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Mercury concentration in meconium and risk assessment of fish consumption among pregnant women in Taiwan ☆

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ABSTRACT

Meconium is a matrix that can be obtained easily and noninvasively and is useful for detecting antenatal fetal exposure to environmental toxins. Taiwan is an island with high fish consumption, and many pregnant women would like to enjoy the benefits of fish without jeopardizing their health or that of their child. The aim of this study is to assess the mercury concentration in meconium in relation to the health risk of mercury exposure. A total of 198 mother–infant pairs residing in the city of HsinChu were recruited for the study between January 2007 and June 2007. The average mean concentration of mercury in meconium was 79.2 ± 7.3 ng g^{-1} dry wt We use the Monte Carlo technique to assess the uncertainty in risk assessment and the impact of these uncertainties on the estimation of expected risk of mercury intake from fish in mothers. Based on the FAO/WHO's tolerable daily intake of methylmercury (0.23 μg kg^{-1} d^{-1}), we found that 17.3% and 14.0% of the daily mercury exposure estimated exceeded the reference dose for foreign-born and Taiwan-born mothers, respectively. We found that the mercury concentration in meconium was much higher than in other studies, except for one study done in Tagum in the Philippines where mercury is used in gold mining. This may be because Asia is the largest emitter of anthropogenic mercury, accounting for 53% of worldwide emissions. Sensitivity analysis suggests that mercury concentration in fish and the rate of ingesting fish may be the key parameters for governments offering risk management guidance to protect the health of mothers and unborn babies.

1. Introduction

Mercury is a well-known neurotoxin in humans, and pregnant women's consumption of mercury-containing foods has been associated with devastating effects on their fetuses (Amin-Zaki et al., 1976; Bakir et al., 1980; Harada, 1978). Humans are exposed to methylmercury (MeHg) through food (especially fish) and elemental mercury vapor from amalgam dental fillings. Both the maternal body mercury burden and current exposure are major mercury sources for the fetus, because mercury can pass through the placenta and blood–brain barrier. Maternal blood mercury is associated with fish intake, and environmental exposure at work and home. Maternal dental amalgam is similarly a major avenue of exposure for the fetus. The amount of mercury in the environment and in fish eaten by expecting mothers can result from human activity as well as natural emissions from oceans and geological sources. Environmental exposure at work and home, and maternal dental amalgam are sources that may warrant concern for the fetus.

Previous studies have determined the concentrations in maternal and cord blood, breast milk, and hair to demonstrate fetal exposure to environmental toxins (Grandjean et al., 1998). The level of environmental toxins found in fetal blood may not reflect the actual degree of exposure, because many substances processed by the fetus accumulate in the fetal intestine. Studies have showed that meconium analysis is useful for detecting antenatal fetal exposure to environmental toxins (Maynard et al., 1991; Callahan et al., 1992; Ostrea et al., 1992, 1993, 1998, 2002). Meconium is a matrix that can be obtained easily and noninvasively and represents a wide period of exposure during gestation. Meconium levels appear to be the most reliable indicator of fetal mercury exposure and are often significant even when mercury levels in maternal blood and cord blood are low (Ramirez et al., 2000).

Taiwan is an island and a high fish-consuming country. Taiwanese eat fish three or more meals per week (DOH, 1999). Blue fin tuna are very popular and Taiwan people love to eat raw fish as sashimi and sushi. In our

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previous study, we showed that breast milk mercury concentrations are not significantly different between urban mothers ($n=56$; range, 0.24–9.45 μg l^{-1}) and mothers married to fishermen ($n=12$; range, 0.26–8.62 μg l^{-1}). Thus, although the frequency of fish consumption among women married to fishermen (75% have more than 7 meals with fish per week) ($p<0.001$) is significantly higher than that among urban mothers (1–2 meals per week in 44.6%), the urban women should also be concerned about mercury concentrations in the fish they consume (Chien et al., 2006). For 89% of women in Taiwan ($n=65$; 9.1 ± 0.4 μg l^{-1}), maternal blood mercury concentrations exceed the US National Research Council (USNRC) recommended limit of 5.8 μg l^{-1} (Hsu et al., 2007; Schober et al., 2003).

Despite the impressive increase in cross-border marriages in Taiwan and the increasing number of children born into these families, no studies have examined whether there are significant mercury body burden differences between babies of foreign-born and Taiwan-born mothers. The purpose of this study is to assess the mercury concentration in meconium in relation to mercury exposure in mothers. Further, we use the Monte Carlo technique to assess the uncertainty in risk assessment and the impact of these uncertainties on the estimation of risk from mercury intake from fish for mothers in Taiwan.

2. Materials and methods

A total of 198 mother–infant pairs (Taiwan-born mothers: 184; foreign-born mothers: 14 mothers) residing in the city of Hsinchu were recruited for the study between January 2007 and June 2007. After obtaining written informed consent, the mothers were recruited into the study. All of the mothers delivered their babies at a single general hospital in Hsinchu. None of the mothers had complications during the study period and only singleton infants were recruited into our study. No mothers refused to participate in our study. Meconium specimens were collected from 198 healthy newborn infants (108 males, 90 females). The mothers were interviewed face-to-face by a trained interviewer after delivery in which information was collected pertaining to the mother's sociodemographic characteristics, occupation, pregnancy and reproductive history, fish intake, and other lifestyle characteristics. Also, the baby's sex, gestational age, birth weight, head circumference and height at birth were recorded. Occupational mercury exposure was defined as a mother working at a fluorescent lamp manufacturing factory, dental clinic, factory manufacturing fungicides or pesticides, a paint factory, and chlor-alkali plant. The Institutional Review Board of Taipei Medical University approved the study (P940030).

