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PATTERNING OF SKELETAL LEAD CONTENT IN BARBADOS SLAVES

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INTRODUCTION

The very small quantities of lead present in natural sources prehistorically have not provided a stimulus for humans to evolve an efficient mechanism for the elimination of lead from the body. Lead products in historical and modern societies have exposed humans to lead quantities that vastly exceed their excretory maximum, resulting in body lead accumulation. Lead is absorbed from intestinal content, from inspired air and through the skin. About 10% of absorbed lead is deposited (with a half-life of 2–4 weeks) in various soft tissues, many of which are quite sensitive to the toxic effects of lead, and 90% of the absorbed but unexcreted lead is deposited in bone (with a half-life of 10–30 years). Continued lead exposure leads to a continual increase in bone lead content. This process creates the archaeological research opportunity to estimate the extent of an individual's lifetime lead exposure by chemical determination of his skeletal lead concentration (e.g. Aufderheide *et al.* 1981, 1985).

The physical remains employed in this analysis derive from Barbados slave skeletal materials recovered during archaeological investigations in the early 1970s. These investigations formed one phase of a project concerned with reconstructing the social and cultural life of the island's slaves from the mid-seventeenth century to emancipation in 1834. The archaeological research included the partial excavation of a slave cemetery at Newton plantation. During the slave era Newton typified medium to large-scale Barbados sugar plantations. The cemetery excavations yielded the remains of 104 individuals interred from about 1660 to 1820. This skeletal collection constitutes the largest and earliest excavated group of African and African-descended slaves yet reported from the Caribbean and mainland North America (Handler and Lange 1978).

Earlier analyses of the physical remains of Newton's slaves, particularly the teeth, have yielded information on demographic characteristics, pathologies, growth and sociocultural behavioral patterns. These data, when combined with historical information, have enhanced our understanding of the life styles of Barbados slaves and the material conditions of their lives (Corruccini and Handler 1980, Handler *et al.* 1982, Handler and Corruccini 1983, 1986, Corruccini *et al.* 1982, 1985, 1986).

Lead concentration patterns have proven useful in interpreting some aspects of slavery in colonial North American sites (Aufderheide *et al.* 1981, 1985). In the present paper we analyze bone lead content and discuss its implications for understanding and interpreting various new dimensions of Caribbean slave life.

MATERIALS AND METHODS

Skeletal tissue for lead analysis was available for 48 individuals from Newton cemetery. Of these, a total of 52 samples was removed from the mandible (usually the ramus in the gonial region) of 23 individuals, from the skull (usually the temporal region) in 21, and from both areas in 4 cases. After cleansing the bone surface mechanically a 3 mm core of bone was removed by using an electric drill fitted with a stainless steel hollow core bit. Attached cancellous bone was carefully removed; only cortical bone was included in the final sample. The sample was then dried to constant weight, ashed, and a 20 mg sample of ash dissolved in nitric acid with added aqueous lanthanum solution to minimize matrix interference (see Wittmers *et al.* 1981). Lead concentrations were estimated with atomic absorption spectrometry employing the graphite furnace method. This method gives reproducibility of 12.4% SD for low (14 μg/g ash) and 8.6% SD for high (60 μg/g) bone lead concentrations (Wittmers *et al.* 1981).

To examine non-random patterns or partitions of variance, we are uncomfortable with the conventional t-test of mean differences as the overall frequency distribution of values is decidedly non-normal and positively skewed. Although parametric statistics must be presented in some cases to interpret confidence intervals, we generally employ the Wilcoxon rank-order statistic for two-sample comparisons and the Kruskal–Wallis rank-order method for multiple-sample comparisons. One-way analysis of variance is also used in the multiple-sample comparisons, as this method is relatively robust to non-normality and with appreciable sample sizes yields closely comparable statistical results with Kruskal–Wallis. Tests are one tailed where appropriate.

