

Fish Consumption and Hair Mercury Among Asians in Chicago

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Objectives: The aim of the study was to characterize the risk for elevated mercury (Hg) from fish consumption among Asians in Chicago. Consumption of fish contaminated with methyl Hg (MeHg) can affect the neurodevelopment in children and cardiovascular disease risk in adults. **Methods:** We collected fish consumption information and hair samples for Hg at two health fairs. We purchased fish from Asian fish markets. **Results:** Geometric mean hair Hg from 71 participants was 0.58 $\mu\text{g/g}$, with 28% overall and 29% of women of childbearing age having hair Hg levels at least 1 $\mu\text{g/g}$; 20% ate fish 4 or more times/wk. Tuna consumption and non-Chinese Asian ethnicity were associated with elevated Hg. Hg levels in purchased fish were generally low. **Conclusions:** Our study confirms other findings that, compared with estimates of the general US population, Asians are at higher risk of elevated MeHg because of frequent fish consumption.

Environmental pollution in global waterways has resulted in the contamination of fish with methyl mercury (MeHg). MeHg is a potent neurotoxin; exposure during the prenatal period and early childhood via fish consumption can result in adverse cognitive and behavioral effects in infants and young children.^{1–4} MeHg has also been associated with higher risk for myocardial infarction in adults.⁵ Epidemiologic evidence shows that Asians in the United States have higher Hg levels compared with other racial/ethnic groups, and that this disparity is caused by frequent fish consumption.^{6–10} Our study sought to investigate fish consumption in Asians in an inland city, Chicago, and their hair Hg levels. We also tested samples of fish purchased in Asian Chicago fish markets for Hg.

METHODS

Recruitment and Survey

Study participants were recruited at two health fairs in Chicago: one was hosted by Asian Human Services in the Uptown neighborhood and the other was organized by the University of Illinois at Chicago Asian Pacific Medical Student Organization and held in Chinatown. Potential participants were adults who spoke at least one of the following languages: English, Chinese, Vietnamese, or Korean. Consent forms were available in all four languages, and all study materials were approved by the University of Illinois Institutional Review Board. We set up a table at the health fairs that included a poster in Chinese on healthy fish consumption and pamphlets titled *Eat Fish, Choose Wisely. Protect Against Mercury*¹¹ in English, Chinese, and Korean, and titled *Mercury in Fish and Shellfish* in Vietnamese.¹² Participants were recruited when

they approached the table. Interpreters were present to interpret the questionnaire and hair collection procedure. Participants provided written consent to allow us to conduct a fish consumption questionnaire and then take a small sample of hair (approximately 15 hairs) from the nape of the neck.

The short questionnaire was administered by study personnel with language interpretation as necessary and included items on demographics, frequency of fish consumption, and types of fish eaten regularly. Owing to the nature of the health fair set-up, we were asked to make our questionnaire as brief as possible. When reviewing the types of fish eaten, participants were shown a slideshow on a laptop of photographs of fish sold in Chicago area Asian supermarkets with the English, Chinese, and Vietnamese names of the fish displayed. Participants were also given the opportunity to name additional fish that were not seen in the slideshow.

Mercury Analysis

Hair samples were collected after the questionnaire was completed. Samples consisted of at least 15 hairs and had a minimum length of 1.5 cm. The 1 cm of hair closest to the scalp was tested for Hg reflecting an average exposure over approximately the last month. The scalp end of the samples were labeled, samples were placed in zip lock bags and sent for analysis for total Hg by Cold Vapor Atomic Fluorescence Spectrometry by Research Triangle Institute (Research Triangle Park, NC) using reference standards. Although Limit of Detection (LOD) varies by batch because of artifacts of the method blanks, LODs ranged from 0.004 to 0.002 $\mu\text{g/g}$. Intralab variability was addressed by processing several standard reference materials aliquots with every batch, and recoveries were consistently within acceptance limits. Based on measurements of two hair samples from each of three individuals, the interassay coefficient of variation was 12%.

Whole fish and fish filets were purchased from fish markets and grocery stores in Chicago neighborhoods with a high Asian population and frequented by a large proportion of Asian customers. Some of the stores were mentioned by our community partners as places their clients shopped for fish. We purchased at least one fish from each store. The following fish were purchased: tilapia (whole), silver pomfret (whole), black pomfret (whole), mackerel (whole), white bass (whole), dace (whole), salmon (fillet/steak), catfish (whole), swai (fillet), yellow croaker (whole), belt fish (whole), and fathead/bighead. We selected fish based on the fish species named by participants and community partners as fish they commonly ate. The swai was farm-raised and imported from Vietnam; the dace was imported from China. The countries of origin of the other fish are unknown.

