Regulatory Toxicology and Pharmacology 70 (2014) 681–686

Contents lists available at ScienceDirect

Regulatory Toxicology and Pharmacology

journal homepage: www.elsevier.com/locate/yrtph

Total mercury concentrations in the general Korean population, 2008–2011

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ARTICLE INFO

Article history:
Received 28 July 2014
Available online 16 October 2014

Keywords:
Korean
Mercury
Methylmercury
Human biomonitoring
Exposure assessment

ABSTRACT

The purpose of this study was to evaluate the blood mercury levels of the general Korean population. The data from subjects of all ages were pooled from recent national surveys. In the combined surveys, the geometric means (GMs) of the blood mercury concentrations in subjects aged 0–7, 8–18, and 19 years and above were 2.05 (2010–2011), 2.12 (2010–2011), and 3.74 μg/L (2008–2011), respectively. There was an increasing trend in blood mercury levels with age until 59 years and then a slight decline in the group above 60 years. The time trend for exposure to mercury in Korea also showed a marked decline. In comparing estimated methylmercury exposure to the Korean health-based guidance value (tolerable weekly intake [TWI]: 2.0 μg/kg bw/week), the GMs of methylmercury exposure for subjects aged 0–7, 8–18, and 19 years and above were 0.30, 0.31, and 0.43 μg/kg bw/week, respectively, while methylmercury exposure did not exceed the TWI (15.0%, 15.5%, and 21.5% compared to the TWI, respectively). The 95th percentiles of estimated methylmercury exposure ranged from 0.71 to 1.61 μg/kg bw/week, which was not above the TWI (range, 35.5–80.5%).

1. Introduction

Mercury is the only common metal that is liquid at normal temperature. Along with lead, it is a heavy metal that has been used for a long time and is still in use in industry today. The World Health Organization (WHO) considers mercury among the top 10 chemicals that are a major public health concern (WHO, 2013).

Mercury is known to be toxic to humans associated with the form and the exposure route (WHO, 2013). In human, the neurologic effects and developmental neurotoxicity are critical effects associated with exposure to organic mercury (e.g., methylmercury). Exposure of a fetus or young child to organic mercury may cause effects on the development of nervous system such as memory, attention and verbal learning. The critical target for toxicity of inorganic mercury is kidney. The issue of mercury in food, particularly the consumption of contaminated fish such as tuna, swordfish, shark and whale, has recently been receiving considerable attention as it is a major pathway of mercury exposure (Diez, 2009; Park and Zheng, 2012). However, it also is considered the benefits of fish consumption, which fish consumption lowers the risk of suboptimal neurodevelopment in infants, children and adolescents compared with not eating fish in most circumstances evaluated (FAO and WHO, 2011). Therefore, there are currently global efforts to establish food consumption guidelines in order to reduce the risk of mercury exposure and institute mercury management practices to reduce mercury emissions, and to increase the benefits of fish consumption (UNEP and WHO, 2008; FAO and WHO, 2011).

In 2012, the Korea Ministry of Environment issued the mercury blood levels of adults in some local regions where people had been eating *dombaegi* over an extended period. *Dombaegi* is salted shark

Abbreviations: CHMS, Canadian Health Measures Survey; EFSA, European Food Safety Authority; FAO, Food and Agriculture Organization of the United Nations; GM, geometric mean; HBM, human biomonitoring; KNEHS, Korean National Environmental Health Survey; KNHNES, Korean National Health and Nutrition Examination Survey; KRIEFS, Korean research project on the integrated exposure assessment to hazardous materials for food safety; LOD, limit of detection; MFDS, Ministry of Food and Drug Safety; NHANES, National Health and Nutrition Examination Survey; NIER, National Institute of Environmental Research; TWI, tolerable weekly intake; UNEP, United Nations Environment Programme; WHO, World Health Organization; 24HR, 24-hour recall.

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http://dx.doi.org/10.1016/j.yrtph.2014.10.004
0273-2300/

meat, which is made from the mako shark (*Isurus oxyrinchus*), star-spotted shark (*Mustelus manazo*), and smooth hammerhead (*Sphyrna zygaena*). At that time, the geometric means (GMs) of blood mercury of the adults in the studied regions were 16.69–16.81 μg/L. The blood mercury levels in the general Korean population (3.90 μg/L) have also been found to be higher than those of other countries, such as the United States (0.83 μg/L), Canada (0.69 μg/L), and Germany (0.58 μg/L) (Becker et al., 2002; Caldwell et al., 2009; Eom et al., 2014; Lye et al., 2013).

The Korean Ministry of Food and Drug Safety (MFDS) required to know whether the exposure to mercury based on the blood levels of the general population in Korea is appropriate. Therefore, MFDS re-assessed the exposure levels regarding mercury in food. In this study, we collected recent nationwide survey data from the Korean Research Project on Integrated Exposure Assessment to Hazardous Materials for Food Safety (KRIEFS), the Korean National Health and Nutritional Examination Survey (KNHANES), and the Korean National Environmental Health Survey (KNEHS) to obtain the value of mercury in the blood of the general population and to describe the distribution of blood mercury in the general Korean population (Lim et al., 2012; Park, 2013; NIER, 2011). We also evaluated the general population's levels of methylmercury exposure, which we extrapolated from blood mercury concentrations by using a one compartment model, and estimated methylmercury dietary exposure level.

