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Determinants of blood lead levels in children: A cross-sectional study in the Canary Islands (Spain)

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ABSTRACT

The adverse effects of lead exposure on children are well known. Low blood lead levels (BLL) produce neurodevelopmental delay and cognitive disorders. However, since BLL thresholds for adverse effects on children's health are not known, the children population at risk of excessive lead exposure still has to be identified. This study was aimed at evaluating BLL in a children population of Gran Canaria (Canary Islands, Spain). Up to our knowledge, this is the first study to report on BLL in this population. Lead was identified and quantified in blood samples of 120 children, by means of Graphite furnace atomic absorption spectrometry (GFAAS). Lead was undetected in 80% of samples; BLL was 1 to 5 μg/dl in 15% of samples, and higher than 5 μg/dl in more than 4% of samples. BLL values in the evaluated children were low and similar to those described for other populations in Western countries. However, samples with the highest contamination (those in percentile 95) reached BLLs as high as 5.2 μg/dl. Positive associations were found between BLL and recent immigration (children adopted from non-western countries), and between BLL and parental smoking in children with low weight at birth. Since lead exposure in childhood may be a causative factor in adverse health trends – especially those involving the neurological system – and since threshold values for adverse lead effects are unknown, our finding that around 20% of the studied children had BLL higher than 1 μg/dl are of concern. Enhancing preventive measures for reducing lead exposure in children from the Canary Islands deserves further study.

Introduction

Lead is a heavy metal whose toxic effects have been known for more than 2000 years. The most sensitive targets for lead toxicity are: the nervous system (both central and peripheral), the hematological and cardiovascular systems, and the kidney (Koyashiki et al., 2010).

There are a number of environmental lead sources, and the continued use of this substance has contaminated air, water and soil. Nowadays, tap water and food should be considered the main lead sources for humans (Brown et al., 2001; Rubio et al., 2005). Good correlation has been found between blood lead levels (BLL) and water lead levels, even in situations where problems with the lead content of water have not been identified (Lanphear et al., 1998). Moreover, changes in water treatment (switching from chlorine to chloramine use, to avoid the production of desinfection by-products, i.e. trihalomethans) may increase the amount of dissolved lead in water resulting in considerable increase in children's BLL (Miranda et al., 2007). Although exposure to other lead sources could be relevant, lead-based paint in old houses is a major cause of lead intoxication (Olivero-Verbel et al., 2007). The use of leaded gasoline is a major cause of air pollution in urban areas (Schmidt, 2010). Despite the fact that the introduction of unleaded petroleum products significantly reduced the levels of atmospheric lead deposited on soils, as well as the BLL and the dietary lead intake in human populations, leaded gas is still a surprisingly important source of urban pollution (Schmidt, 2010). Other potential sources of lead exposure include industrial environmental sources, such as electronic waste (Zheng et al., 2008) or fishing tools like sinkers (Olivero-Verbel et al., 2007). The increasing globalization phenomenon has marked effects on the risk of lead exposure. As a matter of an example, made-in-China toys painted with lead-based

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paint have been distributed all over the world (Centers for Disease Control and Prevention, CDC, 2004, 2006).

Although the well-known toxic effects of lead have been reported in subjects of all ages, children are most susceptible to the deleterious effects of this heavy metal. This age group is at the highest risk for lead toxicity due to a number of factors. Infants' behavior, which includes frequent hand-to mouth activities, results in high intake of potentially lead-contaminated environmental materials (dust, paints, colored papers, etc.). Toxicokinetic differences between children and adults account for much of children's higher susceptibility to the adverse health effects of lead; actually, children absorb more of this metal across the gastrointestinal tract than adults (40% in children vs 10% in adults) (Ziegler et al., 1978). Gastrointestinal lead absorption may increase by factors such as fasting, iron deficiency and calcium deficiency (Mahaffey, 1990). In fact, the treatment for iron deficiency hinders lead uptake, so prevention of iron deficiency might be considered a public health intervention for reducing lead exposure in humans (CDC, 2002). Lead absorption through the respiratory tract is also possible (air pollution). Once absorbed into the blood, lead is distributed into blood and soft tissues, and mainly into mineralized tissues. Lead can be stored into calcified tissues for years (the half-life of lead in the bones ranges from 10 to 30 years). However, the proportion of the total lead burden that is stored in bones and teeth in adults is 94%, while in children it reaches only 70%. Lead stored into calcified tissues is released slowly, depending on the bone turnover rate, which varies with age. Actually, continuous growth during childhood involves continuous bone remodeling for skeletal development and, consequently, continuous lead release into the bloodstream (Barbosa et al., 2005). From bloodstream this metal can reach Central Nervous system, especially in children who present an immature blood–brain barrier (World Health Organization, WHO, 2005). Blood lead is excreted through the kidneys (urine) and via fecal (biliary). Children younger than two years retain approximately 33% of the absorbed lead, while adults retain only 1% (ATSDR, 2000). As a consequence of the above cited data, children have the highest exposure and the highest absorption, increased penetration of the blood–brain barrier and a developing nervous system that is most sensitive to damage resulting from this heavy metal pollutant (WHO, 2005).