Frozen fish, in original store packaging, were delivered to the Department of Earth and Environmental Sciences at the University of Illinois at Chicago where they were immediately placed in a -20°C freezer. Fish handling and preparation followed protocol described in US Environmental Protection Agency (EPA) methods 1631 E¹³ and 245.7.¹⁴ Glass and stainless steel equipment were cleaned in solutions of 10% HNO_3 and 10% HCl (trace metal grade), followed by rinsing with high purity water (more than 18 $\text{m}\Omega\text{-cm}$). All glassware was heated at 450°C for 1 hour and stored in cleaned plastic bags. Quartz boats used in the direct Hg analyzer (DMA-80, Milestone Inc, Shelton, CT) were heated to

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650°C for 10 minutes, cooled in the furnace, and stored in a clean plastic box. The mass and length of individual fish was recorded before removing 30% to 70% (approximately 40 to 200 g) of one fillet using a stainless steel chef's knife and cutting board. After removing skin and bones, the fillet portion was homogenized by repeated chopping and mixing, wrapped in two zip lock bags, and returned to the freezer. The tilapia was ground completely in a stainless steel blender before freezing. Approximately 0.03 g of homogenized fish was sampled with a stainless steel spatula and placed directly into a quartz boat for each analysis. The analyzer was calibrated using standards prepared from a 10 ppm Hg(NO₃)₂ solution (Spex CertiPrep, Metuchen, NJ) and results verified every five to six analyses with standard reference materials (NIST SRM 1947: Lake Michigan fish tissue with reproducibility of 9.0% and NIST SRM 2586: Baltimore soil with reproducibility of 2.1%).

Data Analysis

Participants were excluded from the analysis if their country of origin was not in Asia or was missing ($n = 4$) or age was under 18 years ($n = 1$), leaving 71 participants for the analysis. Two hair samples for Hg were below the limit of detection; their Hg levels were imputed as the level of quantification ($5 \times 10^{-3} \mu\text{g/g}$) divided by the square root of 2. Because hair Hg was log-normally distributed, a natural log transformation was performed for analysis. Hair Hg levels were considered to be elevated when above $1 \mu\text{g/g}$ (equivalent to the EPA reference dose of $0.1 \mu\text{g/kg/d}$).¹⁵⁻¹⁷ Bivariate associations of hair Hg with demographic and fish consumption measures were evaluated using t tests, chi-square tests, and Pearson's correlation coefficients, as appropriate. We used linear and logistic regression models to evaluate the multivariable associations of demographic and fish consumption characteristics with hair Hg levels, with stepwise selection to select significant predictors of hair

Hg ($P < 0.2$ for model entry, $P < 0.1$ for model retention). Statistical analyses were performed using SAS 9.3 (SAS Institute Inc, Cary, NC).

Data on total blood Hg measurements in relevant population subgroups from the 2011 to 2012 National Health and Nutrition Examination Survey (NHANES) were analyzed as a comparison to our population. Geometric means and proportion of the population subgroup with elevated blood Hg were analyzed using NHANES sampling weights for Mobile Examination Center examination to adjust for differential selection probabilities in NHANES and including survey design variables to account for the complex sampling design.

For total Hg from fish tissue examined in the current study, average and standard deviation for replicate measurements were calculated.

RESULTS

Table 1 shows the demographic characteristics, fish consumption, and hair Hg of study participants and the subset of women of childbearing age (WCBA). Seventy-one Asian adults participated in this study: 47 women, 23 men, and 1 who did not identify sex on the questionnaire. Regarding country of ethnic origin, 70% self-identified as Chinese or Taiwanese, with the remaining 30% identifying themselves from non-Chinese Asian or the Pacific Islands (PI) (11 from Vietnam, 5 from the Philippines, 2 from Korea, and 1 each from Burma, Indonesia, and Japan). Sixty-three (89%) of the participants were foreign born, having lived in the United States on average for 14 years. The mean participant age was 54 years, with a range of 22 to 82 years old. All but one of the participants reported eating fish. Nine (13%) reported eating fish every day and 20% ate fish 4 or more times/wk. Regarding the species of fish consumed, tilapia, salmon, tuna, pomfret, and croaker were the most often reported as "regularly" eaten, in that order (Table 1).

