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Time trends and exposure determinants of lead and cadmium in the adult population of northern Sweden 1990–2014

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ABSTRACT

Introduction: This study follows cadmium and lead concentrations in blood in the adult population in northern Sweden over 24 years.

Material and methods: Concentrations of lead and cadmium were measured in single whole blood samples (B-Pb and B-Cd) from 619 men and 926 women participating in the Northern Sweden WHO MONICA Study on one occasion 1990–2014. Associations with smoking and dietary factors were investigated. Consumption of moose meat was asked for in 2014.

Results: In the adult population in northern Sweden, the median B-Pb in 2014 was 11.0 μg/L in young (25–35 years) men and 9.69 μg/L in young women. In an older age-group (50–60 years), the median B-Pb was 15.1 μg/L in men and 13.1 μg/L in women. B-Pb decreased from 1990 to 2009, after which time no further decrease was observed. B-Pb was higher in smokers than in non-smokers. In never-smokers, positive associations were found between B-Pb and consumption of wine and brewed coffee (women only) in 2004–2014. Higher B-Pb with consumption of moose meat was demonstrated in men, but not in women. B-Cd was essentially stable over the whole period, but an increase in B-Cd, of 3% per year, was detected in never-smoking women between 2009 and 2014. In 2014, median B-Cd in never-smokers in the four groups was; 0.11 μg/L in younger men, 0.15 μg/L in younger women, 0.14 μg/L in older men, and 0.21 μg/L in older women. B-Cd was higher in smokers than in non-smokers. The only positive association between B-Cd and food items in 2004–2014 was with consumption of brewed coffee (men only).

Conclusions: The lack of a decrease in B-Cd from 1990 to 2014 and the absence of a further decrease in B-Pb after 2009 are unsatisfactory considering the health risks these metals pose in the general population at current concentrations.

1. Introduction

Human lead exposure has decreased dramatically worldwide following different actions, especially the ban of lead in petrol (EFSA, 2012a). In parallel, the blood lead concentrations (B-Pb) considered safe have decreased as new studies have found neurological effects at concentrations previously considered safe (Skerfving et al., 2015). Today, no B-Pb concentration is considered safe. The European Food Safety Authority (EFSA) has assessed that a B-Pb of 18 μg/L in children is associated with a mean loss of 1 point on the IQ scale. After taking uncertainty into account, the EFSA took 12 μg/L as a reference point. For adults, blood pressure and kidney effects are of concern already at low concentrations (EFSA, 2010). B-Pb concentrations in Sweden have been relatively low, but an association between lead and renal failure has been observed in adults in northern Sweden (Sommar et al., 2013), and EFSA's reference value is exceeded by a considerable fraction of Swedish children (Skerfving et al., 2015). A further decrease in B-Pb is therefore desired in the Swedish population, as well as in many other populations, but it is unknown if such a decrease is currently occurring. The knowledge about sources of exposures has become out-dated since the major source, lead in petrol, has been eradicated. Therefore, there is a need to characterise today's lead exposure determinants in order to identify ways to further decrease the exposure. Adult B-Pb concentrations have been previously monitored in 1990–1999 in northern

Abbreviations: B-Cd, concentration of cadmium in blood; B-Pb, concentration of lead in blood; Ery, erythrocytes; EVF, erythrocyte volume fraction; FFQ, food frequency questionnaire; LOD, limit of detection; R_s, Spearman rank correlation; SD, standard deviation; MONICA, Monitoring of Trends and Determinants of Cardiovascular Disease

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Sweden, showing a decrease to a median of 21 μg/L in men and 14 μg/L in women in 1999 (as calculated from erythrocyte concentrations of 49 μg/L and 33 μg/L, respectively) (Wennberg et al., 2006).

Smoking is a major source of cadmium exposure. Non-smokers are mainly exposed to cadmium from the diet, and mainly from crops absorbing cadmium from the soil (EFSA, 2012b). Low iron status increases the uptake of cadmium in the intestine causing higher cadmium concentrations in women compared to men (Barany et al., 2005). For cadmium, no evident change was detected in blood concentration in northern Sweden in 1990–1999 (Wennberg et al., 2006), despite long-term efforts to limit cadmium dispersal on cultivated land. This is unfortunate because cadmium has been associated with both kidney disease and fractures in a number of epidemiological studies, even at exposure levels that are common in the general population both in Sweden (Akesson et al., 2014; Wallin et al., 2014, 2016) and elsewhere (EFSA, 2012b). Cadmium might also be associated with some types of cancer (Akesson et al., 2014). In a recent review cadmium concentrations in urine was associated with increased all-cause mortality as well as mortality from cancer and cardiovascular disease (Larsson and Wolk, 2016).

The objective of this article is to describe how lead and cadmium concentrations in blood (B-Pb and B-Cd) have developed in the northern Swedish population over 24 years (1990–2014) in younger and older men and women and to identify exposure determinants of concern during the recent years.

