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Blood cadmium determinants among males over forty living in Mexico City

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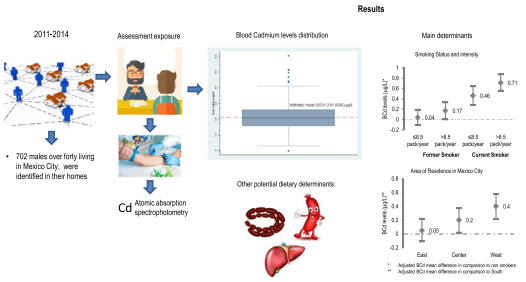
HIGHLIGHTS

- In Mexico City, sources and human exposure to cadmium (Cd) have been scarcely evaluated.
- Cd main exposure sources and blood Cd levels were determinated in males aged ≥40 years.
- In this population, blood Cd levels are among the highest reported so far.
- Smoking, place of residence and intake of some foods were identified as the main Cd exposure sources.
- Previous location of a large land trash in west zone of the city could be a potential Cd source.

GRAPHICAL ABSTRACT



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ABSTRACT

Background: Mexico City has air, water and food pollution problems; however, human exposure to cadmium and its sources have not been described.
Objectives: To determine the blood cadmium (BCd) level and its main exposure sources among males aged 40 years or older living in different areas of Mexico City.
Methods: After receiving informed consent, we interviewed 702 males aged ≥40 years to collect data on their sociodemographic characteristics, lifetime occupation, smoking history, and dietary habits, using a validated questionnaire. The BCd level (μg/L) was determined by atomic absorption spectrophotometry.
Results: The BCd mean level ± SD was 2.61 ± 0.82 μg/L, and 20% of men reported a potential cadmium occupational exposure. After adjusting for age and other potential confounders, the main determinants of the BCd level were the current smoking status at interview, with low ($\beta_{\leq 8.5 packs/year\ vs.\ non\text{-}smoker} = 0.46$; 95% CI: 0.28–0.64 μg/L; $p < 0.01$) and high ($\beta_{> 8.5\ packs/year\ vs.\ non\text{-}smoker} = 0.71$; 95% CI: 0.56–0.87 μg/L; $p < 0.01$) smoking intensity, and living in the Center ($\beta_{Center\ vs.\ South} = 0.20$; 95% CI: 0.02–0.37 μg/L; $p = 0.02$) or West area of the city ($\beta_{West\ vs.\ South} = 0.40$, 95% CI: 0.21–0.58 μg/L; $p < 0.001$). Moreover, the potential dietary sources of BCd included: liver ($\beta_{Yes\ vs.\ No} = 0.13$, 95% CI: 0.03–0.23 μg/L; $p = 0.01$), "*Chorizo*" ($\beta_{>1-3servings/month\ vs.\ No} = 0.14$, 95% CI: 0.01–0.26 μg/L; $p < 0.001$), sausage and ham.
Conclusions: The BCd levels observed in this population are high and only similar to those observed in workers from a sanitary landfill area in Southern Thailand. Potential environmental Cd exposure sources, such as industrial activity and previous land use, in the West and Center areas of the city should be explored in detail, especially in vulnerable population groups, such as children.

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1. Introduction

Cadmium (Cd) is a non-essential metal that does not degrade and thus persists in the environment. Because of its ability to accumulate in certain tissues, chronic Cd exposure is associated with potential toxic effects, mainly in the kidney (Kim et al., 2015), liver (Kang et al., 2013), lung (Lampe et al., 2008), bone (Engström et al., 2009) and nervous system (Méndez-Armenta and Ríos, 2007), and there is evidence of Cd toxic effects on testicular function (Wang et al., 2016). Furthermore, Cd has been classified as a Group 1 carcinogen due to its consistent association with lung cancer as well as with liver cancer and, potentially, other types of cancer (kidney, pancreas, bladder, breast and prostate) (IARC, 2012).

Cd, along with other elements, is naturally present in the Earth's crust (volcanic areas) in association with other metals; however, the main sources of Cd exposure are considered to be anthropogenic: industrial emissions; burning fossil fuels, such as coal or oil; incineration of common waste; industrial processes through the generation of steam, gases and suspended particles; and cigarette smoking. Cd is also present in fertilizer production and as an additive in the manufacture of paints, lacquers, enamels, and plastics, among others (ATSDR, 2012). In non-occupationally exposed populations, the main sources of Cd are tobacco smoke, ingestion of contaminated food (Garner and Levallois, 2016) and residence in polluted places (Filippini et al., 2016; Nie et al., 2016). Nevertheless, the Cd contribution from each source varies according to the studied population (Berglund et al., 2015).

