Environmental Research 160 (2018) 212–222

Contents lists available at ScienceDirect

Environmental Research

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

Association of methylmercury intake from seafood consumption and blood mercury level among the Asian and Non-Asian populations in the United States

Yangyang Liu[a,*], Susan Buchanan[b], Henry A. Anderson[c], Zhiwen Xiao[b], Victoria Persky[a], Mary E. Turyk[a]

[a] University of Illinois at Chicago, School of Public Health, Division of Epidemiology and Biostatistics, 1603 West Taylor Street, Chicago, IL, USA
[b] University of Illinois at Chicago, School of Public Health, Environmental and Occupational Health Sciences, 2121 West Taylor Street, Chicago, IL, USA
[c] University of Wisconsin-Madison, Department of Population Health Sciences, 614 Walnut Street, Madison, WI, USA

ARTICLE INFO

Keywords:
Methyl mercury
Daily mercury intake
Fish
Asian populations
NHANES

ABSTRACT

Background: MeHg is a well-established neurotoxicant for fetal brain growth and development and has been shown to increase the risk of cardiovascular disease in aging populations. In the U.S., Asian populations are of particular concern because of their seafood consumption behaviors.
Objectives: Our objective was to calculate the average daily MeHg intake (ADMI) from seafood and to assess the relationship between ADMI with blood methylmercury (BMeHg) concentrations, specifically among women of reproductive age (WORA) and adults ≥ 50 years of age.
Methods: We estimated ADMI from seafood using the 30-day fish consumption data from the NHANES 2011–2014 datasets. Using multivariable linear regression, we estimated the proportional change in mean BMeHg associated with a doubling of the ADMI. Further, correlations between ADMI and BMeHg were compared between Asians and other racial/ethnic groups.
Results: Our analysis found both Asian WORA and Asian adults age ≥ 50 years old had significantly higher BMeHg levels and ADMI than their Non-Asian counterparts. Correlations between ADMI from seafood and blood Hg levels were stronger among Asian WORA than among Non-Asian WORA. Key fish species that influenced the dietary MeHg intake for Asians were mackerel, tuna, and "other known/unknown fish species".
Conclusion: We confirmed that Asian populations have higher MeHg intake than the Non-Asian population in the U.S. and seafood intake is a key predictor of blood Hg concentration, especially among Asian women of reproductive age. Future studies should incorporate information on other known and unknown fish species that are frequently consumed by Asian populations and different parts and fish organs eaten to better understand determinants of MeHg exposure.

1. Background

Mercury (Hg) is a naturally occurring metal found throughout the environment. Release of Hg into the environment is mainly from human activities, particularly coal-fired power stations, residential coal burning, industrial processes, waste incinerators and as a result of mining for mercury, gold and other metals (WHO, 2016). Mercury combines with carbon and hydrogen to make organic mercury compounds. The most common organic mercury compound, methylmercury (MeHg), is produced mainly by microscopic organisms in sediments and soil and can accumulate up the aquatic food chain, leading to elevated concentrations in predatory fish (ATSDR 2016; Patrick, 2002). For the general human population, the predominant route for MeHg exposure is dietary exposure via consumption of seafood, especially fish (Diez, 2009).

MeHg is of particular public health concern because it is a well-

Abbreviations: ADMI, average daily MeHg intake; A/P/N/M, Asian, Pacific Islander, Native American, or multiracial; BMeHg, blood methylmercury; CI, confidence interval; DHA, docosahexaenoic acid; FAO/WHO, Food and Agriculture Organization of the United Nations and World Health Organization; Hg, mercury; MEC, Mobile Examination Center; MeHg, methylmercury; N/A, not available; NHANES, The National Health and Nutrition Examination Survey; R^2, coefficient of multiple correlation; Se, selenium; TBHg, total blood mercury; WHO, World Health Organization; WORA, women of reproductive age

* Correspondence to: University of Illinois at Chicago, School of Public Health, Division of Epidemiology and Biostatistics, 912 SPHPI, MC 923, 1603 West Taylor Street, Chicago, IL, USA.
E-mail address: yliu217@uic.edu (Y. Liu).