RESULTS

Data are given in table 1. The overall mean lead content of the bones is 117.6 ± 94.9 ppm (μg lead/g bone ash). This relatively high and variable value is three to four times that of other North American slave samples (Aufderheide *et al.* 1985) and is comparable with mainland Colonial elitist whites with known consistent lead exposure (Aufderheide *et al.* 1981). It is also comparable with various analyses of possibly lead-contaminated British Romans (Mackie *et al.* 1975, Waldron *et al.* 1976, Molleson 1987). To date no other samples have demonstrated such a wide range of values, from zero to more than 400 ppm. Some 81% of the 21 specimens that died after the age of 30 years (when appreciable lead could have accumulated from constant sources) have a lead content above 100 ppm.

In order to interpret this high lead content, the following factors are examined.

Table 1 *Lead concentration (measured in bone and derived for blood), age-at-death and sex for Barbadian slave specimens. Data for other parameters mentioned in text are given in Handler and Lange (1978 Appendix A)*

Rank	*Burial*[a]	*Lead concentration*		*Age*	*Sex*
		Bone (μg/g ash)	*Blood (μg/100 ml)*		
1	48-1[b]	0.0	1	30	F
2	78-1	0.5	1	40	M
3	35-1[b]	1.4	1	30	F
4	73-1	5.0	7	15	M
5	20-2	17.9	7	50	M
6	75-1	18.8	12	30	F
7	43-2	20.3	17	23	M
8	28-1	25.4	19	25	?
9	13-2[b]	25.6	23	21	M
10	80-2	32.0	30	20	?
11	54-2	36.8	43	16	F
12	31-1	40.0	27	28	F
13	22-2	48.1	36	25	F
14	64-1	55.4	30	35	M
15	76-1	59.4	59	19	M
16	44-1[b]	62.2	39	30	M
17	34-2	66.0	59	21	F
18	33-1[b]	68.0	25	50	F
19	46-2	71.1	67	20	M
20	53-2	79.2	53	28	M
21	56-2	88.6	55	30	M
22	31-2	100.0	67	28	F
23	15-2	100.3	34	55	?
24	90-1	100.8	54	35	F
25	79-2[b]	101.8	38	50	M
26	77-1	105.5	79	25	?
27	81-2	108.0	26	47	M
28	72-1	108.9	41	50	M
29	24-2	115.3	66	33	M
30	37-2	116.9	40	55	?
31	39-2	116.9	69	32	?
32	74-2	118.7	70	32	M
33	26B-2	130.0	145	17	?
34	65-1	131.9	124	20	?
35	38-1	139.5	65	40	?
36	27-1	141.7	89	30	M
37	6-1	145.1	91	30	F
38	63-2	145.1	68	40	?
39	30-2	148.1	62	45	M
40	51-2	148.1	111	25	?
41	72-2	174.1	65	50	M
42	26A-1	188.5	177	20	?
43	29-2	245.0	219	21	?
44	9-2	249.7	235	20	F
45	55-1	268.6	144	35	M

(continued)

Table 1 *(continued)*

Rank	*Burial*[a]	*Lead concentration*		*Age*	*Sex*
		Bone (µg/g ash)	*Blood (µg/100 ml)*		
46	55-2	273.3	147	35	M
47	85-1	273.3	114	45	M
48	69-1	280.8	96	55	M
49	11-1	282.7	266	20	?
50	60-2	292.1	106	52	F
51	83-1	329.8	177	35	F
52	60-1	424.0	153	52	F

[a] Burial numbers from Handler and Lange (1978 Appendix A). No. 26 was subsequently divided into two separate burials. Nos. 31, 72, 55 and 60 were sampled from both the cranium (1) and mandible (2).

[b] Identified as probable African-born slave by presence of dental mutilation or north-headed burial.

Site of bone sampling While many samples were taken from either the cranium or mandible, only four were obtained from both sites in the same individual (owing to poor bone preservation). This is not enough matched observations to employ the Wilcoxon signed-ranks test reliably. Cranial *versus* mandibular sites were contrasted with the conventional Wilcoxon, yielding $z = -0.15, p > 0.88$. We conclude data from the different sites cannot be considered different for present purposes; in further analysis both values are used for the four twice-sampled individuals, and the degrees of freedom adjusted downward by four in calculations.

