded cremains weights greater than the means for their group, and a few obese cadavers produced cremains weights at or slightly below the mean. The correlation between cremains weight and cadaveric weight ($r = .547$; $p < .01$) is confounded by several other variables. Obese cadavers burn more efficiently and at greater maximum temperatures, and were often cremated for longer periods. Also, extremely obese cadavers were loaded into the retort head-first (opposite from the usual procedure), to prevent ignited oils from exuding through the retort door. This places the chest and abdomen of these cadavers behind the primary cremation burner instead of directly under it.

The lower correlation between cadaveric weight and cremains weight in males is presumably from the greater range of both variables among that group. A scatterplot of weight versus cremains weight produces a significant number of outliers and the regression formulae for predicting cremains weight from cadaveric weight produces the greatest standard error of estimate among the three variables tested (see Fig. 2). The regression formula for predicting cremains weight (Y) from cadaveric weight (V_1) is:

Male: $Y = 2451.0 + 5.9030 \times V_1$ (Std. error of est: 468.52)
Female: $Y = 964.74 + 16.088 \times V_1$ (Std. error of est: 307.67)
Total: $Y = 1487.9 + 14.300 \times V_1$ (Std. error of est: 584.65)

Calculated skeletal weight was significantly correlated with cremains weight ($r = .7986$; $p < .01$). Again, this variable contains an element of stature, skeletal robusticity, and cadaveric weight. The regression formula for predicting cremains weight (Y) from calculated skeletal weight (V_2) is:

Male: $Y = 1136.9 + .18070 \times V_2$ (Std. error of est: 435.50)
Female: $Y = 556.34 + .19197 \times V_2$ (Std. error of est: 330.99)
Total: $Y = 89.284 + .27913 \times V_2$ (Std. error of est: 420.52)

See Fig. 3 for a scatterplot of cremains weight versus calculated skeletal weight. Stature had the highest correlation with cremains weight ($r = .8473$; $p < .01$). This was expected—the correlation between stature and skeletal weight has been documented (Trotter, 1954). The regression formula for predicting cremains weight (Y) from stature (V_3) is:

Male: $Y = -4497.0 + 42.084 \times V_3$ (Std. error of est: 383.08)
Female: $Y = -4410.0 + 39.089 \times V_3$ (Std. error of est: 293.95)
Total: $Y = -6820.0 + 54.833 \times V_3$ (Std. error of est: 371.10)

See Fig. 4 for a scatterplot of cremains weight versus cadaver stature.

All cremations reached a temperature of 830°C, with an average maximum temperature of 965°C. The average cremation time was 120.21 min and ranged from 73 to 207 min. Both maximum cremation temperature and cremation duration were not significantly correlated with cremains weight.

Cremationists tend to use longer cremation cycles for obese cadavers, which burn at higher maximum and average temperatures. Once the remains were reduced to calcined bone, additional cremation time did not seem to further reduce the cremains to a significant degree. This was particularly evident during the cremation of the fetus, which was reduced to a calcined skeleton within a few minutes. Additional time in the retort did not appear to significantly reduce the skeletal components of the fetus, although the stainless steel container in which it was cremated glowed a brilliant orange.

Characteristics of Cremated Bone

Almost all bone commercially cremated could be classified as "Baby Type I." (3) It was completely calcined and devoid of all of its organic components. The bone was white or bluish-white in color and extremely brittle. There was no odor associated with the burned bones, but occasionally incompletely burned wood in the retort exuded the familiar smell of a wood fire.

It seems the loss of collagen affected tensile strength more than compressive strength. Those parts of the skeleton composed of trabecular bone still retained some compressive strength, such as the femoral and humeral heads. These fragments could be easily removed from the retort intact, allowing for the taking of certain measurements. Although the cranium was often intact after incineration, it had lost almost all tensile strength and broke into fragments as soon as it was touched during removal from the retort. The dense cortical bone of the long bone diaphyses were also very fragile and often fractured during removal. The fracturing occurred in deep curved lines and extended through the entire cortex of the bone.

Many parts of the skeleton were readily identifiable after incineration. Common fragments were the femoral and humeral heads, vertebral centra, calcaneuses, tali, distal humeri, femoral condyles, and patellae. Closer examination led to the identification of most other fragments. The long bone diaphyses of the humeri, femora, and tibiae were often intact, though warped and deeply checked. Teeth occasionally survived the extreme temperature.

