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Bone Lead in the Prehistoric Population of Gran Canaria

E. GONZALEZ-REIMERS,[1]* M. ARNAY-DE-LA-ROSA,[2]
J. VELASCO-VAZQUEZ,[2] L. GALINDO-MARTIN,[3]
E. DELGADO-URETA,[3] AND F. SANTOLARIA-FERNANDEZ[1]
[1]Departamento de Medicina Interna, Hospital Universitario de Canarias, Tenerife, Spain
[2]Dpto. de Prehistoria, Antropología e Historía Antigua, Universidad de La Laguna, Tenerife
[3]Dpto. de Química Analítica, Universidad de La Laguna, Tenerife

ABSTRACT The present study determined the lead concentration in bone tissue from 40 prehistoric individuals of Gran Canaria, and in a sample of 19 modern day residents of the Canary Islands. Higher bone lead values were observed in the modern sample (18.65 ± 12.13 μg/g dry bone tissue) than in the ancient sample (4.41 ± 3.45 μg/g dry bone tissue, $P < 0.001$). Older individuals showed higher bone lead values than younger individuals, but only in the modern group. The correlation between age and bone lead approached statistical significance ($P = 0.058$). Low bone lead observed in the prehistoric sample suggests a low lead exposure in prehispanic times in Gran Canaria. Am. J. Hum. Biol. 11:405–410, 1999.

Dietary lead is absorbed in the duodenum, jejunum, and ileum, but alimentary absorption approximates only 5–10% in humans (Underwood, 1977). Absorption of inhaled lead via the respiratory mucosa is quantitatively more important, of the order of 30–50% (Smith, 1976). Absorbed lead reaches soft tissues and bones, and a small amount undergoes biliary excretion. However, excretion does not keep pace with total intake, resulting in accumulation in the body over time, especially in bone tissue (Cartón, 1988). Thus, bone lead may serve as an indicator of lead exposure (Rabinowitz et al., 1976).

Although in several countries, as in the Canary Islands, lead is no longer used as an additive in paint or in soldering cans, and consumption of lead-free gasoline has progressively replaced that of leaded gas, environmental exposure to lead is still a common day-to-day occurrence. Industrial production of gasoline has dramatically increased the amount of lead to which modern people are exposed. Lead is not only inhaled, but also contaminates air, water, and soil, and thus, edible plants and animals. Even relatively low levels of lead exposure are associated with adverse health effects, such as diminished neurocognitive function in children (Needleman et al., 1979; Needleman and Gatsonis, 1990), and hypertension (Sharp et al., 1987; Hu et al., 1996) and impaired renal function (Kim et al., 1996) in adults. Also, increased lead exposure and bone lead have been associated with delinquent behavior (Needleman et al., 1996) and with anemia (Hu et al., 1994). Moreover, lead may adversely affect bone development through disruption of mineralization during growth (Hamilton and O'Flaherty, 1995). Some reports point to an adverse effect of lead on bone mass (Escribano et al., 1997), although others have failed to find this relationship both in clinical (Van de Vyver et al., 1988) and in experimental (Massie and Aiello, 1992) studies.

Except for some examples of bone lead in samples from the Roman era (Patterson et al., 1987), which was derived from widespread utilization of lead-containing artifacts and ornaments, and from sapa, an ingredient added to wine prepared in lead cauldrons, bone lead in ancient cultures is very low, about 20–1000 times lower than in modern bones (Patterson et al., 1987). In this context, the aim of the present study is

*Correspondence to: E. Gonzalez-Reimers, Departamento de Medicina Interna, Hospital Universitario de Canarias, Tenerife, Spain.

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to compare bone lead concentrations between prehispanic individuals of Gran Canaria and modern inhabitants of the Canary Islands.

The Canary Islands were inhabited in prehistoric times by people of North African origin, who probably arrived at the archipelago towards the middle of the first millennium BC (Báez et al., 1983). Agriculture, consisting mainly of barley and wheat, was probably the main economic activity, which was complemented by cattle-raising and shell-fish gathering. The primitive Canarians did not use metals, because no metal ores existed on the Islands. Therefore, they presumably should have been exposed to low levels of lead.

