Impacts of Maternal Fish Consumption and Natural Environment on Placental Mercury Levels in Jamaica

P Ricketts[1], M Voutchkov[1], H Fletcher[2]

ABSTRACT

Objective: *Mercury is a neurotoxin that is introduced to pregnant women from the soil, air pollutants and fish intake. Mercury in the placenta can be a biomarker for both maternal and fetal exposure. The objective of this study was to investigate how dietary patterns and environmental conditions can affect mercury concentration levels in the human placenta.*

Method: *Ethical consideration was granted to collect placental samples from participants at the University Hospital of the West Indies (UHWI), in November 2012 and Mandeville Regional Hospital (MRH) in July 2014. Cold vapour atomic absorption analysis was performed on the samples to determine the total mercury concentration in the placentae. The participants were interviewed on their fish intake and residence. The samples were categorized into industrial (Kingston and Mandeville) and agricultural areas (St Elizabeth, Clarendon and Trelawny).*

Results: *The placental mercury concentration ranged from 0.45–3.7 μg/kg, median 0.5 μg/kg. The mean maternal fish intake per week for industrial and agricultural areas was 78.4 ± 52.3 g and 86.3 ± 90 g, respectively and the mean placental mercury concentrations were 0.67 ± 0.4 μg/kg and 0.58 ± 0.2 μg/kg, respectively. There was no significant difference between fish intake and placental mercury. There was a statistically positive correlation ($p = 0.04$) between the mean placental mercury and the study areas. The area with the highest soil mercury of 500 ppb, had the highest mean placental mercury 1.13 ± 0.2 μg/kg.*

Conclusion: *The study showed that the environment can also influence placental mercury. The placental mercury levels in Jamaica were found to be below the 10 μg/kg reference level, at which fetal health could be adversely affected.*

Keywords: Fish, mercury mining, placenta, pollution, soil

Efectos del Entorno Natural y el Consumo de Pescado de las Madres en los Niveles de Mercurio Placentario en Jamaica

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RESUMEN

Objetivo: *El mercurio es una neurotoxina que se introduce en las mujeres embarazadas desde el suelo, los contaminantes del aire, y el consumo de pescado. El mercurio en la placenta puede ser un biomarcador de exposición materna o fetal. El objetivo de este estudio fue investigar cómo los patrones dietéticos y las condiciones ambientales pueden afectar los niveles de concentración de mercurio en la placenta humana.*

Método: *Se concedió aprobación ética para recoger muestras placentarias de las participantes en el Hospital Universitario de West Indies (HUWI) en noviembre de 2012, y el Hospital Regional de Mandeville (MRH) en julio de 2014. Se realizó un análisis de absorción atómica*

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de vapor frío sobre las muestras para determinar la concentración de mercurio total en las placentas. Las participantes fueron entrevistadas sobre su consumo de pescado y su residencia. Las muestras se categorizaron como correspondientes a áreas industriales (Kingston y Mandeville) o áreas agrícolas (St. Elizabeth, Clarendon y Trelawny).

Resultados: *La concentración de mercurio placentario osciló entre 0.45 – 3.7 µg/kg, media 0.5 µg/kg. El consumo de pescado materno promedio por semana para las áreas industriales y agrícolas fue 78.4 ± 52.3g y 86.3 ± 90g, en tanto que las concentraciones de mercurio placentario promedio fueron 0.67 ± 0.4 µg/kg y 0.58 ± 0.2 µg/kg, respectivamente. No hubo diferencia significativa entre la ingestión de pescado y el mercurio placentario. Hubo una correlación estadísticamente positiva (*p = *0.04) entre el mercurio placentario promedio y las áreas de estudio. El área con el mayor mercurio de suelo, 500 ppb, tuvo el promedio de mercurio placentario más alto 1.13 ± 0.2 µg/kg.*

Conclusión: *El estudio demostró que el medio ambiente también puede influir sobre el mercurio placentario. Los niveles de mercurio placentario en Jamaica se encontraron por debajo de 10 µg/kg – el nivel de referencia a partir del cual la salud fetal podría ser afectada.*

Palabras claves: Pescado, mercurio, minería, placenta, contaminación, suelo

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INTRODUCTION

When ethyl mercury is released from industrial activities into the rivers, bacteria transform it into methyl mercury. Microscopic organisms absorb this methyl mercury and fish eat these microscopic organisms (1). Mercury is naturally found in bauxite (2), and Jamaica has the sixth largest bauxite reserve in the world (3). According to a study done by Lalor in 1995, the mercury concentration range in Jamaican soil is from 40–830 ppb (3), where concentrations higher than 300 ppb were found in bauxitic soils. Pregnant women may expose their fetuses to mercury in their placenta from eating fish (4) or as a result of air emissions and soil (5). Methyl mercury is a neurotoxin that is able to pass through the placental barrier where the methyl mercury level in the fetal blood is at least 25% higher than the methyl mercury level in the maternal blood. This is because of a greater affinity of fetal blood to absorb mercury (6). It is necessary to monitor prenatal exposure to mercury within the Island and coastal populations that have a history of high fish consumption.

