



Influence of socio-demographic and diet determinants on the levels of mercury in preschool children from a Mediterranean island



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ABSTRACT

Mercury levels measured in 302 hair samples of 4 year-old children from Menorca (western Mediterranean Sea) are reported. Their concentrations, arithmetic mean 1.4 µg/g, ranging between 0.040 µg/g and 10 µg/g, were higher than in other children inland populations but lower than in previously studied island cohorts, e.g. Faroe, Madeira and Seychelles. 20% of the samples were above the WHO recommended values. Higher concentrations in females than males were observed. Frequent consumption of fish and other seafood were significantly related to the observed mercury concentrations. Oily fish was the main source of this pollutant but shellfish and squid consumption were also associated with high mercury concentrations. Maternal smoking, occupational status or previous siblings were also found to significantly influence the levels of this pollutant. McCarthy Scales of Children's Abilities used to assess children's motor and cognitive abilities did not show association with mercury concentrations at 4 years of age.

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1. Introduction

Mercury is a recognized toxic pollutant of public health concern (WHO/IPCS, 1990). It is distributed globally by both natural processes and anthropogenic activities. Inorganic mercury may be transformed into organic forms (mainly methylmercury, MeHg) which may then accumulate and biomagnify through the food chain.

The developing foetus is particularly vulnerable to acute and chronic mercury exposures. As MeHg crosses the placenta it may accumulate and damage the developing central nervous system because it may get across the permeable blood–brain barrier (Davidson et al., 2004). Contamination episodes in Japan showed irreversible neurological damage upon exposure to this compound (Harada, 1995). Several studies have focussed on neurotoxicity and neurodevelopmental risk among children exposed to low or moderate mercury levels (Karagas et al., 2012) but the association is still inconclusive.

It is generally agreed that seafood consumption, either fish or mammals, is the main source of MeHg in humans (International

Programme on Chemical Safety, 1991; Centers for Disease Control and Prevention, 2005; US Environmental Protection Agency, 2007; McDowell et al., 2004). Accordingly, infants from the populations of several islands have been studied for assessment of the accumulation patterns and neurodevelopmental effects, e.g. Faroe Islands ($n = 917$; Grandjean et al., 1997), Madeira Islands ($n = 149$; Murata et al., 1999), Seychelles Islands ($n = 229$; Myers et al., 2009).

The Mediterranean basin is a global store of mercury due to important cinnabar deposits (Renzi et al., 1998). Marine organisms living in this basin accumulate higher mercury concentrations than those from other seas. To the best of our knowledge, mercury accumulation in people on Mediterranean Islands have only been considered in three sites, Eastern Aegean Islands ($n = 246$; Gibicar et al., 2006), Sardinia ($n = 22$; Carta et al., 2003) and Menorca ($n = 65$; Montuori et al., 2006; Díez et al., 2009) and the two former studies concerned adult populations. The present study is devoted to provide a description of the main socio-demographic and dietary factors that determine the levels of mercury in children from Menorca based on a large cohort ($n = 302$).

Menorca is a Balearic Island located in the northwestern Mediterranean Sea. Its resident population is about 94 000 inhabitants and their livelihoods depend on extensive farming and tourism,

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with little industry. The inhabitants also have easy access to fish and seafood, a portion of them being fishermen. The fresh fish and shellfish consumed in the island are of local origin, i.e. Mediterranean. This island is therefore an interesting site for the assessment of the exposure levels of mercury in children from general population living in a Mediterranean environment.

Spain is a country with high fish and seafood consumption (Welch et al., 2002). Studies in newborns and preschool children in Catalonia, Valencia, Granada and Menorca showed elevated exposure to mercury contamination which was related to high fish intake (Montuori et al., 2006; Ramón et al., 2008; Díez et al., 2009; Freire et al., 2010).

In the present study detailed socio-demographic and diet analyses of the exposure to mercury contamination of a cohort of preschoolers from a typical Mediterranean population, e.g. Menorca, has been performed. The body burden of mercury in four year-old children has been estimated by collection and analysis of hair samples. Significant associations between the concentrations of this metal and socio-demographic factors such as sex, residence site and other maternal and paternal characteristics have been investigated. The influence of fish and seafood consumption in the observed mercury concentrations has also been assessed. The study has also encompassed an assessment of the effects of this contamination in neurodevelopment. The McCarthy Scales on Children's Abilities (MSCA) has been used for this purpose.

2. Materials and methods

2.1. Study population and sampling

The Menorca cohort was established within the Asthma Multicenter Infants Cohort Study (Polk et al., 2004). 482 pregnant women were recruited from prenatal clinics over 12 months in 1997–1998 and their children were followed-up until 4 years of age, within the Childhood and Environment research network (INMA) (Ribas-Fitó et al., 2006). Children at 4 years visit provided a hair specimen for total mercury (THg) analysis. Information on dietary intakes was obtained from a food frequency questionnaire (FFQ) given to their mothers. Preliminary analyses of mercury and methylmercury concentrations on a small number of cases ($n = 59$ and 65, respectively) from the same infant population were carried out (Montuori et al., 2006; Díez et al., 2009). The present study provides mercury data for 302 children whose hair THg concentrations were analysed using an improved methodology (see next subsection below).