Sexing of the incinerated skeletal remains did not prove to be difficult. Many nonmetric characteristics were observable. The os coxae were usually fragmented, but the morphology of the sciatic notch, inferior pubic ramus, and auricular surfaces were often observable. Diagnostic landmarks were also present on the cranial vault fragments.

TABLE 2—*Raw data for total group.**

Case	Age	Sex	Stature	Weight	Epicondylar Breadth	Bistyloid Diameter	Bicondylar Breadth	Bimalleolar Diameter	Cremains Weight	Calculated Skeletal Weight
M001	86	M	178	79.2	74	52	102	65	2872	9.55 kg
M002	69	F	166	50	53	52	95	63	1881	7.18 kg
M003	80	F	152	59	56	45	88	57	1439	5.75 kg
M004	75	F	163	70.4	73	49	102	62	2523	8.33 kg
M005	75	F	147	52	64	50	87	61	1530	6.31 kg
M006	75	F	173	66.8	70	44	93	62	2304	7.82 kg
M007	47	M	183	56.5	62	58	n/a	n/a	1798	n/a
M008	78	F	157	64.8	51	51	67	52	1827	4.79 kg
M009	68	M	159	53.9	61	54	87	62	2442	6.93 kg
M010	n/a	M	180	57.3	66	54	81	69	3183	8.20 kg
M011	fetal	M	24	0.291	n/a	n/a	n/a	n/a	3	n/a
M012	n/a	M	168	48.4	66	56	97	71	2081	8.83 kg
M013	43	M	178	43.7	70	58	99	66	3610	9.55 kg
M014	91	F	165	57.7	46	54	72	64	1536	6.24 kg
M015	84	M	180	102.3	87	65	114	76	2920	13.14 kg
M016	82	M	169	41.1	73	60	93	64	2115	8.88 kg
M017	59	M	179	159.1	69	59	113	73	2810	11.03 kg
M018	2	M	80	12	36	25	41	34	259	n/a
M019	79	M	173	43.4	68	58	91	63	2000	8.48 kg
M020	74	F	160	41.3	60	45	77	61	2219	5.91 kg
M021	58	M	177	83.5	64	55	103	71	2813	9.50 kg
M022	58	M	188	57.3	74	55	96	63	2244	9.75 kg
M023	63	M	173	108	79	52	100	65	3661	9.47 kg
M024	54	F	149	46.9	49	48	78	52	1542	4.80 kg
M025	97	M	157	48.1	60	52	91	68	1914	7.21 kg
M026	60	M	179	69.1	68	59	96	75	3713	9.93 kg
M027	56	M	177	47.2	62	58	97	73	2241	9.30 kg
M028	62	M	178	79.3	71	51	92	69	3035	8.91 kg
M029	58	F	165	41.9	66	52	84	64	1704	7.30 kg
M030	75	M	191	105.9	76	60	111	73	3444	12.22 kg
M031	89	F	152	38.7	60	51	82	57	1554	5.94 kg
M032	n/a	F	152	25.3	57	45	80	61	1123	5.61 kg
M033	62	F	163	63.5	67	51	86	65	2642	7.37 kg
M034	n/a	M	177	53.5	70	50	96	66	2919	8.80 kg
M035	4	M	100	25.1	n/a	n/a	n/a	n/a	636	n/a
M036	81	M	182	58	69	59	100	71	3310	10.17 kg
M037	90	F	160	45.7	52	44	77	58	1850	5.37 kg
M038	72	F	159	44.6	60	47	82	68	2071	6.56 kg
M039	53	F	174	82.2	61	48	92	64	2750	7.64 kg
M040	56	M	183	73.5	67	58	100	65	3381	9.62 kg
M041	52	F	155	55.7	62	49	85	57	1746	6.20 kg
M042	82	F	163	45.7	59	49	83	65	1782	6.68 kg
M043	81	F	163	44.5	57	49	87	58	1748	6.42 kg
M044	69	M	177	63.8	63	55	97	69	2967	8.92 kg
M045	79	F	165	45.4	56	51	82	56	1562	6.19 kg
M046	25	M	188	70	71	57	95	72	3490	10.23 kg
M047	58	M	174	48.7	77	58	91	76	2582	9.92 kg
M048	76	F	159	37.2	58	48	76	57	1440	5.68 kg
M049	87	F	157	33.5	54	43	83	62	1244	5.75 kg
M050	77	M	170	c.170	79	57	116	76	3091	11.43 kg
M051	89	M	160	75.3	70	54	105	65	1887	8.64 kg
M052	70	M	178	127.1	81	61	109	74	3002	11.75 kg
M053	77	M	175	51.1	68	57	97	67	2804	9.14 kg
M054	76	M	185	64.3	70	59	104	75	3055	10.97 kg
M055	70	M	182	69.7	67	59	102	69	3400	10.03 kg
M056	77	F	171	64.1	62	51	89	60	2143	7.34 kg
M057	14	M	168	65.5	68	55	98	71	2624	8.95 kg
M058	75	F	151	36.4	58	47	82	63	1541	5.90 kg
M059	c.65	M	170	35.8	69	57	95	72	2774	9.12 kg
M060	c.70	M	177	63.3	69	58	97	76	3349	9.96 kg
M061	81	F	163	44.1	61	43	77	57	1704	5.77 kg
M062	c.60	M	171	57.9	72	61	97	79	3023	10.20 kg
M063	60	F	160	59	71	55	99	65	1918	8.41 kg
M064	n/a	F	164	65.8	56	48	82	62	1900	6.30 kg
M065	102	F	156	27.5	56	45	83	59	1316	5.76 kg
M066	82	M	166	55.4	64	55	97	67	2385	8.31 kg
M067	75	M	166	39.7	69	54	90	68	2072	8.19 kg
M068	56	M	180	95.6	72	56	105	69	3784	10.26 kg
M069	83	F	160	66.7	63	53	90	67	2097	7.45 kg