TABLE 1. Participant Characteristics, Fish Consumption, and Hair Mercury

| Characteristic | All Participants | WCBA* |
|--|----------------------------------|--------------------------------|
| <i>n</i> | 71 | 14 |
| Age, yrs, mean, SD (range) | 53.5, 14.1 (22–82) | 31.9, 7.2 (22–41) |
| Sex, <i>n</i> (%) | | |
| Men | 23 (33) [†] | 0 |
| Women | 47 (67) | 14 (100) |
| Country of ethnic origin, <i>N</i> (%) | | |
| Chinese or Taiwanese | 50 (70) | 5 (36) |
| Non-Chinese Asian or Pacific Islander | 21 (30) | 9 (64) |
| Foreign born, <i>N</i> (%) | 63 (89) | 8 (57) |
| Yrs in the United States, mean, SD (range) | 13.7, 10.5 (0.2–38) [‡] | 19.2, 15.5 (2–38) [‡] |
| Fish consumption, <i>N</i> (%) | | |
| Eat any fish | 70 (99) | 14 (100) |
| Eat fish everyday | 9 (13) | 0 |
| Eat fish ≥ 4 times/wk | 14 (20) | 0 |
| Eat locally caught fish | 16 (24) [§] | 5 (38) |
| Regularly eat tilapia | 43 (61) | 11 (79) |
| Regularly eat salmon | 42 (59) | 9 (64) |
| Regularly eat tuna | 35 (49) | 7 (50) |
| Regularly eat pomfret | 35 (49) | 3 (21) |
| Regularly eat croaker | 33 (46) | 1 (7) |
| Regularly eat red snapper | 24 (34) | 3 (21) |
| Regularly eat catfish | 23 (32) | 3 (21) |
| Regularly eat mackerel | 21 (30) | 4 (29) |
| Regularly eat white bass | 13 (18) | 1 (7) |
| Regularly eat anchovies | 11 (15) | 2 (14) |
| Regularly eat skate fish | 3 (4) | 0 |
| Hair Hg ($\mu\text{g/g}$)—mean, SD (range) | 0.91, 0.93 (0.004–5.24) | 0.86, 0.62 (0.12–2.14) |
| Hair Hg ($\mu\text{g/g}$)—geometric mean, 95% CI | 0.58 (0.44, 0.76) | 0.65 (0.40, 1.06) |
| Elevated hair Hg $\geq 1 \mu\text{g/g}$, <i>N</i> (%) | 20 (28) | 4 (29) |

*WCBA=women of childbearing age, 18 to 44 years of age.

[†] $n = 1$ missing sex.

[‡] $n = 8$ missing years living in the United States.

[§] $n = 5$ missing consumption of locally caught fish.

The arithmetic mean for hair Hg in this cohort was 0.91 µg/g, and the geometric mean was 0.58 µg/g (95% confidence interval [CI] 0.44, 0.76). Hair Hg levels ranged from undetectable to 5.24 µg/g. The geometric mean in the 14 WCBA (18 to 44 yrs) was 0.65 µg/g (95% CI 0.40, 1.06). Of the 71 participants, 28% had hair Hg levels at least 1 µg/g, the hair level equivalent to the EPA's reference dose of 0.1 µg/kg/d of Hg.¹⁵⁻¹⁷ Four (29%) of the WCBA had hair Hg levels at least 1 µg/g. None reported eating fish daily or 4 or more times/wk.

Geometric mean Hg (µg/g) was higher in persons reporting regular consumption of tuna fish (0.76 for consumers vs 0.45 for nonconsumers, *P* = 0.05) or catfish (0.8 for consumers vs 0.5 for nonconsumers, *P* = 0.06), and in persons of non-Chinese Asian or PI versus Chinese or Taiwanese ethnicity (0.94 vs 0.47, respectively, *P* = 0.004) (not shown). Geometric mean Hg, however, did not differ by age, sex, immigration status, eating locally caught fish, and frequent consumption of fish species other than catfish and tuna (not shown). In multivariable linear regression analysis, stepwise selection of predictors of LnHg identified only tuna fish consumption (*P* = 0.04) and non-Chinese Asian or PI ethnicity (*P* = 0.02, not shown). These analyses were not performed for WCBA because of the low number of participants.

The bivariate odds ratio for having elevated hair Hg (more than 1 µg/g) was 3.39 (95% CI 1.003, 11.43) for those eating fish at least 4 times/wk compared to those who reported eating fish less than 4 times/wk (not shown). Tuna was the only fish species that was significantly associated with elevated hair Hg level (odds ratio 4.65, 95% CI 1.46, 14.80, not shown). The survey did not include detail regarding the types of tuna (canned chunk light, albacore, tuna steaks, Bluefin, etc). Bivariate analyses found no significant associations between elevated hair Hg and sex, age, country of origin, or being foreign born (not shown). In a multivariable logistic regression analysis, stepwise selection identified ethnicity, age, fish consumption at least 4 times/wk, consuming tuna, and consuming red snapper as predictors (*P* < 0.10) of elevated hair Hg (Table 2).

Because ethnicity was associated with hair Hg, with significantly higher levels in non-Chinese Asian or PI ethnicity, we examined the relationship of fish consumption characteristics with ethnicity. Participants of non-Chinese Asian or PI were more likely than those of Chinese or Taiwanese ethnicity to eat local fish (*P* = 0.07); report regular consumption of tilapia (*P* = 0.08) and mackerel (*P* = 0.03); report that they did not regularly consume pomfret (*P* = 0.005) or croaker (*P* = 0.0001); were younger (*P* = 0.0001); and were not foreign born (*P* = 0.003). In a multivariable model, however, non-Chinese Asian or PI ethnicity versus Chinese or Taiwanese ethnicity was only associated with younger age and not consuming croaker (not shown). Because of the low number of WCBA, we did not perform these analyses on this subset.

In Table 3, we compare our results to two other surveillance studies of Asians in the United States and to our analysis of 2011 to

2012 NHANES data. Tsuchiya et al¹⁰ published data from Japanese and Korean American WCBA in Seattle that showed a geometric mean for hair Hg of 0.86 µg/g and 33% of participants with elevated hair Hg levels. McKelvey et al⁸ conducted a New York City HANES study that reported data on elevated blood (not hair) Hg levels > 5 µg/L. Forty-six percent of Asian participants had blood Hg levels higher than the reportable level for New York State. For the first time in 2011, NHANES included a separate race/ethnicity designation for Asians, therefore allowing us and others¹⁸ to perform analyses for this group. Our NHANES analysis for Asians 18 years of age and older show a mean blood total Hg of 2.20 µg/L and 19% with elevated blood Hg.

Table 4 shows the Hg concentrations in fish that were reported to be eaten regularly by participants and/or measured in the current study. Tissue concentrations of Hg in selected fish species reported by the US Food and Drug Administration (FDA),¹⁹ a synthesis of measurements from fish consumed in the United States by Karimi et al,²⁰ and levels in fish purchased in Asian markets in Seattle²¹ and New York City²² are shown for comparison. All levels measured in the current study are below 1 ppm, the FDA Action Level for Hg in fish tissue.²³ Tilapia, the most commonly eaten species among the overall group and the WCBA subset, had the lowest Hg concentration. For numerous species, there was high variability in Hg concentration among the data sources. For example, the tilapia we purchased had fivefold lower Hg concentration than the levels reported by the FDA and Karimi et al.²⁰ Concentrations for tuna were relatively high, from one-third to one-half the Action Level for Hg in fish.

Figure 1 depicts the Hg concentrations in the fish tissue samples from the current study, and the four sources noted above superimposed on the percentage of the cohort who reported eating those fish species.

DISCUSSION

This pilot study conducted at health fairs in two Chicago Asian immigrant communities found that almost one-third of participants had elevated hair Hg levels. This is especially concerning for the female participants of childbearing age, whose geometric mean hair Hg level of 0.65 µg/g is over 3 times the level found in non-Asian WCBA in the 1999 to 2000 NHANES (0.20 µg/g).²⁴

All but one of the participants ate fish, and 20% consumed fish at least 4 times/wk. We found that consumption of fish at least 4 times/wk, consumption of tuna, older age and non-Chinese Asian or PI ethnicity were associated with elevated hair Hg levels. In our analysis of 2011 to 2012 NHANES,²⁵ blood Hg levels (not hair), 14.6% of WCBA who ate fish at least 2 times/wk had elevated Hg. In this current analysis of a small cohort of Asians in Chicago, tuna was the third most frequently consumed fish behind tilapia and salmon, both of which are known to have low Hg levels.²⁶ It is possible that participants consumed types of tuna with higher Hg levels such as tuna steaks, Bluefin, or albacore, instead of the more popular chunk light tuna, but we are unable to determine this because our survey did not include this level of detail.

Other studies, including NHANES, have assessed hair Hg levels and fish consumption practices among Asians in the United States, generally finding more frequent fish consumption and higher Hg exposures compared with other ethnic groups (Table 3). A survey of adults in Wisconsin,²⁷ 48% of whom reported eating sport caught fish, found a mean hair Hg level of 0.71 µg/g overall and 0.87 µg/g among Asians, the subgroup with the highest mean. Overall, 29% of men and 13% of women had hair levels more than 1 µg/g. The mean fish intake was 7.7 fish meals/month. In a study of WCBA in Duval County, Florida,²⁸ the geometric mean hair Hg was 0.33 µg/g, and among Asians it was 0.64 µg/g. Overall, 7% had hair Hg levels more than 1 µg/g. Fish consumption was 12.4 fish

TABLE 2. Final Logistic Regression Model for Predictors of Elevated Hair Mercury (>1 µg/g) (*n* = 71)

| Characteristic | OR for hair hg ≥ 1 µg/g | | |
|---|-------------------------|-------------|----------|
| | OR | 95% CI | <i>P</i> |
| Age, yrs | 1.05 | 0.99, 1.11 | 0.096 |
| Non-Chinese Asian or Pacific Islander vs Chinese or Taiwanese | 7.07 | 1.23, 40.52 | 0.03 |
| Eat fish ≥4 times/wk vs <4 times/wk | 4.40 | 0.96, 20.08 | 0.06 |
| Regularly eat tuna | 6.48 | 1.71, 24.59 | 0.006 |
| Regularly eat red snapper | 0.19 | 0.04, 0.88 | 0.03 |

CI, confidence interval; OR, odds ratio.