2. Materials and methods

2.1. Study population

The Northern Sweden MONICA (multinational monitoring of trends and determinants in cardiovascular disease) Study was initially a part of a WHO multicentre study that began in the middle of the 1980s. Sampling in the two most northern counties of Sweden – Norrbotten and Västerbotten, with a total population of around 500,000 people – has continued every fourth or fifth year, and the latest survey was conducted in 2014. Each survey year, 2000 or 2500 randomly selected participants aged 25–74 years (upper limit 64 years in 1986 and 1990) are invited to participate in the survey, which consists of a lifestyle questionnaire and a medical examination with a focus on cardiovascular disease. Equal numbers of men and women in 10-year age groups have been invited, and the samplings for the different surveys have all been independent of each other. Participants are asked to donate blood samples for future research, and these are stored frozen in the Medical Biobank in Umeå (Stegmayr et al., 2003).

Participants of both sexes and all ages examined in the MONICA Study were included in the study on time trends of metals 1990–1999 (100 men and 100 women each study year) (Wennberg et al., 2006). In the later study years, a younger (25–35 years) and an older (50–60 years) age group were analysed for B-Pb and B-Cd. Only women were included in 2004 (n = 287), while both men and women were included in 2009 (150 men and 177 women) and in 2014 (170 men and 163 women) (Fig. A).

Participation rates in the Northern Sweden MONICA Study in 1990, 1994, 1999, 2004, 2009, and 2014 were 79.2%, 76.8%, 72.9%, 76.2%, 69.2%, and 62.5%, respectively (Eriksson et al., 2011, 2016).

In 1990–1999, concentrations of metals were measured in erythrocytes. From 2004 and onwards, whole blood has been used instead. For lead and cadmium, it is possible to convert the concentrations in erythrocytes to corresponding concentrations in whole blood (Fernlund et al., 1991).

This study was approved by the Ethical Review Board in Umeå (diary number 2013/97-31) and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

2.2. Sampling of blood

Blood samples were obtained by venipuncture into Venoject tubes (Terumo, Leuven, Belgium) with lithium-heparin. During 1990–1999, erythrocytes and plasma were separated into aliquots, centrifuged at 1500 × *g*, and stored at − 80 °C in the biobank in Umeå. During 2004–2014, blood samples were kept cool (+ 4 °C) until they were sent to the laboratory for analysis (usually the same day, and no more than four days after sampling). The tubes were tested for contamination of cadmium and lead.

2.3. Chemical analysis

All erythrocyte (Ery) samples from 1990 to 1999 were analysed in one campaign by inductively coupled plasma-mass spectrometry (ICP-MS; Thermo X7, Thermo Elemental, Winsford, UK) with a preparation method according to Barany et al. (1997). The samples, diluted 10 times with an alkaline solution, were analysed in peak-jumping mode for Cd (*m/z* 114 with correction equation for the spectral overlap of 114Sn) and Pb (the sum of the counts at *m/z* 206, 207 and 208). The internal standard for Cd was In, and the internal standards for Pb were Bi (*m/z* 209) and Tl (*m/z* 205). The results are presented in a time trend study by Wennberg et al. (2006).

In 2004, 2009, and 2014, B-Cd and B-Pb were determined in whole blood samples with the same instrumentation, preparation method, and instrument settings as in 1990–1999. In the current study, B-Cd and B-Pb were calculated from the erythrocyte levels of 1990–1999, using the formulas B-Cd = Ery-Cd × the erythrocyte volume fraction (EVF) and B-Pb = Ery-Pb × EVF (Fernlund et al., 1991) where EVF = 0.42, which was the median value in the 2004 study.

The limit of detection (LOD), calculated as three times the standard deviation of the blank for Cd, was 0.09 μg/L in 1990–1999 (Wennberg et al., 2006), 0.02 μg/L in 2004, 0.06 μg/L in 2009, and 0.05 μg/L in 2014. The corresponding values for Pb were 0.26 μg/L, 0.04 μg/L, 0.09 μg/L, and 0.06 μg/L, respectively. For Cd, there were values below LOD (1990, n = 21; 1994, n = 32; 1999, n = 36; 2004, n = 0; 2009, n = 14; 2014, n = 0). All values of B-Cd were used, even when below the formal LOD, because such values, though uncertain, contain more information than the usually employed LOD/2 values (Helsel, 1990).

2.4. Accuracy

All analysed samples were prepared in duplicate, and the precision was calculated as the coefficient of variation of the measurements of duplicate preparations. The analytical accuracy was verified with certified reference material, including Seronorm Trace elements whole blood (SERO AS, Billingstad, Norway) and human blood reference samples originating from the International Comparison Programme of the Centre de Toxicologie du Quebec, Canada (CTQ). The accuracy of the B-Cd and B-Pb measurements was determined with Seronorm batches; 1990–1999, lots 404107 and MR9067; 2004, lot MR4206; 2009 lots MR4206 and 503109; and 2014, lot 1103128) and samples from the CTQ (2004, lots C0515 and QMEAQAS06-08; 2009, lots C0515 and C0912; and 2014, lots C0616 and L0807) were used. The results from the quality analysis are shown in Table 1.

2.5. Lifestyle variables

Current cigarette smoking was asked for with the answer alternatives “yes, regularly (at least one cigarette a day)”, “no”, or “sometimes (less than one cigarette a day)”. Those not reporting being current daily smokers were asked for previous smoking with the question “Did you ever smoke regularly?” with the answer alternatives “yes, regularly” or “no”. In this study, participants were dichotomised as ever-smokers or never-smokers.

An 84-item food frequency questionnaire (FFQ) was used to monitor