TABLE 2—*Continued*

Case	Age	Sex	Stature	Weight	Epicondylar Breadth	Bistyloid Diameter	Bicondylar Breadth	Bimalleolar Diameter	Cremains Weight	Calculated Skeletal Weight
M070	50	F	155	42	58	46	79	54	1518	5.44 kg
M071	71	M	174	52.2	71	54	92	66	2995	8.71 kg
M072	71	M	178	101.1	71	60	96	72	3339	9.95 kg
M073	30	M	170	51.4	67	52	92	65	2608	8.09 kg
M074	77	F	165	90.3	61	51	126	68	2047	9.66 kg
M075	n/a	F	157	47.2	53	47	84	64	2315	6.04 kg
M076	81	F	169	58.3	62	47	97	61	1930	7.53 kg
M077	78	M	168	67.6	68	57	92	64	2673	8.29 kg
M078	83	F	163	58.9	56	53	97	63	1975	7.37 kg
M079	n/a	F	165	80.4	62	50	108	61	2324	8.14 kg
M080	57	M	180	69.2	71	59	99	67	2471	9.86 kg
M081	63	M	185	118.5	83	64	115	73	3734	12.98 kg
M082	50	M	184	85.9	76	45	97	72	2811	9.67 kg
M083	66	M	183	89	76	61	101	72	2943	10.99 kg
M084	73	F	163	62.5	53	52	96	66	1870	7.26 kg
M085	88	F	161	50.4	56	49	93	61	1646	6.75 kg
M086	65	M	170	59.4	68	59	87	64	3115	8.21 kg
M087	75	M	173	60.3	70	55	97	68	2681	9.09 kg
M088	69	F	147	58.2	60	47	86	60	1196	5.88 kg
M089	71	M	183	84.7	76	61	107	71	3629	11.35 kg
M090	72	M	166	87.5	76	57	101	68	2608	9.46 kg
M091	77	F	157	39.7	65	52	90	63	1647	7.15 kg
M092	65	F	164	105.5	67	52	132	67	2265	10.36 kg
m093	63	M	183	80	70	59	100	67	2392	10.02 kg
M094	64	M	166	71.3	66	56	101	67	2664	8.73 kg
M095	79	F	142	36.8	63	48	84	55	876	5.55 kg
M096	40	M	183	61.7	72	57	100	69	3036	10.16 kg
M097	75	F	165	42.2	52	48	67	64	1808	5.50 kg
M098	60	M	184	136.4	72	58	122	71	2934	11.99 kg
M099	62	M	183	86.7	79	62	102	77	2577	11.71 kg
M100	64	M	171	75.3	85	54	98	64	2748	9.68 kg

*Note: "Age" is recorded in years; "stature" is recorded in centimeters; "weight" and "calculated skeletal weight" are recorded in kilograms; "cremains weight" is recorded in grams; all other measurements are in millimeters.