TABLE 3. Comparison of Total Mercury in US Adult Asian Populations and NHANES

| Study Location | Ethnic Group | Age, yrs | Sex | N | Hair Hg, $\mu\text{g/g}$ | Blood Hg, $\mu\text{g/L}$ | % With Elevated Hg* |
|----------------------------------|----------------------|-----------|-------|-------|--------------------------|---------------------------|---------------------|
| | | | | | Geometric Mean (95% CI) | Geometric Mean (95% CI) | |
| Chicago (this study) | Asian or PI | ≥ 18 | Both | 71 | 0.58 (0.44, 0.76) | NA | 28 |
| | Asian or PI | 18–44 | Women | 14 | 0.65 (0.40, 1.06) | NA | 29 |
| | Chinese/Taiwanese | ≥ 18 | Both | 50 | 0.47 (0.33, 0.68) | NA | 24 |
| Seattle ¹⁰ | Non-Chinese Asian/PI | ≥ 18 | Both | 21 | 0.94 (0.71, 1.25) | NA | 38 |
| | Japanese | 18–45 | Women | 106 | 1.23 (0.98, 1.48) | NA | 53 |
| | Korean | 18–45 | Women | 108 | 0.61 (0.52, 0.70) | NA | 13 |
| | Japanese/Korean | 18–45 | Women | 214 | 0.86 (0.72, 1.00) | NA | 33 |
| New York City ⁸ | Asian | ≥ 20 | Both | 231 | NA | 4.11 (3.24, 5.21) | 46 |
| NHANES 2011–2012 (this study) | Asian | 18–44 | Women | 191 | NA | 1.69 (1.32, 2.16) | 12 |
| | Asian | ≥ 18 | Both | 729 | NA | 2.20 (1.84, 2.65) | 19 |
| | Non-Asian | 18–44 | Women | 1,049 | NA | 0.65 (0.56, 0.75) | 2 |
| | Non-Asian | ≥ 18 | Both | 4,582 | NA | 0.81 (0.71, 0.92) | 3 |

CI, confidence interval; NA, not available; PI, Pacific Islands.

*Elevated Hg: hair $\geq 1 \mu\text{g/g}$ for Chicago, hair $> 1.2 \mu\text{g/g}$ for Seattle; blood $> 5 \mu\text{g/L}$ for New York City; blood $> 5.8 \mu\text{g/L}$ for NHANES.

meals/month. Vietnamese residents of Montreal, many of whom reported consuming fish they caught from the St. Lawrence River, had arithmetic mean hair Hg of $1.23 \mu\text{g/g}$ compared with Montreal ice-fishers in general ($0.73 \mu\text{g/g}$).⁶ Asian populations in Seattle and New York City had high Hg body burdens compared with non-Asian participants in our NHANES analysis (Table 3). They were also frequent fish consumers: the average daily intake of Hg from fish in the Seattle population of Japanese and Koreans was $0.11 \mu\text{g/kg/d}$ ¹⁰—greater than the EPA reference dose of $0.1 \mu\text{g/kg/d}$. In New York City,⁸ consumption of at least 20 meals of fish in the last 30 days was highest in Asians compared with whites, blacks, and Hispanics.

The proportion of Asian women with elevated Hg levels in the four studies presented in Table 3 ranges from 12% to 44%. Our comparison of results in Chicago to two coastal cities, where fish consumption may be higher because of proximity to seaways, and to NHANES, suggests that Asians in general and particularly Asian WCBA may be at risk of adverse health effects because of fish consumption, regardless of where they live. In particular, our findings that 29% of Asian women had elevated Hg compared with the Seattle cohort, in which 33% had elevated Hg. This may indicate that cultural dietary practices may influence fish consumption more than geographic location or availability fresh fish. On the contrary,

TABLE 4. Mean Total Mercury ($\mu\text{g/g}$) in Fish from Pilot Study and from Published Data