There have been many analytical techniques used to measure placental mercury concentrations. They include; cold vapour atomic absorption (4) and energy dispersive X-ray fluorescence (7). For the purpose of a large-scale bio-monitoring study, the analytical technique used should be cost-effective and sensitive at low concentrations. In Jamaica, a study was conducted in 2010 at the University Hospital of the West Indies (UHWI), by Grant *et al* to determine the elements concentrations in 52 human placental samples using neutron activation analysis (8). Only 25% of the participants from that study reported eating fish during pregnancy. One of the aims of that study was to investigate the relationship between placental mercury levels and maternal fish consumption. For this current study, a larger sample size of pregnant women with a detailed history of fish consumption was required to confirm the hypothesis of Grant *et al*. This study also investigated the significant difference between placental mercury and the natural environment. The natural environments selected were: Kingston, Mandeville and some rural parishes. This research project was approved by the Research Ethics Committee of the University Hospital of the West Indies/ The University of the West Indies/Faculty of Medical Sciences, Mona and the Ministry of Health, Jamaica.

SUBJECTS AND METHODS

Two cross-sectional studies were conducted on the Labour wards of the UHWI in Kingston/St Andrew and the Mandeville Regional Hospital (MRH). The UHWI was selected for the participants living in Kingston, while the participants from MRH lived in Mandeville and other rural parishes. A total of 177 placental samples were collected at delivery from patients. Each patient signed a written consent to participate in the study. The hospitals represent two categories of participants living in industrialized and non-industrialized areas. The participants were asked to identify the types of fish and vegetables they ate during pregnancy as well as the frequency of consumption. The intake options included never, once per month, two-to-three times per month, once per week, two-to-times per week, four or more times per week.They selected from a list of 12 fresh-fish and four canned-fish. They also indicated whether they used cough syrup while pregnant and were asked to indicate the amount of dental amalgams they had. This information was necessary, as some cough syrups contain thimerosal ethyl-mercury, while some dental amalgams contain liquid mercury. Their location of residence and child birthweights were also recorded.

Sampling sites

The study sites were divided in two categories, Groups A and B based on their industrial and agricultural activities and also based on low and high soil mercury concentrations (Figure).

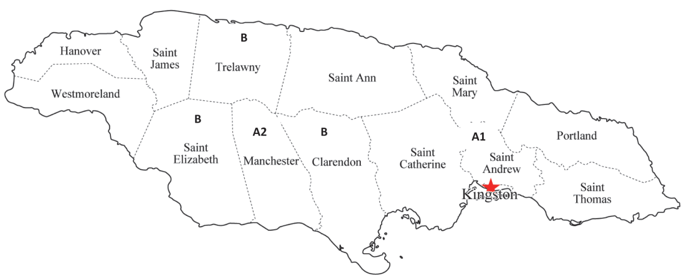

Figure: Map of Jamaica showing two study sites (Groups A and B).

Group A

The parishes in Group A are classified as industrial areas (A1 and A2). Kingston (A1) is a metropolitan region with 30% of Jamaica's population (10). It is the capital city, which has large-scale industrial activities such as cement processing and petroleum refinery. The mean soil mercury for Kingston is 82.02 ± 16.1 ppb (3). Manchester (A2) is located in the west-central part of the Island which also has large-scale industrial activities such as bauxite mining. The mean soil mercury for Manchester is 535.2 ± 37.1 ppb (3).

Group B

The participants from Group B lived in the rural parishes of Clarendon, St Elizabeth, Trelawny and St Ann. This area is mainly known for its agriculture and farming. The mean soil mercury concentration for this group is 271.3 ± 113 ppb (3).

