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Total mercury levels in hair of children aged 7 years before and after the Great East Japan Earthquake

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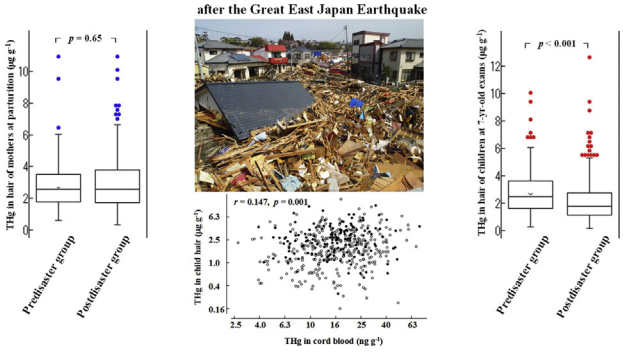
HIGHLIGHTS

- Total mercury (THg) levels before and after the Great East Japan Earthquake were compared.
- 7-year-old THg levels were lower in the postdisaster group than in the predisaster group.
- No difference of THg levels at birth was seen between the groups.
- The natural disaster altered the fish-eating lifestyle.
- Nevertheless, 7-year-old THg reflected THg at birth to some extent.

GRAPHICAL ABSTRACT



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ABSTRACT

The Great East Japan Earthquake on March 11, 2011 caused severe damage to the Sanriku coastal area, where we have been conducting a birth cohort study. The disaster occurred in the middle of 7-year-old examination. The mother-child pairs who participated in our study were compulsorily divided into two groups: the examination was finished for 157 children before the disaster, and for 335 after the disaster. We examined whether the disaster affected total mercury (THg) levels of the cohort, as well as a relationship between the THg levels at birth and at present. Although there was no significant difference between the predisaster and postdisaster groups for THg levels in cord blood (16.3 and 16.1 ng g^{-1}, respectively) or maternal hair at parturition (2.57 and 2.55 μg g^{-1}, respectively), the THg in hair of the 7-year-old children was significantly lower in the postdisaster group (1.79 μg g^{-1}) than in the predisaster group (2.51 μg g^{-1}). The difference remained significant after adjusting for the prenatal exposure level of THg. In the 492 mother-child pairs, the cord-blood THg was significantly correlated with the THg in maternal hair at parturition ($r = 0.846$) and in hair of the 7-year-old children ($r = 0.147$). In conclusion, the 29% decrease in hair THg after the disaster appears to have been due to the fact that children in the affected area could not consume fish/seafood as usual, probably because of destructive damage to the fishery. Nevertheless, the THg levels at 7 years of age reflected the prenatal exposure levels to some extent.

Abbreviations: ANCOVA, analysis of covariance; BAEP, brainstem auditory evoked potential; BW, body weight; FFQ, food frequency questionnaire; PCBs, polychlorinated biphenyls; PUFA, polyunsaturated fatty acid; SD, standard deviation; THg, total mercury; TSCD, Tohoku Study of Child Development.

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1. Introduction

Fish contain not only long-chain polyunsaturated fatty acids (PUFA) but also methylmercury and polychlorinated biphenyls (PCBs). Methylmercury is known to be a neurotoxic substance, and the exposure level is frequently estimated from the total mercury (THg) content in hair (Grandjean et al., 1992; Sheehan et al., 2014). When the exposure level at birth is required in a study, a birth cohort study can collect umbilical cord blood/tissue or maternal hair at parturition as a biological specimen (Grandjean et al., 1997), but a cross-sectional or case-control study cannot do so. In the latter type of study, hair THg levels of mothers who have not changed their dietary habits after pregnancy may be used as a proxy for THg exposure at parturition (Murata et al., 1999a, 2004a; Weihe et al., 2002); however, a relationship between THg levels at birth and at present of children has hardly been examined except for one report (Murata et al., 2004b). For assessing developmental effects of prenatal and postnatal methylmercury exposures resulting from fish, it is important to clarify the relationship between these THg levels.

The Great East Japan Earthquake on March 11, 2011, followed by subsequent tsunamis, was the most powerful among those that had ever struck Japan (Fujiwara et al., 2014; Sugimoto et al., 2014). It destroyed thousands of houses/buildings, harbors, and fishing boats/grounds on the Pacific Ocean coast of Iwate, Miyagi, and Fukushima prefectures. Since 2001, we have performed a birth cohort study, the Tohoku Study of Child Development (TSCD), focusing both on the potential risks and benefits of fish eating during pregnancy (Suzuki et al., 2010; Tatsuta et al., 2012, 2014). The research field was comprised of an urban area (i.e., Sendai city of Miyagi prefecture) and a coastal area (i.e., Sanriku coastal area of the same prefecture). At the time when we were conducting the 7-year-old examination of the cohort, the latter area suffered destructive damage because of the tsunamis. For this reason, dietary habits of those residing in the coastal area might have changed drastically after the disaster. In this study, we focused on exposure markers of the children and examined the effect of the disaster on THg levels of the cohort, as well as a relationship between THg levels at birth and at 7 years of age, to estimate the extent to which current THg reflects the prenatal exposure level.

2. Materials and methods

2.1. Study population

The study protocol of TSCD has been described elsewhere (Nakai et al., 2004). As mentioned above, the mother-child pairs in the coastal area were examined. Eight hundred seventy-nine pregnant women who gave their written informed consent were enrolled in this study, and 749 mother-child pairs were registered in the years 2003–2006. To establish the study population, the eligibility criteria included a singleton pregnancy, Japanese as the primary language, birth at term gestation (36–42 weeks) without obvious congenital anomalies or diseases, and a birth weight (BW) of >2400 g. Information about child sex, BW, birth order (first-born or not), maternal age at parturition, gestational duration, and delivery type (spontaneous or not) was obtained from medical records. The medical ethics committee of the Tohoku University Graduate School of Medicine approved this protocol.

Although we had been conducting the 7th year examination for the mother-child pairs since January 2010, it was interrupted by the Great East Japan Earthquake. The examination was resumed in August 2011 (Tatsuta et al., 2015). As a result, we finished the examination of 160 mother-child pairs before the disaster (i.e., predisaster group), and that of 338 pairs after the disaster (i.e., postdisaster group). Of these pairs, two were excluded because one did not agree to hair collection and the hair of another was too short to cut. Moreover, exposure data at birth for four children were incomplete. Finally, a total of 492 mother-child pairs participated in this study.

2.2. Methods

Hair samples 3 cm long were collected from the occipital area of each mother after delivery and after the disaster, together with that of each child at the 7-year-old examination. Cord blood samples were collected into a tube containing heparin at delivery, and whole blood was stored at −80 °C until analysis. THg levels in cord blood and hair were measured using cold vapor atomic absorption spectrometry (HG-201, Sanso Seisakusho Co. Ltd., Tokyo, Japan). The analytical method for THg has been described elsewhere (Ministry of the Environment, Japan, 2004; Iwai-Shimada et al., 2015). The accuracy was ensured using a certified reference material (Seronorm Trace Elements Whole Blood L-2, Lot 0503109, Sero, Norway) for quality control. The mean ± standard deviation (SD) of THg determinations was 7.51 ± 0.50 ng g^{-1} (coefficient of variation in 17 subjects, 6.6%), and the certified value and acceptable range were 8.7 ng mL^{-1} and between 6.1 and 11.3 ng mL^{-1}, respectively. The mean ± SD of THg determinations in human hair NIES No. 13 was 4.31 ± 0.03 μg g^{-1}, and the certified value ± uncertainty expressed was 4.42 ± 0.20 μg g^{-1}. Analysis of THg in child and maternal hair at the 7-year-old examination was performed at IDEA Consultants, Inc. (Tokyo, Japan), using the above method with an external quality assurance programs (Schaller et al., 2002). Maternal methylmercury intake during pregnancy was assessed using a food frequency questionnaire (FFQ) that was administered by trained interviewers after delivery. We selected several kinds of seafood that were often found at fish market in the study area and classified them into 18 items considering the methylmercury levels and fish species. The method used for estimation of weekly methylmercury intake (μg kg^{-1} BW per week) has been described elsewhere (Yaginuma-Sakurai et al., 2009). Information about drinking and smoking habits during pregnancy (yes or no) was obtained from a questionnaire (Tatsuta et al., 2015).

2.3. Statistical analysis

The basal characteristics and exposure levels of the predisaster and postdisaster groups were compared using Student *t*-test, Mann-Whitney *U* test and Fisher exact test. The Wilcoxon signed rank test was used to compare hair THg levels at parturition and at the age of 7 years of each group. After comparing the slope of the regression line of the THg in child hair on the prenatal THg levels between the predisaster and postdisaster groups by using *F* test, analysis of covariance (ANCOVA) was employed to compare the THg levels in child hair between the two groups. The relationships among these markers were tested using the Pearson product-moment correlation coefficient (r). All analyses with two-sided p values were performed using the Statistical Package for the Biosciences (SPBS V9.68) (Murata and Yano, 2002), and the statistical significance was set at $p < 0.05$.

3. Results

The basal characteristics of the 492 mother-child pairs in the coastal area of TSCD are provided in Table 1. There were no significant differences between the predisaster and postdisaster groups for any variables except for drinking habit during pregnancy. Table 2 presents THg levels of the mother-child pairs; whereas, there were no THg data in maternal hair at the 7-year-old examination of the predisaster group inasmuch as we did not collect hair samples from the mothers. The THg level in child hair was significantly lower in the postdisaster group than in the predisaster group, but the prenatal exposure markers did not differ significantly between the groups. In the postdisaster group, the THg level in child hair was lower than those in maternal hair at parturition and the 7-year-old examination (both, $p < 0.001$); but, no significant difference was seen between the mother-child pairs of the predisaster group ($p = 0.730$).