The CDC considers lead poisoning as one of the most common preventable pediatric health problems. Acceptable BLLs were reduced to <10 μg/dl (0.5 μmol/dl) in 1991 and active prevention of lead poisoning was advocated through community-wide screening, education and environmental intervention (CDC, 2005). Over the last 2 decades, the percentage of children between 1 and 5 years old with BLL >10 μg/dl in the USA, fell from 88.4% to 4.4%, which was attributed to removal of lead from gasoline, paint and food (CDC, 2005); Nevertheless, evident adverse effects of BLL <10 μg/dl have been documented in children since 1990 (Laraque and Trasande, 2005; 5–10 μg/dl BLL has been associated with neurocognitive and behavioral deleterious effects in children. Available data suggest that attention, executive functions, visual-motor reasoning skills, vestibular-propioceptive control, and social behavior are especially affected by low levels of lead exposure (Needleman et al., 2002; Wright et al., 2008). BLL <10 μg/dl is inversely associated with children IQ scores (Bellinger, 2004; Canfield et al., 2003; Surkan et al., 2007). Thus, the relationship between BLL and cognitive-academic deficit in 6-years or older children might be the most cogent measure of the persistent and deleterious effects of subclinical lead toxicity (Lanphear et al., 2000). These findings suggest that there may be no threshold for the adverse consequences of lead exposure (Lanphear et al., 2000; Schwartz, 1994), thus evidencing the importance of prevention in decreasing children's BLL.

As mentioned, the hematological system is one of the major targets for lead exposure. This substance inhibits certain steps in the heme synthesis pathway. Consequently, the decrease in hemoglobin synthesis leads to anemia, usually observed at high BLLs (Jain et al., 2005; Lubran, 1980).

Bearing in mind the widespread use of lead and its well-known toxicological effects on the developing brain, evaluating the level of lead contamination in children should be mandatory in populations all over the world (CDC, 2005).

In spite of the international recommendations on screening children BLL and the well-documented presence of lead in foodstuffs consumed in the Canary Islands (Rubio et al., 2005), studies on BLL of children living in this region have never been conducted. The present cross-sectional study is aimed at filling this gap by evaluating lead levels in blood of children from the Gran Canaria Island, one of the most populated islands in the Spanish Canary Islands archipelago.

Subjects and methods

Study population

The Canary Islands are located in the Atlantic Ocean 1600 km Southwest from continental Spain, and hardly 100 km from the coast of Africa (Southwest Morocco). Fig. 1 shows the archipelago, which consists of seven major islands plus a number of smaller, mainly uninhabited islands. In geographical terms, the Islands are a part of the African continent. Yet, from a historical, economic, political and socio-cultural point of view, the Canary Islands are fully European. The economy of this region is based on a few economic sectors: tourism and, to a much lesser extent, farming and fishing. Traditionally polluting industries have a limited presence in the Islands.

This study was conducted on a children population living in the Gran Canaria Island, which is the second most populated island in the archipelago with a population of about 900,000 at the moment of the study (52,000 of them were children between 6 months and 6 years of age).

This study was conducted from June 2007 to January 2008. Participants were randomly selected from children between 6 months and 6 years of age, who attended the Complejo Hospitalario Universitario Insular Materno Infantil de Gran Canaria (CHUIMIGC) for blood tests as part of a preoperative protocol. Subjects were selected in the mentioned age-range because children these ages are at the highest risk of suffering the toxic effects of lead. The design of the study was approved by the ethical committee of the CHUIMIGC.

Parents were provided with a written description of the study and asked to fill-in a structured questionnaire and to sign a voluntary consent before their children participated in the study. Parents had to fill-in a structured questionnaire similar to that of the CDC for evaluating the risk of lead intoxication (CDC, 1991). The questionnaire consisted of 15 items on factors that may influence children BLL, such as sociodemographic status, parental smoking habits, recent immigration or characteristics of the residence (year of construction, alterations, painting, etc.).

120 children were eventually recruited. Anthropometric evaluation, detailed anamnesis and complete physical exploration were performed to the selected subjects. Tables 1 and 2 detail the characteristics of the studied population.

Blood sampling and analysis

Blood samples for determination of hematological parameters and BLL, were collected by trained nurses at the CHUIMIGC in evacuated tubes containing EDTA, and stored at −7 °C until analysis in laboratory. All plastic materials used for blood collection were