Sample preparation (placenta)

The whole placenta was thoroughly examined for any abnormalities. It was washed to remove maternal blood. The weight of the placenta was recorded and approximately, a quarter of the flat part of the placenta from the region of the umbilical cord was severed with a surgical blade. It was then placed in a sealed plastic bag and stored in a freezer at -18 °C. Each placental sample was placed in an aluminum disposable tray. The electronic balance (sensitivity ± 0.1 g) was used to weigh the wet placental sample and (Memmert, Germany) the empty tray. These values were recorded. They were dried in the Memmert drying oven at 60 °C. The oven was set to maintain a constant temperature for approximately 96 hours. The sample was removed from the oven and weighed intermittently every 30 minutes until a constant dry-weight was obtained. About 0.3 g of dried placental tissue sample was placed in a biochemical oxygen demand (BOD) bottle with 8 mL of concentrated sulphuric acid and 2 mL of concentrated nitric acid. The BOD bottle was placed in a water bath maintained at 80 °C until the tissue was completely dissolved (approximately 30 minutes). The sample was cooled and 15 mL of potassium permanganate and 8 mL of potassium persulfate solutions were added and returned to the water bath and digested for an additional 90 minutes at 30 °C. The digested sample was diluted with 55 mL of reagent water and 6 mL of sodium chloride-hydroxylamine sulphate solution was added to reduce the excess permanganate. Five millilitres of stannous chloride solution was added and cold vapour atomic absorption (Model 400A Mercury Analyzer system, Connecticut) analysis was performed. The amount of mercury present was recorded and calculated for wet-weight.

Quality assurance

The accuracy of the cold vapour atomic absorption method was checked by using the International Atomic Energy Agency (IAEA)–407, fish homogenate certified reference material, control standards and reagent blanks. An instrument calibration curve was established by plotting the standard concentrations against the instrument reading absorbance. A regression statistics, $R^2 = 0.998$ was calculated. The method detection limit was found to be 0.5 µg/kg. The concentrations were calculated to wet-weight. A recovery study was done on a placental sample spiked with 0.3 µg of mercury. The average recovery was 77% recovery of the total mercury in the samples. Ninety per cent of the mercury in the IAEA (fish homogenate) certified reference material was also recovered from this method.

Statistics

The sample concentrations that were found to be below the method detection limit (MDL), were classified as 'non-detects'. The substitution method was used where these values were replaced with half of the MDL concentration, $p \leq 0.05$ was considered as the statistically significant level. SPSS Version 19 for Windows and Microsoft Excel 2007 were used to perform the statistical analyses of the data. Independent sample *t*-test and analysis of variance (ANOVA) were used to test for the associations among the key variables.

RESULTS

The mean placental whole-weight was 624 g. The whole placenta weight ranged from 220–1050 g. After drying, each sample had approximately 88% moisture removed. The mercury concentrations are all reported in wet-weight (*w/w*). The placental mercury concentration ranged from 0.45–3.7 µg/kg, median 0.5 µg/kg. There was a weak positive correlation between the placental mercury and maternal fish intake ($R^2 = 0.02$). Table 2 shows the significant findings of the study. Table 1 shows the average frequency of fish meals per week for the participants. The types of fish that were frequently consumed had a mercury concentration range from 0.013–0.18 ppm (11). None of the participants reported eating shark.

Industrial area (Group A) had a significantly higher placental mercury concentration than the agricultural area (Group B), with a significant difference, $p = 0.04$. Manchester (A2) recorded the highest placental and soil mercury concentrations. The soil mercury concentration was found to be as high as 830 ppb (3), which is about three times more than that of the other parishes, with a statistical significance, $p = 0.001$. There was no correlation between the placental mercury concentration and child weight ($R^2 = 0.006$, $p = 0.48$) and maternal age ($R^2 = 0.032$, $p > 0.68$).

Table 1: Average frequency of fish consumption among the participants

Frequency	Types of fish	Mercury concentration /ppm (8)
2–3 times per week	Mackerel S Atlantic (canned)	0.18
	Saltfish/cod	0.11
	Grunt/whitefish	0.09
	Tilapia	0.013
	Sardine (canned)	0.013
Once per week	Tuna (canned)	0.35
	Red/yellow snapper	0.17
Once per month	Salt mackerel	0.1
	Bangamary/weak fish	0.2
	Parrot fish/pollock	0.03
	Salmon	0.008
	Sprat	–