2. Methods

2.1. Blood mercury level data collection

To identify the recent levels of blood mercury in the general Korean population, we pooled the data from three nationwide surveys, namely KRIEFS (2010–2011), KNHANES (2008–2011), and KNEHS (2009–2011).

KRIEFS, a nationwide study that evaluated integrated exposure to hazardous materials through the intake of foods, oriental medicine, and health supplements, was conducted by the MFDS from 2010 to 2012 (Lim et al., 2012). The survey categorized subjects based on age (i.e., adult, child, adolescent, and infant). For adults, a minimum number of samples were obtained according to region, gender, and age, and these were then extrapolated using a square-root percentage quota method based on the distribution ratio of the population. Meanwhile, for children, adolescents, and infants, the survey employed a cluster sampling method centering on schools or organizations in three or four main areas in each city. For this survey, we used the data collected in 2010–2011 of 4246 subjects of all ages, comprising 2007 males and 2239 females.

KNHANES had been conducted by the Korean Centers for Disease Control and Prevention from 1998 and was composed of a health interview survey, a health examination survey, and a nutrition survey (Park, 2013). The 2008–2011 survey represented the second and third years of KNHANES IV (2007–2009), and the first and second years of KNHANES V (2010–2012). The survey employed a rolling sampling design, which involved a complex, stratified, multistage, and probability-cluster survey of a representative sample of the non-institutionalized civilian population in Korea. The survey investigated the heavy metal levels of people 20 years and older before 2009 and people 10 years and older after 2010. Minors under the age of 10 were not included in the study. For this survey, we used the data of 8747 subjects, comprising 4348 males and 4399 females, which were collected from 2008 to 2011.

KNEHS was conducted from 2009 by the National Institute of Environmental Research (NIER) in Korea (NIER, 2011). This survey was designed to monitor the biomarkers of major environmental pollutants in Korea. From 2009 to 2011, the survey included a questionnaire, sampling, and instrumental analysis, which was conducted annually among 2000 subjects from 117 enumeration districts, to measure the concentration levels of 16 different toxic pollutants in human blood and urine. The survey employed stratified multistage probability sampling units based on geographical area, gender, and age. For this survey, we used the data of 6311 subjects, comprising 2928 males and 3383 females, which were collected from 2009 to 2011.

In the pooled surveys, blood mercury concentrations were measured using the gold-amalgam collection method with the Direct Mercury Analyzer 80 (DMA 80, Milestone, Bergamo, Italy). The limit of detection (LOD) for blood mercury in KRIEFS, KNHANES, and KNEHS was 0.2, 0.158, and 0.2 μg/L, respectively. In this study, 0.2 μg/L was used for the imputation of values lower than the LOD.

For the descriptive analyses, age was treated as a continuous variable or categorized as follows: 0–7, 8–9, 10–12, 13–15, 16–18, 19–29, 30–39, 40–49, 50–59, and 60 +years. In this study, women of childbearing age were categorized as females aged 19–45 years according to the legal age of adulthood (i.e., 19 years) in Korea and the age in birthrate above one birth per 1000 people of the Korea National Statistical Office.

2.2. Extrapolation of methylmercury exposure from blood mercury concentrations

To extrapolate methylmercury exposure from blood mercury concentrations, we used the one-compartment model, which was employed by the Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives, the European Food Safety Authority (EFSA), and the United States Environmental Protection Agency, to establish the health-based guidance values for methylmercury (Stern, 2005):

$$d = C \times b \times v/(A \times f \times \mathrm{bw})$$

where d is daily intake (μg/kg bw/day), C is the mercury concentration in blood (μg/L), b is the elimination rate constant (0.014 per day), v is the blood volume (7% of body weight: infants/toddlers 17.5 kg, children/youth males 53.7 kg, children/youth females 47.4 kg, adult males 70.2 kg and adult females 58.0 kg), A is the fraction of the dose absorbed (0.95), f is the absorbed fraction distributed to the blood (0.05), and bw is body weight (kg).

2.3. Dietary assessment

To estimate methylmercury dietary exposure, it was assumed that 100% of mercury in fish and shellfish products is present as methylmercury. We used the data of KRIEFS, which carried out a two-day 24-hour recall (24HR) that included 16 food groups (i.e., grains, potatoes, sugars, beans, seeds, vegetables, mushrooms, fruits, meats and poultry, eggs, fish and shellfish, seaweeds, milk and dairy products, oils, beverages, and seasonings) and 119 foods. In this study, the exposure to methylmercury for an individual was calculated by their amount of fish and shellfish consumption, and the means of the mercury concentrations in fish and shellfish. Total methylmercury exposure was calculated by summing the methylmercury exposure from each food, including fish and shellfish. The basic equation is as follows: