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Exposure and risk characterization for dietary methylmercury from seafood consumption in Kuwait

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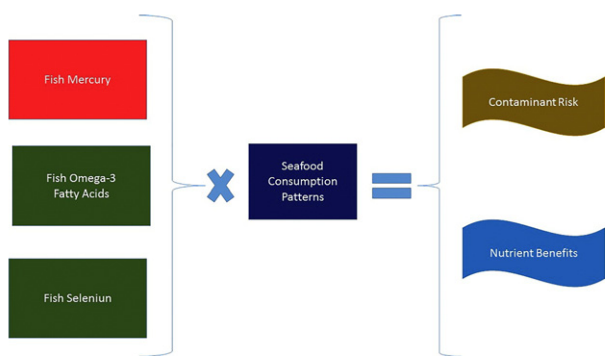
HIGHLIGHTS

- Mercury exposure among Kuwaiti adults and children was estimated.
- Over half of participants exceeded the MeHg intake guideline.
- Hamoor consumption drives MeHg exposure among Kuwaiti's.
- Restricting Hamoor intake may be necessary to mitigate public health risk.

GRAPHICAL ABSTRACT



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ABSTRACT

Seafood is an important source of essential nutrients; however, it can also confer health risks from methylmercury (MeHg). In this paper, we evaluate the levels of potential methylmercury exposure among Kuwaiti seafood consumers in order to support the development of dietary recommendations for fish consumption in Kuwait. Total mercury (HgT) concentration for most of the studied fish and shellfish species were on average below the 0.5 μg g^{-1} Codex guideline. The notable exception to this was Hamoor (*Epinephelus coioides*), which averaged 1.29 μg g^{-1} HgT and 0.55 μg g^{-1} MeHg. A dietary survey of 2393 households demonstrated that large quantities of fish and shellfish are commonly consumed in Kuwait (average consumption: 103 g d^{-1}). Most participants (53.6%) exceeded the Tolerable Daily Intake of MeHg; this percent exceedance was as high as 78% in children 6–12 years of age. The majority (Mean: 50–51%) of Kuwaiti's dietary MeHg exposure comes from the consumption of Hamoor; therefore, advisories to limit the consumption of Hamoor may be necessary. Nutrient:Methylmercury ratios are reported herein; these ratios may assist efforts to create dietary advice that limits contaminant risk while promoting the nutritional benefits of seafood in Kuwait.

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1. Introduction

Fish and shellfish are tremendously important food resources, contributing 20% of animal protein intake for 2.9 billion people globally (FAO, 2014). Due to seafood's nutritional density (in terms of both micro- and macronutrients), consuming fish and shellfish can provide important health benefits (U.S. Food and Drug Administration, 2014). For example, the selenium (Se) conferred through fish consumption helps regulate the production of thyroid hormones and can protect against oxidative damage (e.g. via glutathione peroxidase activity) (Boucher et al., 2008; Institute of Medicine, 2000; Ursini and Bindoli, 1987). Also, seafood is among the best and most accessible sources of long chain omega-3 fatty acids (LC n-3 FA), such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)(NHMRC, 2005). Nutritional research has shown LC n-3 FA to: demonstrate anti-inflammatory properties by limiting the production of pro-inflammatory cytokines, decrease circulating low-density lipoprotein (LDL; so-called "bad cholesterol"), and reduce the risk of cardiovascular disease (Chapman et al., 2011; Tonkin and Byrnes, 2014).

Despite these nutritional benefits, seafood consumption can also pose potential health risks. For example, long-lived piscivorous fish can bioaccumulate potentially harmful contaminants like methylmercury (MeHg), which is among the most bioavailable and hazardous forms of mercury (Hg) (Health Canada, 2007a). In addition to MeHg, inorganic Hg (e.g. Hg^{II}) is also frequently detected in seafood (Forsyth et al., 2004). As has been reviewed extensively elsewhere, there are several toxicokinetic and toxicodynamic differences between Hg^{II} and MeHg which have important implications on the risk characterization of Hg (ATSDR, 1999). It is commonly presumed that the mercury in fish is almost exclusively present as MeHg, the form of Hg for which children and women of child-bearing are sensitive subpopulations (Health Canada, 2007b). However, inorganic Hg^{II} can, on occasion, contribute substantial proportions of HgT in seafood. For example, previous reports have shown Hg^{II} may contribute 29% of HgT in northern pike, 39% in stubnose pompano, 47% in roach, and 54% in bream, 64% in cockle, 70% in shipjack tuna, 87% in clams, and 91% in catfish (Forsyth et al., 2004; Kensova et al., 2012; Liang et al., 2011; Wang et al., 2013; Zmozinski et al., 2014). Such studies have shown that, generally, shellfish: i) contain lower HgT and MeHg levels and ii) have higher proportions of HgT as Hg^{II} than predatory fish (Clemens et al., 2011). However, substantial deviations from these general trends are possible depending upon the species, age and trophic position of the fish/shellfish, as well as the presence of anthropogenic Hg contamination within the local aquatic environment (Clemens et al., 2011; Forsyth et al., 2004; Wang et al., 2013). Therefore, there is growing consensus of the importance of collecting information regarding Hg speciation within seafood in order to improve the precision of mercury risk assessments.