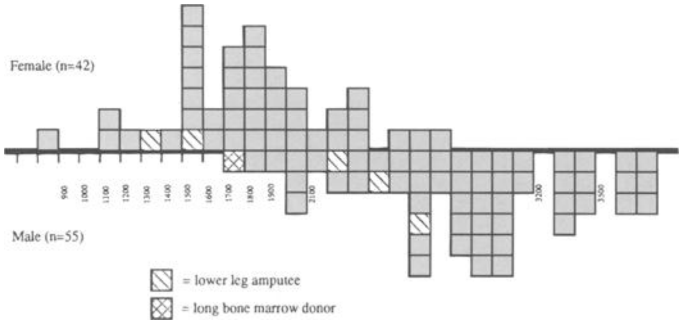

FIG. 1—*Cremains weight distribution.*

TABLE 3—*Amputees and long bone donor.*

Case	Age	Sex	Stature	Weight	Cremains Weight	
M007	47	M	183	56.5	1798	Bone Donor
M022	58	M	188	57.3	2244	Amputee
M045	79	F	165	45.4	1562	Amputee
M065	102	F	156	27.5	1316	Amputee
M080	57	M	180	69.2	2471	Amputee
M087	75	M	173	60.3	2681	Amputee

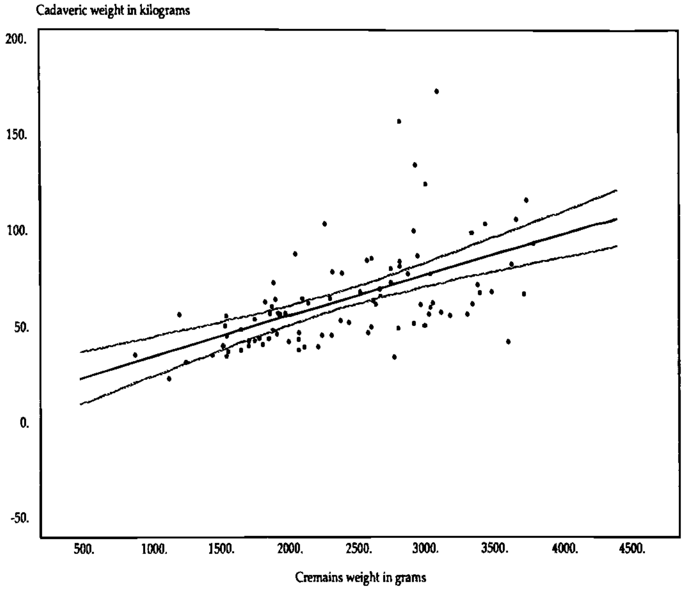

FIG. 2—*Scatterplot of cadaveric weight versus cremains weight.*

Many age markers were present as well. One of the most commonly preserved fragments were the vertebral centra, where osteophytic development could be noted. Osteoarthritic changes in the articular surfaces of the humeral and femoral heads were easy to determine. Maxillary fragments sometimes retained the alveolar fossae. Therefore, even in cases in which tooth fragments were not recovered, the presence of dentition could be determined in some individuals.

The age was recorded prior to cremation, so a blind test of age determination could not be conducted. However, it can be reported that elderly individuals could be generally differentiated from younger individuals in the sample by the presence or absence of osteophytic development in the vertebral column.