http://dx.doi.org/10.1016/j.envres.2017.09.031
Received 31 July 2017; Received in revised form 25 September 2017; Accepted 28 September 2017

established neurotoxicant (ATSDR 2016; Myers et al., 2000). MeHg can cross the placenta, penetrate the blood-brain barrier and concentrate in the fetus (Diez, 2009; Morrissette et al., 2004; Stern and Smith, 2003), which can increase the risk of behavioral and cognitive impairment in offspring (Grandjean et al., 1997; Myers et al., 2000; Oken et al., 2005; Prpić et al., 2017; Stokes-riner et al., 2012). However, seafood also contain nutrients, such as docosahexaenoic acid (DHA), an omega-3 long chain polyunsaturated fatty acid that is important for fetal brain growth and development and has cognitive benefits for children (Daniels et al., 2004; Oken et al., 2008). Therefore, balancing the risks and benefit of seafood consumption is critical for healthy neurological development of the fetus. In 2010, the joint Food and Agriculture Organization of the United Nations and World Health Organization (FAO/WHO) report found that maternal fish consumption is associated with optimal neurodevelopment in her offspring (WHO and FAO, 2010). Fish is also highly recommended to prevent cardiovascular diseases (Djoussé et al., 2012; WHO and FAO, 2010; Zheng et al., 2012). At the same time, a growing body of evidence has been shown that the risk of cardiovascular disease increases with elevated levels of blood MeHg (Genchi et al., 2017; Roman et al., 2011; Stern, 2005)

Investigations in Asian countries [e.g., Cambodia (Agusa et al., 2007), Taiwan (Hsu et al., 2007), Japan (Sakamoto et al., 2007)] have reported fish/shellfish consumption levels greater than average worldwide consumption. Studies have also demonstrated that in the U.S., people of Asian descent, whose food choices are influenced by Asian dietary patterns (Sechena et al., 2003; Xu and Newman, 2015), consume seafood more frequently, in greater variety, and in greater quantity than non-Asian Americans. Asian populations in the United States have higher Hg levels compared to other racial/ethnic groups due to their higher seafood consumption (Buchanan et al., 2015a; Lin et al., 2013; Mahaffey et al., 2009; Mckelvey et al., 2007; Sechena et al., 2003; Tsuchiya et al., 2008a, 2008b; Xu and Newman, 2015). McKelvey et al. found that Asians in New York City have higher blood mercury levels than other racial/ethnic groups and that foreign-born Chinese New Yorkers, in particular, had higher mercury levels than non-Asian frequent fish consumers (Mckelvey et al., 2007). Buchanan, Anglen and Turyk (Buchanan et al., 2015a) found that both Asian women of reproductive age (WORA) and Asian adults older than 50 years had higher BMeHg levels than other racial/ethnic groups. About a quarter of Asian WORA had BMeHg greater than 3.5 μg/L, a proposed level of concern that accounts for fetal concentration of maternal MeHg (Mahaffey et al., 2004; Stern and Smith, 2003).

The National Health and Nutrition Examination Survey (NHANES) is designed to assess the health and nutritional status of adults and children in a nationally representative sample (US NHANES). Since 2011–2012, NHANES has measured total blood mercury (TBHg) and, in addition, speciated blood methylmercury (BMeHg) to include a direct measurement of MeHg (NCHS, 2011). Because blood mercury is predominantly in the methylated form in the seafood consuming population (Mahaffey et al., 2009), past epidemiological studies have used TBHg or TBHg minus urinary inorganic Hg rather than BMeHg to estimate exposure to MeHg (Ayotte et al., 2011; Miller et al., 2016; Valera et al., 2008).