2.1. Sample collection

In order to study the daily mercury exposure from different forms of fish consumption, we divided "fish" into two groups, fish cutlets and sashimi, the most popular types consumed by pregnant women according to the results of individual questionnaires. Sashimi samples were randomly obtained at fish markets, seaports, and coastal areas around Taiwan. Samples were placed in a refrigerated container and transferred to the laboratory immediately after collection. Flesh from the samples was obtained, cleaned, and homogenized. Approximately 5 g of each sample was digested in flasks for 10 h with 5 ml nitric acid at 60 °C in a water-bath. After cooling, the residual fluid was diluted to 50 ml with distilled water. Meconium was collected on the first postnatal day and frozen at −20 °C until analysis.

2.2. Mercury determination of sashimi and meconium

Mercury concentrations in the fish were analyzed with a mercury analyzer (HG-200, Hiranuma, Mito, Japan). Certified reference material (CRM) DORM-3 was used to perform a standard material test to ensure the precision and accuracy of the analyses of fish. The precision was 100.4% and accuracy 93.4%. The detection limit for Hg analysis was 0.04 μg g^{-1}. The entire meconium sample was lyophilized and 30 mg of the sample was transferred to a boat and activated alumina, sodium carbonate and calcium hydroxide were added. Mercury concentrations were determined by a mercury analysis system (Mercury/MA-2000SC, Nippon Instruments Corporation). Each sample was analyzed in triplicate. Standard reference material (SRM) 1566b Oyster Tissue was used to perform a standard material test to ensure the precision and accuracy of the meconium analyses. The precision was 99.9% and accuracy was 99.8%. The detection limit for Hg analysis was 0.23 ng g^{-1}.

Table 1
Input variables/parameter values used to define distributions for the Monte Carlo simulation.

Input variable	Symbol	Distribution
Hg concentration (μg/g)		
Fish cutlets	C_{mf}	Lognormal (Geomean = 0.06, GSD[a] = 2.74)
Sashimi	C_{ms}	Lognormal (Geomean = 0.35, GSD = 1.64)
Ingestion rates (g/d)		
Fish cutlets	IR_f	Lognormal (Geomean = 52.6, GSD = 1.64)
Sashimi	IR_s	Lognormal (Geomean = 4.95, GSD = 0.65)
Maternal body weight (kg)		
Taiwanese mothers	BW_T	Lognormal (Geomean = 54.3, GSD = 1.22)

[a] GSD – Geometric standard deviation.

2.3. Daily mercury exposure

Information on dietary fish intake was obtained from individual questionnaires. The mercury concentration of various species of fish

Table 2
Demographic characteristics of mothers and newborn babies.

Characteristic	All subjects ($n=198$)	Taiwan-born ($n=184$)	Foreign-born ($n=14$)	p-value
Age (years)	31.5 ± 4.3	31.7 ± 4.3	27.6 ± 3.6	0.0007
Maternal height (cm)	159.8 ± 5.1	159.8 ± 5.0	159.1 ± 4.5	0.64
Pre-pregnant weight (kg)	54.5 ± 9.5	55.4 ± 11.1	47.6 ± 4.7	<0.0001
Prenatal weight (kg)	69.0 ± 11.0	69.8 ± 11.3	64.2 ± 7.7	0.07
Gestation (weeks)	38.6 ± 1.8	38.6 ± 1.7	38.7 ± 1.2	0.74
Head circumference (cm)	33.4 ± 1.3	33.5 ± 1.3	33.8 ± 1.2	0.39
Baby's height (cm)	49.5 ± 4.5	49.3 ± 4.8	50.9 ± 1.9	0.19
Baby's birth weight (g)	3106 ± 514	3104 ± 473	3116 ± 922	0.93
Sex of newborn baby				
Male	54.1	53.3	64.3	0.43
Female	45.9	46.7	35.7	
Parity				
≤1	49.2	50.9	28.6	0.11
≥2	50.8	49.1	71.4	
Occupational exposure				
Yes	3.9	4.3	0	0.43
No	96.1	95.7	100	
Amalgam fillings during pregnancy				
Yes	1.7	1.8	0	0.61
No	98.3	98.2	100	
Smoking during pregnancy				
Yes	2.8	3.0	0	0.51
No	97.2	97.0	100	
Alcohol consumption				
Yes	3.9	4.3	0	0.61
No	96.1	95.7	100	
Consumed traditional Chinese herbs				
Yes	23.3	24.7	7.1	0.14
No	76.7	75.3	92.9	
Fish cutlet consumption				
<1 meal/week	41.4	43.1	21.4	0.16
1–2 meals/week	39.1	38.8	42.9	
≥3 meals/week	19.5	18.1	35.7	
Sashimi consumption				
<1 meal/week	97.7	97.5	100	0.84
1–2 meals/week	1.7	1.9	0	
≥3 meals/week	0.6	0.6	0	

Values are given as mean ± standard deviation or %.