| Fish Species | This Study | | | FDA ¹⁹ | | | Karimi et al ²⁰ | | | Tsuchiya et al ²¹ | | McKelvey et al ²² | |
|--------------------|------------|--------|---|-------------------|--------|-----|----------------------------|--------|-------|------------------------------|----|------------------------------|----|
| | Mean | SD | n | Mean | SD | n | Mean | SD | n | Mean | n | Mean | n |
| Tilapia | 0.0026 | 0.0004 | 2 | 0.0130 | 0.0230 | 32 | 0.0190 | 0.0970 | 129 | | | <0.004 | 15 |
| Salmon | 0.0340 | 0.0006 | 2 | 0.0220 | 0.0340 | 94 | 0.0480 | 0.1430 | 2,818 | 0.0720 | 17 | | |
| Tuna, all | | | | 0.3910 | 0.2660 | 420 | 0.4500 | 1.6190 | 3,780 | | | | |
| Tuna, albacore | | | | 0.3580 | 0.1380 | 43 | 0.3170 | 0.4750 | 296 | 0.3610 | 64 | | |
| Tuna, light | | | | 0.1280 | 0.1350 | 551 | 0.1180 | 0.3000 | 972 | 0.1270 | 55 | | |
| Pomfret, all | 0.0216 | | 5 | | | | | | | | | | |
| Pomfret, silver | 0.0194 | 0.0071 | 3 | | | | | | | | | | |
| Pomfret, black | 0.0248 | 0.0003 | 2 | | | | | | | | | | |
| Croaker | 0.0732 | 0.0185 | 3 | 0.0650 | 0.0500 | 57 | 0.0920 | 0.3080 | 856 | 0.0530 | 8 | 0.0330 | 15 |
| Red snapper | | | | 0.1660 | 0.2440 | 67 | 0.2430 | 0.5140 | 279 | 0.2210 | 27 | 0.0350 | 15 |
| Catfish or swai | 0.0059 | 0.0020 | 3 | 0.0250 | 0.0570 | 57 | 0.1180 | 0.5860 | 1,757 | 0.0170 | 23 | | |
| Mackerel, all | 0.0638 | 0.0004 | 2 | | | | 0.5860 | 3.2370 | 2,481 | 0.0400 | 18 | 0.1470 | 13 |
| Mackerel, Atlantic | | | | 0.0500 | | 80 | 0.0450 | 0.1920 | 191 | | | | |
| Mackerel, chub | | | | 0.0880 | | 30 | 0.0990 | 0.1660 | 129 | | | | |
| Mackerel, king | | | | 0.7300 | | 213 | 1.1010 | 3.4700 | 821 | | | | |
| Mackerel, Spanish | | | | 0.1820 | | 43 | 0.4400 | 1.1050 | 1,168 | | | 0.1470 | 13 |
| White bass, all | 0.2729 | | 5 | | | | | | | | | | |
| White bass, # 1 | 0.0812 | 0.0014 | 2 | | | | | | | | | | |
| White bass, # 2 | 0.1190 | 0.0944 | 3 | | | | | | | | | | |
| White bass, # 3 | 0.4420 | 0.2430 | 5 | | | | | | | | | | |
| Anchovies | | | | 0.0170 | 0.0150 | 14 | 0.1030 | 0.1970 | 455 | | | | |
| Skate fish | | | | 0.1370 | | 56 | 0.1380 | 0.0930 | 70 | | | | |
| Belt fish | 0.1790 | 0.1090 | 5 | | | | | | | | | | |
| Dace | 0.0623 | 0.0149 | 3 | | | | | | | | | 0.0220 | 15 |
| Fathead carp | 0.0979 | 0.0009 | 2 | 0.1100 | 0.0990 | 14 | 0.1560 | 0.5210 | 477 | | | 0.0230 | 15 |

n, number of replicates for current study, number of samples for published literature.

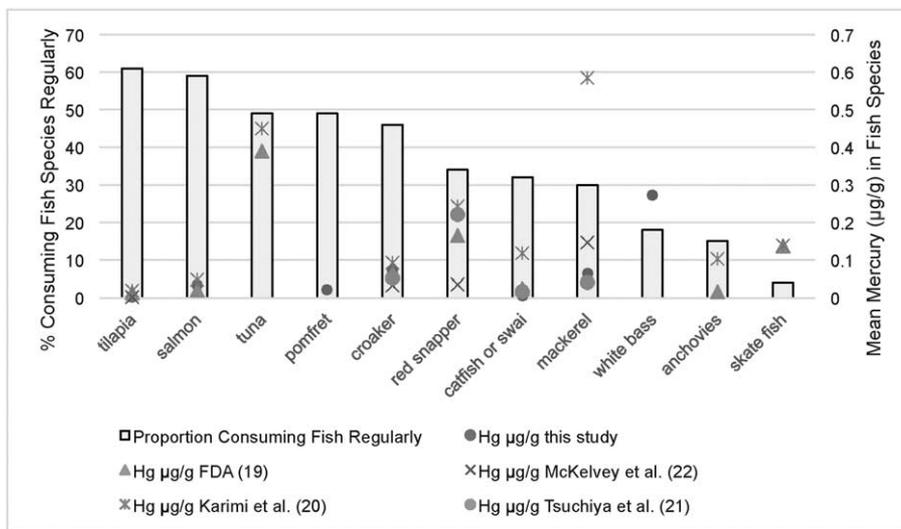


FIGURE 1. Commonly consumed fish species in pilot study: proportion of participants consuming fish species and mean µg/g total mercury in fish species.

the New York City cohort had a much higher proportion of Asians with elevated blood Hg level (43%), but 19% of that cohort had consumed fish at least 20 times in the previous 30 days, possibly indicating higher fish consumption than the participants in Chicago. In the current study, the non-Chinese/Taiwanese Asian and Pacific Islanders, who had significantly higher Hg levels than the Chinese and Taiwanese participants, reported consuming more locally caught fish, had differences in consumption of four species of fish and were less likely to be foreign born than Chinese and Taiwanese participants. In Seattle, substantial differences in fish consumption behaviors and Hg levels were noted in Japanese and Korean women.¹⁰ These data suggest that influences of ethnicity-specific cultural dietary practices on Hg exposures may also be operative at the local level.

Our findings of higher Hg levels among non-Chinese/Taiwanese Asian and Pacific Islanders, who as a group reported more frequent consumption of locally caught fish, raise the questions of (1) whether Pacific Islanders in Chicago eat fish more frequently than Chinese residents, and (2) if consumption of locally caught fish among Asian subgroups increases the risk for elevated Hg. Clearly, more research is needed on cultural fish consumption practices among Asian subgroups including the consumption of locally caught fish. Moreover, Hg levels for our non-Chinese/Taiwanese Asian and Pacific Islanders participants were elevated compared with Chinese/Taiwanese participants even after adjusting for frequency of fish consumption and fish species. Other studies have also found that, among Asians, risk of elevated Hg does not correlate well with fish consumption frequency.^{10,29,30} This might indicate that there are other sources of fish in the diet that are not captured on traditional dietary surveys such as the use of fish sauce or the consumption of fish soups. To decrease the risk of elevated Hg in US Asians, proper surveillance should be performed that addresses cultural fish consumption practices and captures all possible dietary sources of fish products.