Sex Sex determination was only provisional. Three-group Kruskal–Wallis analysis of ranked lead values for males, females and unknowns yields $x^2 = 1.86, p > 0.17$, indicating higher values for females cannot be considered statistically significant, and may be due to sampling variation and error. However, the variation in females is demonstrably higher ($F = 2.65$, $p < 0.05$), perhaps reflecting a wider spectrum of occupational exposure to environmental lead as might have occurred with domestic servants as opposed to fieldworking slave females. Assumed domestic assignment of some female slaves in Virginia was used to explain similar higher lead values observed by Aufderheide *et al.* (1981).

Age Parametric ($r = +0.30$) and rank-order correlation ($R = +0.28$) are significant ($p < 0.02$) for age-at-death and lead concentration. A weak general trend is suggested by advancing lead levels per decade of life: age 10–19, 58 ppm; age 20–29, 110 ppm; age 30–39, 112 ppm; age 40–49, 136 ppm; age 50–59, 158 ppm. The large variation within each age partition renders analysis of variance non-significant. Besides the inexactness of skeletal aging (see Corruccini *et al.* 1982 p. 445), a factor confounding age regression would be the combination of slaves newly imported from Africa (where there would have been limited opportunities for lead exposure) with Barbados-born slaves having lifelong contact with lead sources. By the age of 35 it becomes likely that both types of slaves would have had opportunity for exposure. Using age 35 as the dividing point for a two-sample Wilcoxon test, we find $z = 2.129, p < 0.015$, allowing confident rejection of the null hypothesis. The age progression of lead accumulation supports the interpretation of a constantly available environmental source of lead for the slaves.

Tooth mutilation An interesting feature discovered in the Newton dentitions is dental mutilation, the intentional filing or chipping of the anterior teeth. Five specimens showed varying forms of this practice. Elsewhere we argue that the custom signals African-born status of the concerned individuals (Handler *et al.* 1982). The five mutilated specimens average much lower lead concentrations (44.7 ppm) than the remaining general sample (126.2 ppm), all the more noteworthy because none of the five was particularly young at death. Their average rank-order values are half what would be expected by chance: $z = -2.00, p < 0.023$. This significant result strengthens the supposition that lead sources were largely unavailable to slaves of African birth while they lived in Africa. The five dentally-mutilated specimens indicate progressive age increase in lead values comparable with the remaining sample.

Burial orientation Handler and Lange (1978) originally suggested the Newton remains indicate aspects of African-derived *versus* Christian-influenced mortuary behaviors. West-oriented burials and coffin presence tend to indicate later (hence more likely Barbados-born) status. We find no difference in lead concentration according to these two factors. However, the three north-facing burials show extremely low lead values, averaging 9.0 ppm (a rank of fourth from the bottom) compared with 124.8 ppm for the remaining sample. Wilcoxon yields $z = -2.42, p < 0.008$. Two of these three specimens have filed teeth and thus were probably African born; the association of north orientation and dental mutilation, even with these small samples, is quite significant ($p < 0.01$ by a one-tailed Fisher Exact test). Furthermore the association of coffin absence is significant with north orientation plus dental mutilation ($p < 0.02$). There is scant African ethnographic basis for interpreting north-oriented burials (Handler and Lange 1978) and admittedly the dead do not bury themselves, but the statistical associations argue for a burial trait complex which possibly identifies African birth: this consists of physical evidence including dental mutilation and tooth root hypercementosis (Corruccini *et al.* 1987) associated with north-headed burial orientation and/or absence of a coffin. All six individuals reflecting this complex have lead values lower than the total sample's median. This trait complex and the previously discussed age progression are the most significant identified factors influencing lead accumulation in the slaves. Three-way rank analysis of variance for (a) African-born, (b) older (35 years or more) and not demonstrably African-born and (c) younger residual groups yields Kruskal–Wallis $x^2 = 13.31$ with two degrees of freedom. The probability is less than one in 200 that such difference could obtain in three random samples from the same parent statistical population. Parametric analysis of variance yields $F = 6.30$; i.e. there is six times more variance between groups than within groups according to this partition.

Redware in burials Burials associated with plain unglazed earthenware (redware) sherds show significantly lower lead content ($z = -2.44$). This result is entirely due to redware being associated with all the inferred African-born individuals mentioned above; thus this is a redundant factor.