MATERIALS AND METHODS

Modern population

Bone specimens were obtained from 19 males 10–67 years of age, who were victims of traffic accidents at the Intensive Care Unit of the local hospital. All lived in the northeastern part of Tenerife, an area with a population of more than one-half million people in less than 400 square kilometers. Only one of the subjects worked in agriculture; 3 were students, 3 were unemployed, 2 were bricklayers, 2 were shop assistants, and the others were carpenters and skilled workers in industry.

Ancient population

Forty-pelves or complete skeletons belonging to prehispanic inhabitants of Gran Canaria were analysed (33 males, 7 females). Ages at death ranged between 18 and 50 years, as assessed by inspection of the pubic symphysis (Ferembach et al., 1979). In one pelvis, the absence of the pubic symphysis precluded estimation of an exact age at death, although this bone belonged to a young man, since fusion between the lip of the iliac crest and the iliac bone was incomplete. Several individuals showed incomplete fusion of the lip of the iliac bone, so they were also classified as "young."

These samples belong to the anthropological collection of the "Museo Canario" (Las Palmas), and were found in collective burials at the archeological site of Guayadeque in the eastern part of Gran Canaria. Guayadeque is, by far, the most important funerary complex of Gran Canaria, with several huge collective burial caves containing remains of hundreds of individuals. Several of these caves still remain unexcavated. Nearly 80% of all of the anthropological remains from prehistoric Gran Canaria has been found in Guayadeque. The sample analyzed in this study accounts for more than 30% of the pelves of individuals from Guayadeque which currently belong to the anthropological collection of the "Museo Canario." Radiocarbon dating results on the anthropological materials yield figures ranging from 875 ± 60 bp to 1740 ± 90 bp.

Bone samples were obtained with a 7 mm inner diameter Bordier's trephine at the usual site, 2–3 cm behind and below the anterior iliac crest. Samples were dehydrated, dissolved in nitric acid (p.a. Merck) and hydrogen peroxide. The solutions were quantitatively transferred to volumetric flasks and diluted to 10 ml with ultrapure water (prepared using a Milli-Q OM 140 deionization system). Bone lead was determined using a Varian Spectra A 640Z atomic absorption spectrophotometer equipped with a 6TA 100 graphite furnace.

Levels of bone lead of the prehispanic population were compared with those of the modern sample by means of the Student's "t" test. In order to discern if there was a relationship between bone lead and age in the prehistoric population, Student's "t" test was used to compare bone lead of the older individuals with that of the younger ones. Since exact ages at death of the control population were known, bone lead was also compared between younger and older individuals using the Student's "t" test and correlation between bone lead and age in years. All "t" tests were two-tailed. A "P" value of 0.05 or less was considered statistical significance. Results are expressed as means ± standard deviations.

RESULTS

Bone lead in the modern population ranged from 2.2–38 μg/g dry tissue (18.65 ± 12.13 μg/g). Significant differences were observed between older individuals (>40 years, 27.94 ± 11.56 μg/g) and younger ones (12.97 ± 9.27 μg/g, $t = 3.10$, $P < 0.01$, Fig. 1). Correlation between age and bone lead was approached statistical significance ($r = 0.44$, $P = 0.058$).

Bone lead of the prehispanic population ranged from 0.9–15.3 μg/g dry tissue (4.41 ± 3.45 μg/g); 21 of the 40 individuals (52.5%) showed bone lead values below 3 μg/g. No