Regarding Hg concentrations in fish tissue, the fish we purchased in Asian fish markets were generally low in Hg, especially tilapia and salmon, the two most commonly consumed species. Owing to the requirement to make the questionnaire brief, we do not have data on the frequency of consumption or portion size of the specific species of fish and therefore our models include consumption of specific species as dichotomous variables (yes/no). Of the most commonly consumed species in our survey, Hg levels are reported to be highest in tuna, which is consistent with our multi-variable linear and logistic regression models predicting geometric

mean and elevated hair Hg, respectively. More fish samples and more detail on consumption frequency of specific species and various preparations of fish products (eg, fish sauce) are needed to investigate the contributing factors to the high proportion of participants with elevated hair Hg in our study.

Our study has several limitations. Participants in this study were self-selected from persons who attended health fairs hosted by Asian organizations and chose to visit the table with outreach materials on fish consumption. Thus, persons in the study may be more concerned with their health and more interested in the effects of fish consumption on health than the general Chicago Asian population. Our results were also limited by the small sample size, which limited our ability to conduct detailed stratified analyses. A larger study involving more participants in each ethnic group would allow for better assessment of differences and risks relevant to each group. Also, our comparison to other cohorts of Asians in the United States is limited by the different “levels of concern” for Hg used in each study as well as different types of biological samples for Hg measurements (hair and blood). Nevertheless, we believe it communicates the breadth (and lack thereof) of data on this at-risk group and suits the purpose to make general comparisons. Finally, our fish purchases did not follow a scientific sampling method. Our aim was to “screen” commonly available fish in markets and pilot our tissue analysis procedures. This superficial scan of fish sold in Chicago Asian markets did not find Hg levels that account for the high prevalence of elevated hair Hg.

CONCLUSION

Approximately 30% of the adults in our study had hair Hg levels above the EPA’s level of concern. This indicates that there may be increased risk of adverse health outcomes such as cardiovascular disease in adults and neurodevelopmental delays in children because of Hg exposure from fish consumption in this study population. Regarding fish consumption during pregnancy, infants born to Asian women in the Chicago area may be at higher risk for neurological impairments compared with children born to non-Asian women nationally. Fish is a staple food in many Asian cultures which helps to explain the disproportionately high fish consumption among Asian people and their resulting high exposure to pollutants found in fish. Fish consumption has also been shown to improve neurodevelopment in utero and in childhood. Omega-3 fatty acids, which are abundant in some species of fish, can also prevent mortality from myocardial infarctions and stroke.^{1,31} For

these reasons, public health interventions for the general public must walk a fine line between encouraging healthful fish consumption and discouraging consumption of fish high in harmful contaminants. Public health interventions for high risk subgroups tailored to reflect cultural fish consumption practices will be more successful in lowering exposure to harmful contaminants in fish while maintaining or improving consumption of healthy nutrients in fish. More studies are needed to fully characterize fish consumption patterns in various Asian communities to best tailor public health messages to groups who are at highest risk. Results of future studies could also inform clinical medical practice and the dietary advice given to expectant mothers.