Other factors Various other archaeological factors failing to show significant influence on lead values (all $p > 0.20$) include lead-glazed pottery ($n = 4$), severe dental enamel hypoplasia (a pathology signalling acute childhood illness or malnutrition (Corruccini *et al.* 1985), $n = 5$), pipes and pipestems included as burial goods, pipewear on teeth, depth of burial and the previously mentioned evidence of a coffin ($n = 28$), coffin handles ($n = 13$), and east–west orientation. Extreme skeletal robusticity ($n = 3, p < 0.09$) is more suggestive but the null hypothesis again cannot be rejected.

DISCUSSION AND CONCLUSIONS

It would be of considerable historical interest to be able to predict, on the basis of their post-mortem bone lead content, the frequency and degree of lead poisoning symptoms presented by these Barbadian slaves during their lifetime. Unfortunately, most of the medical literature relates symptoms of lead toxicity not to the level of lead in bones but to that in the more conveniently available blood or urine. Recently, however, the need to monitor the accumulating body burden of absorbed lead in industrial workers has resulted in the development of an X-ray fluorescence method of estimating bone lead content in living persons (Christoffersson *et al.* 1984, Ahlgren *et al.* 1980, Eastwell *et al.* 1983). Preliminary results of such studies (M. Scott pers. comm.) demonstrate a relationship between skeletal lead and blood lead levels if the latter are integrated with the years of exposure. Regression using Scott's data generates a correlation of $+0.82$ with the formula: tibia Pb (μg/g) $= 0.03 \times$ blood Pb (μg/100 ml) $\times$ years of exposure $- 0.9$. This is with wet bone; bone ash lead content predicts the blood lead at 0.531 ± 0.009 the rate of wet bone. This formula was used to derive the mean blood values of the Barbadian slaves using their chronological age at death as an estimate of their lead exposure duration. There are factors limiting the precision of these estimates: the restricted number of subjects tested by Scott ($n = 83$), and the fact that more than half of the slave bone lead values exceed the highest value in Scott's measured lead workers. There is no assurance of linearity of the blood–bone lead relationship at such higher levels. Nevertheless within their limits the data define a clear relationship between bone lead and time-integrated blood lead levels, permitting at least a rough estimate of expected symptomatology.

The derived blood lead values suggest that while the majority of this slave population could be expected to have demonstrated at most only mild, intermittent symptoms of lead intoxication during their lifetime (0–79 μg Pb/100 ml blood), about 27% probably suffered moderate to severe symptoms ($\geqslant 80$ μg Pb/100 ml blood) some approaching a magnitude that suggests life-threatening or fatal consequences. Intestinal colic without diarrhea (historically referred to as 'dry belly ache'), weakness or paralysis of peripheral nerves resulting in wrist or foot drop and brain effects varying from behavior changes to convulsions, coma or death are all symptoms of lead poisoning sufficiently unique to anticipate their notice by early medical observers.

Considerable historical documentation has now been located for the existence of such symptoms among Caribbean slave populations (Handler *et al.* 1986), and by inference there was probably even more lead toxicity among whites (for whom no skeletal materials are available). It is therefore reasonable to assume that lead contact had significant impact on health, mortality and perhaps such factors as fertility, anemia, high blood pressure, newborn survivorship and behavioral anomalies during the seventeenth to eighteenth centuries (Handler *et al.* 1986).

The historical sources indicate that lead-contaminated pewter products, medicines and foods imported from England to the Caribbean probably had little effect on the slaves. Post-mortem contamination of the Newton skeletons can also be ruled out. Handler *et al.* (1986) conclude that rum, which was distilled through several lead-containing devices and which was heavily consumed by slaves (and whites), was probably the major source of ingested lead. The sugar-manufacturing process also contributed to lead contact.

From an archaeological point of view these results suggest the utility of skeletal lead content for interpreting aspects of the unrecorded history of West Indian slave populations. Specifically, we believe that low skeletal lead content relative to age is a powerful indicator of African birth in the Barbadian remains. Where archaeological research is devoted to the retention, modification or loss of African customs among blacks in the New World plantation environments (Handler and Lange 1978), accurate identification of native African interments (as opposed to Creole) is vital. The new relationships uncovered will considerably enhance future studies of culture change in Afro-American mortuary patterns and material culture.

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