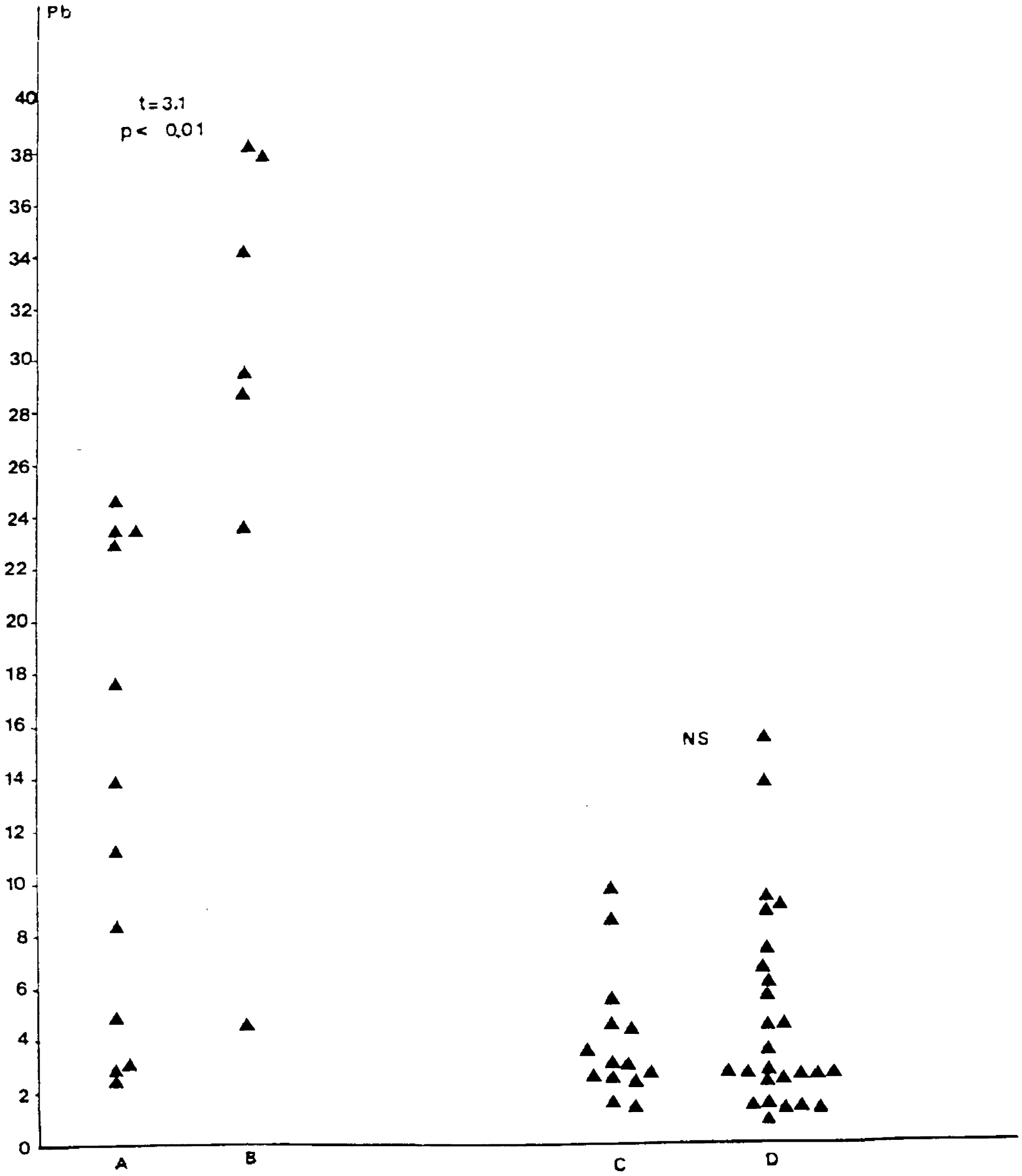

Fig. 1. Bone lead (ppm = μg/g dry weight) in younger (A) and older (B) modern individuals, and younger (C) and older (D) prehispanic individuals.

differences were observed between younger (3.75 ± 2.45 μg/g) and older (4.82 ± 3.91 μg/g) prehispanic individuals (Fig. 1).

Significant differences in bone lead were observed between the prehispanic (4.41 ± 3.45 μg/g) and modern samples (18.65 ± 12.13 μg/g, $P < 0.001$).

DISCUSSION

In the present study lead in dry bone samples of prehistoric inhabitants of Gran Canaria was determined and compared with values in a modern sample. Levels of bone lead in the prehispanic inhabitants of

Gran Canaria are much lower than those observed in the modern population. As previously noted, most of the lead which contaminates air, soil, and water is derived from industrial activities. Except for results obtained in individuals of the Roman Empire, only a few samples from the preindustrial era may have high bone lead values (Aufderheide et al., 1981), but these results are usually explained in relation to preparation or storage of food in leaden containers.

Values obtained in some of the prehispanic samples range 1–1.5 ppm (Fig. 1). These values are similar to others obtained in analyses of earlier populations. Grandjean et al. (1979) report bone lead values ranging 0.4–1.5 μg/g for the ancient (about 3000 years B.C.) Nubian population, and slightly higher values (range 1.4–3 μg/g) in 15 samples of the Pharaonic period (1650–1350 B.C.). Other authors have reported bone lead values of 1.1 μg/g for Egyptian mummies of the Ptolemic period. Bone lead values ranging 0.11–2.7 μg/g have been reported for ancient (0–400 A.C.) Peruvian skeletons (Ericson et al., 1979). Drasch (1982) also reports values ranging from 0.06–1.9 μg/g for ancient (500–1000 A.C.) Peruvian skeletons.