Mexico City is one of the metropolitan areas with highest air pollution problems in the world (Molina and Molina, 2004). Cd has been identified as a component of PM_{10} in studies carried out in the northern and the southern regions of the city (Chow et al., 2002; De Vizcaya-Ruiz et al., 2006; Snow et al., 2014; Vega et al., 2004), likewise in some areas of the State of Mexico, adjacent to the western part of the city (Gutiérrez-Castillo et al., 2006); Cd has also been detected in wastewater used for irrigation of plants and vegetables, which are delivered to Mexico City (Lucho-Constantino et al., 2005). Nevertheless, human Cd exposure has been evaluated in low-sample-size studies, with limited representability, for instance, in pregnant women and their newborns (Galicia-García et al., 1997), students (González et al., 1997), autopsies (Saldivar et al., 1997) and prostate tissue samples (Galván-Bobadilla et al., 2005). Hence, our aim was to determine blood cadmium (BCd) level and its main exposure sources among the male population, aged 40 years or older, living in different areas of Mexico City.

2. Methods

As part of a case-control study carried out between November 2011 to August 2014, which aimed to evaluate prostate cancer risk factors in men living in Mexico City for at least one year (Vázquez-Salas et al., 2016), we enrolled 805 males aged ≥40 years, without prostate cancer or a prostate-related pathology diagnosis. Out of this sample, 702 (87.2%) subjects agreed to provide a blood sample for cadmium analysis. To obtain a representative sample of males over forty living in Mexico City, study subjects were identified in their homes using the following procedure: first, according to the proportional probability of the number of households recorded in the 2005 National Count of Households and Population, we selected 33 basic geostatistical areas (BGAs). BGAs are defined by the National Institute of Geography and Statistics and usually comprised the first-stage unit of surveys on households. Next, from each BGA in the sample, we selected ten blocks and finally, starting from the northeast corner of the block, we visited and knocked on each household's door to determine whether a male met the eligibility criteria and if there were two or more eligible subjects, one was randomly chosen. When an eligible male was not present at the time of visit, we made up to three attempts to locate him before looking for another potential participant. All subjects who did not agree to participate responded to a brief questionnaire regarding sociodemographic characteristics (age, education level, civil status, and birthplace).

The original study was approved by the ethics committee from the National Institute of Public Health (registration number: CI-980) and informed consent was obtained from all participants included in the study.

2.1. Interview

Through a direct interview, we obtained information about sociodemographic characteristics: current area of residence and time of residence (years) in the city, as well as age (years); the last two variables were used as continuous and also as categorical variables. For the construction of categorical variables, we used the tertiles of each distribution as cut-off points. The residence area in the city was grouped according to the legal demarcations of Mexico City (PROFECO), as follows: 1) Center: Azcapotzalco, Cuauhtémoc and Gustavo A. Madero; 2) West: Álvaro Obregón, Cuajimalpa, Magdalena Contreras and Miguel Hidalgo 3) East: Venustiano Carranza, Iztapalapa and Iztacalco and 4) South: Coyoacán, Tlalpan, Tláhuac and Xochimilco (Fig. 1); due to logistic limitations, Benito Juárez and Milpa Alta delegations were not sampled. The South is considered the least polluted area in Mexico City (Vega et al., 2004); therefore, this was used as the reference category.

Moreover, we asked about habitual occupation during the subjects' lifetime, with special emphasis on occupational exposure to cadmium. Males who reported having worked as welders, car painters, and iron-related workers were considered to have a positive history of occupational exposure to Cd, meanwhile mechanics and construction industry workers were considered as potentially exposed to Cd at work. Other reported activities were classified as no history of occupational cadmium exposure. Additionally, we asked about history of tobacco or tobacco products, as well as principal sources of drinking water (not specified, boiled, ozonized or filtered, and bottled water) and dietary habits.

2.2. Smoking history

We classified males who reported that they smoked 100 or more cigarettes in their life as smokers. Based on the smoking status at interview, we categorized participants as never, former or current smokers. To estimate participants' tobacco intensity, a smoking index was constructed multiplying the average number of cigarettes smoked per day by the number of smoking years and dividing by 20. This index was expressed as smoked packs per year and based on the median tobacco index among smokers, they were categorized as low intensity (≤8.5 packs per year) and high intensity (>8.5 packs per year). In addition, we constructed another variable with the following categories to account for smoking status and intensity: Never smoker, former and current smoker with low and high smoking intensity, respectively. For all analyses, the reference category was non-smoker.

2.3. Dietary information

To obtain information regarding the usual daily dietary intake for 3 years before the interview, we used a semi-quantitative food frequency questionnaire (FFQ), which was previously validated in a Mexican population (Hernández-Ramírez et al., 2009). This FFQ contains information about 127 different foods, which were grouped based on the cadmium content reported by the FDA (Food and Drug Administration, 2014), and by crop type (see Appendix A); additionally, we constructed a variable called processed meat, based on ham and sausage intake. The frequency of food options ranged from never to 6 times a day, and portions per day were calculated by the weight corresponding to the frequency of use. The weights used were: six for reported frequencies of consumption of six per day; 4.5 for 4–5 per day; 2.5 for 2–3 per day; one for one per day; 0.78 for 5–6 per week; 0.428 for 2–4 per week, 0.1429 for once a week, 0.065 for 2–3 per month, 0.016 for one per month or less and 0 for never. Most of the food or foods groups were categorized according to their tertile daily intake distribution,