The 2011–2012 NHANES survey also initiated a separate race/ethnicity category for Asians, who were previously included in a category with “other race” (NCHS, 2011). In prior investigations using the new Asian race category, 2011–2012 NHANES data have been used to assess the distribution of BMeHg concentrations for Asian and non-Asian women of reproductive age (WORA) and the older adult population (Buchanan et al., 2015a), and in the overall US population (Mortensen et al., 2014) and exposure to TBHg among Asian subgroups (Awata et al., 2017)

MeHg concentrations within and among fish species are known to vary by more than 10-fold, therefore, understanding patterns of MeHg exposure is challenging (Mahaffey et al., 2004). Numerous studies have investigated the correlations of dietary Hg intake and blood Hg concentrations among NHANES participants (e.g. Awata et al., 2017; Davis et al., 2014; Mahaffey et al., 2004; Xue et al., 2012). Awata et al. identified associations of TBHg and dietary intake of MeHg from fish in Asian subpopulations using the NHANES 24-h dietary recall data and fish MeHg concentrations from the U.S. Federal Drug Administration Total Dietary Study data (Awata et al., 2017). NHANES also provides detailed data on consumption frequencies of 31 seafood species in the previous 30 days, which may reflect habitual fish consumption more accurately than the 24-h dietary recall data (US NHANES). However, recent NHANES datasets have not previously been used to characterize the association between MeHg daily intake from seafood based on past 30 day fish consumption survey and blood MeHg levels among the Asian and non-Asian US population.

In this paper we extended Buchanan, Anglen and Turyk's (Buchanan et al., 2015a) analyses of mercury exposures in vulnerable population subgroups, WORA and adults age ≥ 50 years old, by 1) adding NHANES 2013–2014 dataset to the original NHANES 2011–2012 data; 2) calculating the average daily MeHg intake (ADMI) from different seafood (fish and shellfish) species using the 30 day seafood consumption data; and 3) assessing the relationship between seafood meals and ADMI with blood MeHg and TBHg biomarker concentrations, stratified by subgroup and Asian and non-Asian race/ethnicity.

2. Materials and methods

2.1. Study population

NHANES is a cross-sectional survey designed to provide a representative sample of the US non-institutionalized civilian population (US NHANES). For this study, the two recent NHANES cycles that assessed BMeHg, TBHg, and seafood consumption information were combined: 2011/2012 and 2013/2014. BMeHg and TBHg were measured in eligible participants aged 1 year and older at the physical examination. Seafood consumption frequency was collected from 30-day dietary recalls for participants 18 years of age and older (NCHS, 2011) (NCHS, 2013). For this paper we included participants ≥ 18 years older, which excluded 7954 participants aged younger than 18 years old. Our analysis was restricted to participants in whom both BMeHg and TBHg were measured, which resulted in the additional exclusion of 3839 participants. Participants outside of the age/gender categories selected for subgroup analysis and with missing covariates were further excluded. The final study population in this analysis consisted of 1284 WORA (females 18–44 years of age), among whom 183 participants self-reported their race/ethnicity as “Non-Hispanic Asian”, and 2642 adults ≥ 50 years of age, among whom 249 participants self identified their race/ethnicity as “Non-Hispanic Asian”. These two vulnerable groups (WORA and adults ≥ 50 years of age) were chosen are because of their potential risk for behavioral and cognitive impairment in offspring and cardiovascular disease, respectively. NHANES was approved by the NCHS Institutional Review Board, and all participants provided written informed consent.

Seafood consumption was collected using self-reported dietary recall interview over the past 30 days in-person in the Mobile Examination Center (MEC). The survey included the number of fish and shellfish meals consumed, broken out by specific type of shellfish (clams, crabs, crayfish, lobsters, mussels, oysters, scallops, shrimp, other known and unknown shellfish) and fish (breaded fish, tuna, bass, catfish, cod, flatfish, haddock, mackerel, perch, pike, pollock, porgy, salmon, sardines, sea bass, shark, swordfish, trout, walleye, and other known and unknown fish).

2.2. Hg intake, Hg exposure and covariates

Average daily MeHg intake (ADMI) for each fish species was estimated using the following equation developed by EPA risk assessment module (EPA, 2011b)