Letter to the Editor

Hair Mercury Levels and Their Relationship with Seafood Consumption among Preschool Children in Shanghai*

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Mercury is a global pollutant. Children are vulnerable to environmental toxicants. Seafood consumption is a major source of methylmercury exposure. In order to ascertain children's mercury exposure levels and study their relationship with seafood consumption, we conducted a cross-sectional study among preschool children in Shanghai. According to our data, the geometric mean of the mercury levels in children's hair was 191.9 (95% *CI*: 181.8, 202.4) μg/kg. These results indicate that high income may be a predictor of elevated mercury levels in children's hair. Intake of marine fish, especially tuna and pomfret, was documented in our study and found to increase the risk of high mercury levels. Frequency of fish consumption was positively related with hair mercury levels. Our study is the first to provide baseline data for hair mercury concentration among preschool children in Shanghai.

Mercury (Hg) is a global concern. Hg occurs in three forms: metallic, inorganic, and organic. The three forms differ from each other in terms of the absorption pathway, distribution and accumulation tissue, and health outcomes[1]. In general, organic mercury compounds get the most attention because they are lipid soluble and are absorbed well from the gastrointestinal tract. Methylmercury is the major source of mercury exposure for people and seafood consumption is the main source of methylmercury. Methylmercury may cause nervous and cardiovascular disorders[2], especially ailments of the neurodevelopmental system. As their bodies are not fully mature, children are highly vulnerable and uniquely susceptible to the environmental pollutants. The conception that children have critical time windows for their susceptibilities has been reported by multiple studies[3]. A number of epidemiological studies have shown that high mercury levels may impair the cognitive development in children. Data show that exposure to even low levels of methylmercury by fish consumption can cause developmental effects[4]. At present, there is no safe level of mercury exposure. Due to its toxicity, the United States Environmental Protection Agency (US EPA) considers the methylmercury exposure reference dose (RfD) to be 0.1 μg/kg body weight/day[5].

Knowledge of the mercury exposure levels in children is important to take measures to protect them; however, little is known about the magnitude of exposure to mercury among children in Shanghai. Therefore, we conducted a cross-sectional study to investigate the mercury exposure levels among children in Shanghai and to evaluate the relationship between hair mercury concentration and fish consumption. The research was approved by the Medical Ethics Committee of Xinhua Hospital affiliated to Shanghai Jiao Tong University School of Medicine. In 2006, we selected five districts as the investigation areas: the Jing'an and Xuhui districts (central city), the Yangpu district (an industrial area in 2006), the Jiading district (near suburban), and the Chongming district (distant suburban). Based on the age groups, 4-5 kindergartens were selected from each district and at least 70 children who were 3-6 years old were randomly sampled in each kindergarten. Two to three nursery schools were selected from each district, and at least 50 children who were 0-3 years old were randomly sampled in each nursery school. Informed consent was obtained from the guardians of the children, prior to the study.

Hair collection is simple and non-invasive, and it is reported that hair mercury concentration is an

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indicator of dietary intake of methylmercury. Thus, we collected the children's hair samples to measure the mercury levels. Hair segments about 2 cm close to the scalp were collected from all the participants for mercury level analysis. All these hair specimens were placed in plastic bags and stored in a desiccator for further analysis. Analytical detection of all the hair samples for the mercury content was carried out using a Direct Mercury Analyzer 80 (DMA-80, Milestone Inc., Bergamo, Italy). The protocols for mercury analysis were carried out as described previously[6]. A hair sample was rinsed with distilled-deionized water and air dried in a room. Then, 5-10 mg of the hair sample was weighed to be placed directly into the sample boat. Regular quality control procedures included instrument calibration, procedural blanks, replicates, and certified reference materials to ensure the accuracy of the measuring method. The limit of detection (LOD) for mercury in hair was 0.3 μg/kg.

A simple seafood consumption interview was completed by the children's guardians. The questionnaire recorded the seafood species (marine fish including tuna, hairtail, yellow coaker, pomfret, and eel; freshwater fish including bass, crucian, bream, silver carp and carp, shrimp, crab, and shellfish) consumed by the children and their consumption frequency during the last three months. Simultaneously, the general characteristics (age, sex, monthly income, and education of the father/mother/caregiver) and several lifestyle factors such as hand-mouth habit, father/mother's alcohol intake, and smoking status were obtained.

The initial analysis demonstrated that hair mercury data were non-normally distributed. We thus applied a logarithmic transformation of hair mercury levels for analysis. Arithmetic means (AMs), geometric means (GMs), medians, and percentiles were calculated to describe the distribution tendency of hair mercury levels in preschool children. One-way ANOVA was used for comparisons between the groups. For studying the relationship between hair mercury and seafood consumption, a logistic regression was used to analyze the data. We performed the analysis using SAS software (version 9.4, SAS Institute, Cary, NC). Tests of statistical significance used $\alpha = 0.05$.