Ancient Greeks, and especially Romans, mined and smelted lead intensively. Therefore, lead pollution dramatically increased during the Roman Era, affecting bone lead concentration. Indeed, very high values have been reported for bone samples of Roman individuals (90–155 ppm [ash wt]) analyzed by Gilfillan (cited in Patterson et al., 1987); other authors (Drasch, 1982) have reported bone lead values ranging from 0.9–13.9 μg/g in samples of the late Roman Augsburg period (400 A.C.), with a mean value of 4.7 μg/g. The mean bone lead content of the prehispanic population of Gran Canaria is similar (4.41 ± 3.45 μg/g) to this value. The majority of the prehispanic samples showed bone lead values before 3 μg/g, although some (Fig. 1) showed relatively high values. The highest values were 15.3 and 13.9 μg/g.

Lead may leach from soil into the bones, and perhaps some degree of diagenetical contamination may play a role in some of the observed results. However, this is not very likely to occur in the majority of the cases, since most of the dead were not interred but were deposited in natural caves on stone or vegetal layers. This happened because the prehispanic inhabitants of the Islands believed that bodies should be preserved from contact with the impure soil (Abreu Galindo, 1977). The details about inhumation conditions, however, are not known; hence, diagenetical artifaction of some of the results of the Prehispanic samples, especially in those which show abnormally high bone lead values, cannot be eliminated. However, other explanations are possible, though speculative. At least some of the samples (those with an antiquity of 1750 years) belong to individuals contemporary to the Roman Empire. Romans visited the Canary Islands, but they did not conquer the Archipelago or establish commercial links with the ancient Canarians; thus, no lead was introduced into the Islands by this way. However, northeastern trade winds blow to the Islands from May to September, directly from North Africa and the southern part of the Iberian Peninsula, where enormous amounts of lead and silver were mined and smelted by the Romans during centuries. Although speculative, the possibility exists that some lead contaminated the air in the south of Spain and was then brought to the Islands by the trade winds. This may explain the higher mean values obtained for the population of Gran Canaria compared with those reported for other populations lacking lead technology, an ancient Peruvians or ancient Nubians.

For comparative purpose, bone lead was determined in a modern sample. The results are fully consistent with the statement that absorbed lead is progressively deposited in bone. The individuals analyzed in this study live in an area which may be considered urban, since population density is high (over 1200 inhabitants/km^2). Only one subject worked in agriculture. Thus, the sample may have been exposed to relatively high lead concentrations during life, a fact which explains the nearly significant correlation between bone lead and age, and the significant difference between older and younger individuals in bone lead. The results are somewhat lower than others reported for American and British samples (Barry et al., 1975; Schroeder and Tipton, 1968; Aufderheide et al., 1988), although in these studies bone lead was measured in bone ash, a fact which may explain, at least in part, the differences observed. In the present study, lead was measured in dry bone, i.e., including the organic part of the bone which poor in lead. However, bone lead values lower than those reported to have been found in the contemporary population of Denmark (Grandjean et al., 1979) and Bavaria (Drasch, 1982). The degree of lead contamination and thus, of lead exposure and bone deposition, probably accounts for the differences observed. In this sense, striking differences have been reported for lead in teeth between contemporary populations differing in their degree of industrialization (Shapiro et al., 1975).

In recent times, bone lead has been determined in vivo by X-ray fluorescence (XRF). This technology, especially K-XRF, allows accurate measurement of bone lead in vivo (Landrigan and Todd, 1994). Using this technique, several authors have performed different studies on modern individuals of Australia, Europe, and North America (Price et al., 1984; Kosnett et al., 1994; Hu et al., 1994, 1996). The results with this technology yield bone lead contents ranging between 20 and 70 μg lead/g bone mineral. In addition to clinical and epidemiological relevance, these studies have confirmed the relationship between bone lead content and lead exposure during life.

It may be concluded that exposure to lead was low among the prehispanic inhabitants of Gran Canaria, although mean bone lead content was slightly higher than that of other prehistoric population groups without known lead technology. However, lead exposure has dramatically increased in the Canary Islands as modern inhabitants show bone lead contents similar to those in other Western countries.

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