From 482 children enrolled at birth, 302 (63%) provided complete outcome data at 4 years and hair for mercury measurements. The characteristics of the participant population are described in Table 1. Except for sex, no differences were found between this subset and the children without mercury measurements. More female children were included due to the easier availability of hair samples. The subset with both THg measurements and MSCA neuropsychological test included 298 children (99%), and no differences between the subsets were found.

Written informed consent was obtained from the parents of each child before the study, which was approved by the Ethics Committee of the Institut Municipal d'Investigació Mèdica (Barcelona).

2.2. Hair sample analysis

A lock of scalp hair approximately 5 cm long was obtained, usually from the nape. The samples were coded and stored in sealed plastic bags until analysis. A minimum of 25 mg of hair was required. 25–50 mg of each sample were treated with HNO_3 (1 ml; Baker Instra) and H_2O_2 (0.5 ml; Merck Suprapur) in a Teflon vessel (90 °C overnight). The digested sample was diluted with deionized water (8.5 ml; Purelab Ultra). One procedural blank was included in each sample batch for possible contamination control. THg determination was performed using inductively coupled plasma mass spectrometry (Agilent 7500 CE) operating under standard conditions and using rhodium as internal standard. All samples were above detection limit.

Certified reference materials from the International Atomic Energy Agency, IAEA-085 and IAEA-086, with 23.2 $\mu\text{g/g}$ and 0.57 $\mu\text{g/g}$ total mercury concentrations, respectively (Heller-Zeisler et al., 1998), were used for validation and verification of the accuracy of the analytical method.

2.3. Covariates

Information on maternal and paternal socio-demographic characteristics, parity and maternal age were collected at recruitment. More data were obtained at birth

Table 1

Characteristics of the study population according to participation in the mercury analysis (Menorca, Spain, 1997–2001).

	Children included ^a ($n = 302$)	Children not included ($n = 180$)	<i>p</i> -value ^b
Child			
Sex (%)			<0.01
Female	57	34	
Male	43	66	
Town of residence at 4 yr (%)			0.65
Ciutadella	45	48	
Maó	23	20	
Other municipalities	32	32	
Passive smoking at 4 yr (%)			0.90
No	49	48	
Yes	51	52	
Fish consumption (%)			0.16
Never/Rarely	11	7	
1–2 servings/week	56	64	
>2 servings/week	33	29	
Seafood consumption (%)			0.35
Never/Rarely	15	13	
1–3 servings/month	32	27	
≥ 1 servings/week	53	60	
Total fish + seafood consumption (%)			0.90
<2 servings/week	30	31	
2–3 servings/week	29	30	
>3 servings/week	41	39	
Mother			
Age at delivery (%)			0.54
<30	55	52	
>30	45	48	
Parity at child's birth (%)			0.59
None	51	47	
One	36	41	
Two or more	13	12	
Breastfeeding (weeks) (%)			0.48
<2	19	22	
2–16	25	28	
>16	56	50	
Time of gestation (weeks) (%)			0.082
27–39	23	28	
39–40	56	45	
40–44	21	27	
Smoking during pregnancy (%)			0.92
No	79	79	
Yes	21	21	
Educational level (%)			0.53
Primary school or no education	60	56	
Secondary school or university	40	44	
Occupational status (%)			0.094
Unskilled, partially skilled or housewife	33	41	
Skilled	67	59	
Father			
Educational level (%)			0.70
Primary school or no education	68	66	
Secondary school or university	32	34	
Occupational status (%)			0.95
Unskilled or partially skilled	12	13	
Skilled	88	87	

^a THg concentrations available.

^b *p*-value from Chi-square *t*-test.

(including time of gestation and smoking habits during pregnancy) and in follow-up surveys few months after delivery (such as type and duration of breastfeeding). Information on children's passive smoking at 4 years old, town of residence and dietary intake were gathered at the 4 years post-partum visit from food frequency questionnaires (FFQ).

The children's place of residence was classified into three categories: Ciutadella, Maó (the two main municipalities in the island) and other. Parity at child's birth was categorized as no siblings, one sibling and ≥ 2 siblings. Duration of breastfeeding was divided in 3 categories: <2 weeks (mainly formula-fed children), short-term (2–16 weeks) and long-term (>16 weeks). Time of gestation was divided into: 27–38 weeks, 39–40 weeks and 41–44 weeks. In some analyses, maternal age was divided in two categories: <30 years and >30 years.

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