A total of 2,053 preschool children participated in our study. Hair specimens were collected from 1,982 selected children. Table 1 describes the demographic characteristics of the children. The AMs, GMs, and percentiles of hair mercury levels are presented in Table 1. The GM of hair mercury was 191.9 μg/kg (95% *CI*: 181.8, 202.4). After a trend analysis, we found that children's mercury levels increased with the family income (P = 0.0005). According to a previous study, mercury levels elevated by 39% in the highest income group, relative to the lowest income group[7]. Thus, we confirmed the conception that higher income may be a predictor of elevated mercury levels. Families with higher incomes may have more chances of consuming seafood and purchasing larger fish, which have higher methylmercury concentrations.

To analyze the relationship between hair mercury level and aquatic product intake, a logistic regression model was developed. We divided the mercury level into two groups based on the median. After comparison, we concluded that marine fish intake was associated with increased risk of high mercury level. As shown in Table 2, the odds ratio was 1.298 (95% *CI*: 1.064, 1.583) and the data were significant after adjusting for general characteristics (adjusted for sex, age, and monthly income). In our questionnaire, we recorded several common marine fishes, which were often consumed in Shanghai. Our results confirmed that tuna consumption is a high risk factor for hair mercury concentration (Table 2). Simultaneously, we found that pomfret intake may increase the risk of high hair mercury levels and the odds ratio was 1.295 (95% *CI*: 1.067-1.573) (Table 2). After adjustments, the data was also found to be significant. We also documented some often-consumed freshwater fish. The data presented no significant difference (Table 2). Therefore, our study did not hint that hair mercury level was related to freshwater intake among children in Shanghai.

In our study, we recorded the fish consumption frequency and performed an analysis to explore its impact on hair mercury levels. Hair mercury levels in children who consumed fish more than three times per week were 2.177 times the levels in children who consumed fish once a week (95% *CI*: 1.406-3.371); and 2.953 times the levels in those who reported no consumption (95% *CI*: 1.641-5.311). We confirmed that fish consumption frequency has a positive correlation with hair mercury level.

The hair mercury level among preschool children in Shanghai is 191.9 μg/kg. It is slightly higher than the United States, which reported 0.12 μg/g among children 1-5 years of age in the National Health and Nutrition Examination Survey (NHANES) 1999-2000[8]. However, it is lower than the other studies reported. The mean concentration of hair mercury was 0.96 μg/g

Table 1. AM, GM, and Selected Percentiles of Children's Hair Mercury (μg/kg)

Sample Description	*N* (%)	AM (95% *CI*)	GM (95% *CI*)	Percentile					
				10th	25th	50th	75th	90th	95th
Total	1,982 (100)	297.7 (281.8, 313.6)	191.9 (181.8, 202.4)	90.0	140.0	215.0	347.0	532.0	683.0
Sex									
Boy	1,046 (52.8)	297.2 (275.2, 319.2)	182.9 (169.0, 198.0)	53.0	85.0	209.5	353.0	558.0	673.0
Girl	936 (47.2)	298.3 (275.3, 321.3)	202.4 (188.5, 217.3)	99.0	149.0	220.0	339.5	511.0	702.0
Age group (years)									
-2	56 (2.8)	260.0 (129.6, 390.4)	154.4 (112.3, 212.3)	70.0	115.0	170.5	239.5	397.0	601.0
-3	245 (12.4)	293.6 (259.3, 327.9)	196.6 (170.6, 226.6)	78.0	125.0	213.0	384.0	570.0	705.0
-4	497 (25.1)	328.9 (285.7, 372.0)	191.9 (171.2, 215.2)	90.0	136.0	217.0	350.0	546.0	840.0
-5	503 (25.4)	296.9 (264.6, 329.1)	187.1 (167.2, 209.2)	93.0	143.0	210.0	359.0	518.0	671.0
-6	416 (20.6)	269.0 (249.8, 288.2)	185.3 (164.2, 209.1)	95.0	141.0	219.5	331.5	516.0	650.0
> 6	284 (13.8)	296.8 (262.6, 331.1)	216.4 (192.7, 243.0)	103.0	147.0	223.0	353.0	579.0	674.0
District group									
Jing'an	277 (14.0)	292.4 (243.0, 341.8)	182.7 (158.7, 210.4)	83.0	128.0	202.0	309.0	521.0	671.0
Xuhui	392 (19.8)	283.4 (249.9, 316.9)	179.4 (158.1, 203.4)	80.0	129.0	215.5	340.0	531.0	658.0
Yangpu	432 (21.8)	292.2 (260.9, 323.5)	192.5 (172.1, 215.2)	89.0	140.0	210.5	346.5	537.0	745.0
Jiading	503 (25.4)	323.0 (285.9, 360.0)	196.6 (175.6, 220.1)	101.0	147.0	217.0	354.0	593.0	751.0
Chongming	376 (19.0)	290.4 (263.3, 317.5)	208.9 (187.1, 233.2)	108.0	149.0	231.0	365.0	515.0	621.0
Monthly income (RMB)									
< 2,000	192 (10.1)	279.8 (216.0, 343.6)	153.1 (124.9, 187.7)	77.0	118.5	180.5	287.5	511.0	637.0
2,000-4,000	851 (44.7)	295.3 (270.7, 319.9)	190.1 (175.2, 206.3)	94.0	139.0	210.0	336.0	516.0	697.0
4,001-8,000	581 (30.5)	302.7 (274.1, 331.4)	197.7 (179.1, 218.3)	89.0	144.0	225.0	373.0	553.0	649.0
8,001-15,000	148 (7.8)	323.0 (268.2, 377.8)	216.0 (177.8, 262.5)	100.0	159.0	245.0	395.0	579.0	707.0
> 15,000	134 (7.0)	325.3 (269.4, 381.2)	228.6 (193.6, 269.8)	112.0	150.0	233.5	378.0	671.0	976.0
P for trend*						0.0005			