Table 2: Mean (SD) and *p*-values for variables in each group

Variables	Industrial Group A		Agricultural Group B	*p-value*
	A1	**A2**	**B**	
Sample size, n	100	36	41	
Maternal age/years	29.7 (6.6)	27.6 (6.6)	28.1 (7.7)	0.70
Child birthweight/ kg	3.0 (0.7)	3.3 (0.6)	3.3 (0.9)	0.38
Maternal fish intake/ week	72.2 (48.6)	108.5 (94.4)	96.5 (113.6)	0.75
Placental mercury, µg/kg	0.64 (0.5)	0.70 (0.4)	0.56 (0.3)	0.04*

*Significance at $p < 0.05$, independent sample *t*-test

DISCUSSION

Jamaican pregnant women had a median fish intake of two meals per week, compared to the high fish eating populations, such as Taiwan, which have an intake of three to four meals per week (12). According to Table 1, the most frequently consumed fish are imported. The most significant contribution to methyl mercury intake is from canned-fish (13), in our case Tuna. The placental mercury concentrations in Jamaica are much lower than in the other populations which have high fish consumers. It can then be expected that the placental mercury concentrations would be below 10 μg/kg level derived from the EPA blood reference dose (14) for observable adverse effect. There was no significant difference between the maternal fish intake and the child birthweight. Previous studies have shown that this relationship was inconsistent (13).

The mean mercury concentration in this study 0.65 μg/kg was below the mean concentrations of the preliminary study (9) 7.29 μg/kg. However, both techniques vary based on analytical properties. Due to the non-destructive nature of neutron activation analysis, the concentration sensitivity was dependent on the sample matrix (15). Therefore, the high-value reported by Grant *et al* could be an outlier, and the concentration range in this present study would be more appropriate according to the compiled literature recorded (9). There was a significant difference between the placental mercury concentrations of the two groups (p = 0.04). There was a weak regression coefficient (R^2 = 0.02) between the placental mercury concentration and maternal fish intake within the industrial group; therefore, it is possible that there were additional sources of mercury exposure. Based on the National Environment and Planning Agency (NEPA), other anthropogenic sources of mercury exposure could be from the alumina industry, cement manufacturing, petroleum refining and food production. The highest contribution to mercury emission in the air is from the alumina refinery (2.04 tonnes per year) and cement manufacturing [0.01 tonnes per year] (16). These values are below Canada's (6 tonnes per year) in 2000 (17). Although, Kingston (A1) reported the lowest soil mercury concentration, additional mercury exposure could be from the industrial sources. Pregnant women living in Kingston can also be exposed to mercury from heavy vehicular traffic. Studies showed that mercury emission within a region increases with petroleum and diesel usages (18). Manchester (A2) has the largest deposit of bauxitic soil in Jamaica (19). According to 'A geochemical Atlas of Jamaica', the mercury concentration in Manchester exceeded the normal limits (9). This study showed that prenatal exposure to mercury from maternal fish intake was not prevalent in Jamaica.

Limitations

A critical factor in analysing food frequency questionnaires is the reliability of the participants. Fifty-three per cent of the placental samples were below the method detection limit; therefore, an even more sensitive technique such as inductively couple plasma-mass spectrometry (ICP-MS) could be used to measure lower mercury concentrations. According to the EPA document on analysing data with 'non-detects' values, the replacement method is still appropriate for risk assessment when the 'non-detects' are about 50% of the sample population (20). Using this method eliminates 'overestimating' the exposure to the population. When the 'non-detects' were omitted from the data analyses, the placental mercury concentrations were about 35% higher. However, by handling these data on a case-by-case basis, it became evident that some outliers contributed significantly to the mean placental mercury concentrations.

CONCLUSION

The results of this study showed that placental mercury concentrations for Jamaican women were within the average-range reported in the literature and below the concentration at which they would begin to notice adverse effects in the fetus. Therefore, pregnant women are not putting their fetus at risk for high mercury exposure. It was also found that large-scale industrial activities can also contribute to the uptake of elements in the placenta. Placental mercury concentrations were higher in industrial areas than in agricultural areas. Industries known for mercury emission, such as bauxite mining and cement processing, can contribute to mercury concentrations in the mother and in the fetus. The highest placental mercury concentration was found in bauxitic soil in Manchester (A2). Placental mercury concentration from Kingston (A1) could be as a result of fossil fuel combustion. Overall, the environmental conditions could affect the placental mercury levels. Mercury exposure prevalence in Jamaica is mainly as a result of industrial activities. It is, therefore, recommended that there be an on-going environmental monitoring for the consideration of both maternal and fetal health.

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