Chronic exposure to Hg^{II} (renal and gastrointestinal effects) and MeHg (neurological, immunological, and cardiovascular effects) can cause a variety of adverse effects in human populations (ATSDR, 1999). To protect against these adverse effects, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) established Toxicological Reference Values (TRVs) for Hg^{II} and MeHg that coincide to 0.57 μg kg/d and 0.23 μg kg/d, respectively (JECFA, 2003, 2010). Similarly, in order to promote nutritional sufficiency, regulatory authorities have set Dietary Reference Intakes (DRI) for Se (30–55 μg/d, depending on age) as well as LC n-3 FA such as EPA + DHA (55–160 mg/d, depending on age and sex) (Health Canada, 2010; NHMRC, 2005). Obviously, from a risk-benefit perspective, the ideal scenario would be for contaminant exposure to be beneath the relevant TRV while nutrient intakes meet DRIs. Therefore, efforts to maximize the health benefits associated with fish intake while controlling concurrent mercury risks have focused on identifying fish species with high LC *n*-3 FA:Hg and Se:Hg ratios. For example, several species of salmon, herring, and shellfish are rich in LC n-3 FA but low in Hg (Reyes et al., 2017). Similarly, barber (*Paranthias furcifer*), anchovy (*Sardinella anchovia*), flounder (*Botus* sp.) and red snapper (*Lutjanus* sp.) are all rich in Se but low in Hg (Dewailly et al., 2008). More recently, selenium health benefit values (which are based in part on Se:Hg molar ratios) were developed to serve as a criteria for mercury risk assessments (Ralston et al., 2016). However, such risk-benefit assessments have not yet been done for the majority of seafood species commonly consumed in Middle Eastern countries such as Kuwait.

The primary objective of this research was to assess the methylmercury risks and nutrient benefits conferred to Kuwaiti's through the consumption of fish purchased at local markets. To accomplish this objective, the seafood consumption profiles for 2393 Kuwaiti households were characterized. Additionally, MeHg, Se, and LC n-3 FA levels were measured in 15 types of seafood that are commonly consumed in Kuwait. This process was used to characterize contaminant exposure and nutrient intakes and explore advisories capable of maximizing nutrient intake while lowering Hg exposure in Kuwait.

2. Material and methods

2.1. Dietary survey

A dietary survey was conducted by the Kuwait Institute for Scientific Research in order to characterize Kuwaiti seafood consumption rates (Al-Zenki et al., 2009). This survey was implemented over 4 seasons in order to account for seasonal variation. For the survey, 2393 households (representing 10,646 individuals) completed a Food Frequency Questionnaire (FFQ) for the assessment of fish consumption. In total, 2393 households attending one of Kuwait's three main fish markets (Sharq, Mubarakiya, and Fahaheel) took part in the survey. Based on information provided by the Public Authority for Civil Information, these 2393 households (containing a total of 10,646 individuals) represented 1% of the total number of households in Kuwait. For each of the four survey periods, approximately 298 (Sharq), 150 (Mubarakiya), and 150 (Fahaheel) households completed the FFQ. Among the 2393 households that took part, there were on average 4.4 individuals over 6 years of age per household, 51% of 10,646 individuals represented were male, and the average age of household members was 28 years. The average age among adult participants was 35 years.

For each of the 15 types of seafood included in the survey, participants described the quantity (kg) they purchased over the past week (F), the number of family members within their household over 6 years of age (n), and their self-reported body weights. After accounting for the edible fractions of the seafood (E), the average daily consumption rates (IR) were calculated for each of the 15 species in each household:

$$IR_i\left(g\ d^{-1}\right) = \frac{F_i\left(g\ wk^{-1}\right) \times E_i}{n \times 7\ \left(d\ wk^{-1}\right)}$$

Notably, this approach assumes that all members of the household over the age of six consume equal seafood portion sizes.

2.2. Sample collection

Based on a study of seafood consumption among the Kuwaiti population (Al-Zenki et al., 2009), fish species that were determined to be the most frequently consumed were collected. Fish samples (muscle tissue) were collected over four phases (April–May 2012; June–July 2012; September–October 2012; December 2012–January 2013) from three fish markets (Sharq, Mubarakiya and Fahaheel). The fish samples included those that were: i) locally-caught, ii) imported from Iran and Saudi Arabia, and iii) farm-raised in Kuwait. In addition, canned tuna samples of six leading brands were purchased from the local supermarkets in Kuwait. Among the 15 species, a total number of 578 samples of fish, and shrimp and crab samples were collected from the three markets.