Note. **P* for trend was for monthly income.

Table 2. The Relationship between Hair Mercury Level and Aquatic Product Intake

Aquatic Product	Unadjusted		Adjusted*	
	OR (95% *CI*)	*P*	*OR* (95% *CI*)	*P*
Marine fish	1.298 (1.064-1.583)	0.01#	1.241 (1.011-1.525)	0.03#
Tuna	2.175 (1.119-4.227)	0.02#	2.086 (1.041-4.180)	0.03#
Hairtail	0.948 (0.783-1.146)	0.58	0.993 (0.767-1.136)	0.50
Yellow coaker	1.151 (0.947-1.398)	0.16	1.184 (0.969-1.447)	0.10
Pomfret	1.295 (1.067-1.573)	0.01#	1.278 (1.046-1.562)	0.02#
Eel	1.195 (0.760-1.880)	0.44	1.356 (0.833-2.208)	0.22
River fish	1.154 (0.965-1.379)	0.12	1.137 (0.946-1.366)	0.17
Bass	1.102 (0.916-1.326)	0.30	1.045 (0.836-1.265)	0.65
Crucian	1.007 (0.839-1.208)	0.94	1.067 (0.884-1.286)	0.50
Bream	1.031 (0.834-1.275)	0.78	1.020 (0.820-1.268)	0.86
Silver carp	1.296 (0.916-1.833)	0.14	1.355 (0.943-1.948)	0.10
carp	0.973 (0.625-1.515)	0.90	0.916 (0.578-1.451)	0.70
Shrimp	1.106 (0.913-1.339)	0.30	1.158 (0.951-1.410)	0.14
Crab	1.246 (0.980-1.568)	0.07	1.221 (0.953-1.564)	0.11
Shellfish	1.123 (0.741-1.704)	0.58	1.131 (0.732-1.747)	0.58

Note. *Adjusted for sex, age, monthly income. #P < 0.05. Monthly income was entered into the model as a categorical variable and age as a continuous variable.

in preschool children from Granada, Spain[9]. Compared to the other areas of China, the hair mercury level in Shanghai is low. The concentration of hair mercury is 5.5 μg/g in Wanshan, a mining area in the Guizhou Province of China. We have provided the baseline data to monitor hair mercury levels in China.

Our study presented some significant results to show the relationship between children's hair mercury levels and seafood consumption. Firstly, we found that the marine fish intake (especially tuna and pomfret consumption) was associated with an increased risk of high mercury level. Secondly, freshwater fish consumption was not related with hair mercury in our study. Finally, we confirmed that fish consumption frequency has a positive correlation with the hair mercury level. However, our research also has some restrictions. First, we collected limited covariate variables. Second, our questionnaire did not include other factors that potentially relate to mercury levels. Finally, since our study is a cross-sectional study, the mercury levels were determined at one time point. It cannot reflect the mercury exposure throughout childhood.

Although our study and a number of other studies indicate that fish consumption is highly related to hair mercury levels, we want make an important note here. Fish is a good source of lean proteins. It can supply unsaturated fatty acids such as omega-3, to the consumers. Some nutrients contained in fish are beneficial for children's development[10]. Thus, we cannot refuse to eat fish just because of its possibility of increasing mercury exposure. We need to conduct further studies to explore a balance to maintain a proper diet.

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