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REFERENCES

- Nesheim MC, Yaktine AL, & Institute of Medicine (U.S.). *Seafood Choices: Balancing Benefits and Risks*. Washington, DC: National Academies Press; 2007.
- Stokes-Riner A, Thurston SW, Myers GJ, et al. A longitudinal analysis of prenatal exposure to methylmercury and fatty acids in the Seychelles. *Neurotoxicol Teratol*. 2011;33:325–328.
- Grandjean P, Weihe P, White RF, et al. Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury. *Neurotoxicol Teratol*. 1997;19:417–428.
- Suzuki K, Nakai K, Sugawara T, et al. Neurobehavioral effects of prenatal exposure to methylmercury and PCBs, and seafood intake: neonatal behavioral assessment scale results of Tohoku study of child development. *Environ Res*. 2010;110:699–704.
- Stern AH. A review of the studies of the cardiovascular health effects of methylmercury with consideration of their suitability for risk assessment. *Environ Res*. 2005;98:133–142.
- Kosatsky T, Przybysz R, Shatenstein B, et al. Contaminant exposure in Montrealers of Asian origin fishing the St. Lawrence River: exploratory assessment. *Environ Res*. 1999;80:S159–S165.
- Lin S, Herdt-Losavio ML, Chen M, et al. Fish consumption patterns, knowledge and potential exposure to mercury by race. *Int J Environ Health Res*. 2014;24:291–303.
- McKelvey W, Gwynn RC, Jeffery N, et al. A biomonitoring study of lead, cadmium, and mercury in the blood of New York City adults. *Environ Health Perspect*. 2007;115:1435–1441.
- Hightower JM, O'Hare A, Hernandez GT. Blood mercury reporting in NHANES: identifying Asian, Pacific Islander, Native American, and multi-racial groups. *Environ Health Perspect*. 2006;114:173–175.
- Tsuchiya A, Hinnert TA, Burbacher TM, et al. Mercury exposure from fish consumption within the Japanese and Korean communities. *J Toxicol Environ Health*. 2008;71:1019–1031.
- Eat Fish, Choose Wisely. Protect Against Mercury*. New York City Department of Health and Mental Hygiene. Available at http://www.nyc.gov/html/doh/downloads/pdf/edp/mercury_brochure.pdf. Accessed February 21, 2014.
- Mercury in Fish and Shellfish*. US Food and Drug Administration and US Environmental Protection Agency. Available at <http://www.fda.gov/downloads/Food/ResourcesForYou/UCM222258.pdf>. Accessed February 21, 2014.
- United States Environmental Protection Agency Method 1631, Revision E: Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry, EPA-821-R-02-019, August 2002.
- United States Environmental Protection Agency Method 245.7: Mercury in Water by Cold Vapor Atomic Fluorescence Spectrometry, EPA-821-R-05-001, February 2005.
- National Research Council Committee on the Toxicological Effects of Methylmercury. *Toxicological Effects of Methylmercury*. Washington, DC: National Academy Press; 2000.
- Ramos A, Quintana PJ, Ji M. Hair mercury and fish consumption in residents of O'ahu, Hawai'i, Hawaii. *J Med Public Health*. 2014;73:19–25.
- US Environmental Protection Agency. IRIS Methyl Mercury. Washington, DC: US EPA; 2001. Available at <http://www.epa.gov/iris/subst/0073.htm>. Accessed April 3, 2014.
- Mortensen ME, Caudill SP, Caldwell KL, et al. Total and methyl mercury in whole blood measured for the first time in the US population: NHANES 2011–2012. *Environ Res*. 2014;134:257–264.
- U.S. Food and Drug Administration. Mercury Levels in Commercial Fish and Shellfish (1990–2010). Silver Springs, MD: US FDA; 2014. Available at <http://www.fda.gov/Food/FoodborneIllnessContaminants/Metals/ucm115644.htm>. Accessed May 19, 2014.
- Karimi R, Fitzgerald TP, Fisher NS. A quantitative synthesis of mercury in commercial seafood and implications for exposure in the United States, Supplemental Material. *Environ Health Perspect*. 2012;120:1512–1519.
- Tsuchiya A, Hinnert TA, Burbacher TM, Faustman EM, Marien K. Mercury exposure from fish consumption within the Japanese and Korean communities. *J Toxicol Environ Health*. 2008;71:1019–1031.
- McKelvey W, Chang M, Arnason J, Jeffery N, Kricheff J, Kass D. Mercury and polychlorinated biphenyls in Asian market fish: a response to results from mercury biomonitoring in New York City. *Environ Res*. 2010;110:650–657.
- US Food and Drug Administration. Guidance for Industry: Action Levels for Poisonous or Deleterious Substances in Human Food and Animal Feed. Silver Springs, MD: US FDA; 2000. Available at <http://www.fda.gov/food/guidanceregulation/guidancedocumentsregulatoryinformation/ucm077969.htm#merc>. Accessed May 7, 2015.
- McDowell MA, Dillon CF, Osterloh J, et al. Hair mercury levels in US children and women of childbearing age: reference range data from NHANES 1999–2000. *Environ Health Perspect*. 2004;112:1165–1171.
- Buchanan S, Anglen J, Turyk M. Methyl mercury exposure in populations at risk: analysis of NHANES 2011–2012. *Environ Res*. 2015;140:56–64.
- Sunderland EM. Mercury exposure from domestic and imported estuarine and marine fish in the US seafood market. *Environ Health Perspect*. 2007;115:235–242.
- Knobeloch L, Giori G, Anderson H. Assessment of methylmercury exposure in Wisconsin. *Environ Res*. 2007;103:205–210.
- Traynor S, Kearney G, Olson D, et al. Fish consumption patterns and mercury exposure levels among women of childbearing age in Duval County, Florida. *J Environ Health*. 2013;75:8–15.
- Mahaffey KR, Clickner RP, Jeffries RA. Methylmercury and omega-3 fatty acids: co-occurrence of dietary sources with emphasis on fish and shellfish. *Environ Res*. 2008;107:20–29.
- Jenssen MT, Brantsæter AL, Haugen M, et al. Dietary mercury exposure in a population with a wide range of fish consumption—self-capture of fish and regional differences are important determinants of mercury in blood. *Sci Total Environ*. 2012;439:220–229.
- Adkins Y, Kelley DS. Mechanisms underlying the cardioprotective effects of omega-3 polyunsaturated fatty acids. *J Nutr Biochem*. 2010;21:781–792.