Of the mature sample of 97 individuals, measurements of the femoral head and/or humeral head diameters could be recorded

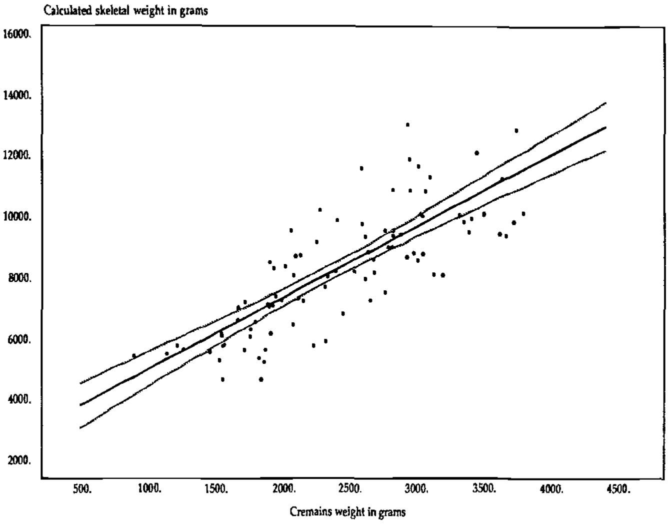

FIG. 3—*Scatterplot of calculated skeletal weight versus cremains weight.*

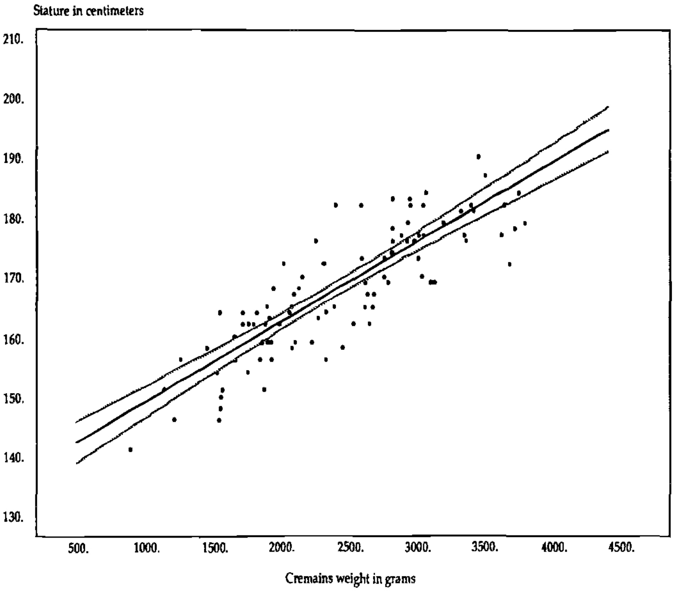

FIG. 4—*Scatterplot of stature versus cremains weight.*

for 46 individuals prior to processing. Average femoral head diameter was 44.2 mm for the males (n = 28) and 38.2 mm for the females (n = 10). Average humeral head diameter was 45.8 mm for the males (n = 17) and 38.16 mm for the females (n = 6). These figures can be compared to those of Dwight, who reported an average femoral diameter of 49.68 mm among the males, and 43.84 mm among the females in the study (26). Similarly, the average humeral head diameters recorded by Dwight were 48.76 mm for males and 42.67 mm for females. Although the number of individuals measured in the present study is very small, the reduced means of the head diameters may serve to illustrate the degree of shrinkage that occurs when bone is incinerated at high temperatures (26).

Discussion

Cremains are principally derived from the inorganic component of the skeleton. Although a number of factors contribute to variability in cremains weights, if a true skeletal weight could be determined, it is probable that cremains weights could be predicted with extreme accuracy. Stature was the most useful variable tested, because it is usually known with reasonable accuracy for most individuals. The four measurements used in the formula to determine skeletal weight were skewed by extreme variations in soft tissue thickness and skin turgor. Had actual bone measurements been possible, it is likely that the calculated skeletal weight would have been more highly correlated with cremains weight than stature. Aside from the negligible contribution of soft tissue to cremains weights, obese cadavers burn more efficiently and at higher retort temperatures than cadavers of "normal" weight. The cremationist will often load obese cadavers into the retort head-first and use a longer cremation cycle to insure that all of the soft tissue is incinerated.

The formula generated by this study, as well as the mean cremains weights and the distribution of these weights, may serve to set reasonable parameters that may be considered in the investigation of cremains during litigation. However, because differences in cremation procedure and/or retort specifications among more than one crematory have not been tested, the formula should not be strictly applied to cremains produced at other crematoria, but used only as a guide in interpreting whether a specific set of cremains falls within the parameters of this population.

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