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Mercury Level in Hair of Primary School Children in Korea and China

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Abstract

Exposure to mercury was assessed in 125 Korean (Gwangju and Busan) and 373 Chinese primary school students (Xinguang village, Goumen town) using hair mercury analysis from November 2006 to September 2007. The geometric mean concentration of mercury was higher among Korean children with recording 0.73 μg/g, compared to Chinese children of 0.12 μg/g, which indicated statistically difference ($P<0.01$). The mean concentration of Korean children living near incineration facilities was higher by recording 0.76 μg/g while the average concentration of their counterpart in Korea reached 0.69 μg/g. In case of Chinese children, those who are living near power plants showed higher level with posting 0.16 μg/g while the others recorded 0.10 μg/g ($P<0.01$). Intake of fish was found to be related to hair mercury level. In case of Korean children, those with high fish intake recorded 0.79 μg/g in terms of the geometric mean concentration while the others with low fish intake posted 0.61 μg/g. Among Chinese children, those who often eat fish recorded 0.13 μg/g compared to the others with low fish intake of 0.11 μg/g. On the other hand, amalgam dental fillings have limited influence on mean hair mercury level. As for vaccination, within a month of vaccination, the geometric mean concentration of Korean children reached 0.76 μg/g, and in case of 15 days after injection, the level was 1.20 μg/g. In China, the level of children at one month after receiving injection stood at 0.15 μg/g while the level within 15 days was 0.13 μg/g. Multiple regression analysis showed that BMI, passive smoking, and fish consumption are closely related to hair mercury level among the Korean subjects. In China, hair mercury level was affected by age, location, passive smoking, fish consumption, and vaccination. Explanatory power was 21.6% with $R^2=0.216$.

Keywords: Mercury, Hair, Exposure, Children

Environmental pollution is emerging as a social issue in developing countries in Asia which have been posting rapid economic and population growths[1]. Mercury concentrations in the environment have generally increased since the industrial revolution. And now there are a variety of compounds containing mercury[2]. Asia accounts for over 50% of world mercury release. In particular, share of China stands at 25% and is increasing year by year[3,4]. Mercury from China moves over the Pacific Ocean to affect receptors of the US and aggravates air quality of the area[5]. Long-range transport of mercury poses serious problems[6]. There is a growing concern that yellow dust and air pollutants of China affect Korea, beyond the national borders. In China, environmental researchers are conducing researches on the subject with identifying health effects of air pollutants[7].

Mercury, together with lead and cadmium, is one of the heavy metals which have high toxicity and is being regarded as a pollutant requiring special management[8]. Even only a small amount is released in the environment, mercury causes bioaccumulation in the ecosystem. Mercury accumulates in the body not only through digestive organ but also skin or respiration[9]. Mercury accumulation is especially hazardous to children and babied because it have fatal effects on their brain[11].

In Europe, biological limits of mercury exposure for children and pregnant women were reviewed and risk of mercury was reported[12]. The US, Canada, and Japan are focused on low-level mercury exposure and

establishment of fish intake guideline for venerable groups such as children and pregnant women[13]. Recently, some studies suggest that mercury exposure is more hazardous to children than adults[14] and some went one step further to highlight important of biological monitoring and exposure assessment fitted to children[15]. Hair, 80-90% of which is made of keratin protein, absorbs metal ion easily and contains accumulated heavy metals, thereby, is being regarded as the most appropriate tool to assess heavy metal exposure[16].

As hair sample is quick and easy to take compared to urine, blood or nail sample, utilization of hair sample is increasing[17]. In addition, direct assessment through hair, a biomarker, helps find exposure factors and their influence on human health while identifying exposure and exposure level. Currently, An seung-choel[18] and Lee Jong-hwa[19] conducted researches on mercury exposure through blood and urine sampling. And NIER[20,21] reported results of environmental health evaluation of children and pregnant women through blood and urine sampling. In China, Ip[22] evaluated hair mercury concentration in children at age of 4 and Li[23] assessed hair mercury level of adults. However, hair mercury level evaluation in children in children in Korea and China has yet to be conducted.

Against this backdrop, this study was focused on evaluation of hair mercury level of Korean and Chinese children, among other biomarkers, to provide basic data for developing counter measures against environmental pollution. The results will be valuable not only for children in Korea and China, but also for children of entire Asia. The purposes of this study are to assess mercury concentration levels in hair of Korean and Chinese elementary school students, to evaluate hair mercury levels of children living in risk areas and those living in control areas, and to assess factors which have a potential to affect hair mercury level.

Characteristics of Subjects

Study subjects are 497 primary school children who include 125 Korean students and 372 Chinese students. Gender composition of the subjects is showed in Table 1. As for Korean subjects, 60% are male students while 40% are female students. In case of Chinese subjects, male students account for 41.9% and female students were 58.1%. Table 2 presents age distribution of the subjects. Among the Korean subjects, children aged from 6-9 occupied 48% and those aged from 10-12 were 52.0%. Among their Chinese counterparts, students from 6-9 of age accounted for 49.9% while those from 10-12 of age were 50.1%.

Average BMI of entire Korean students are 17.49. The level of male students was 18.06 while that of female students was 16.59 in Table 3. Average BMI of Chinese students was 18.15. The level of male students and that of female students recorded 18.56 and 17.83, respectively.

Table 4 shows dietary conditions of subjects in Korea and China. In case of drinking water, those who drink purified water were the largest group among the Korean subjects, by accounting for 45.5%. Among the Chinese students, those who drink tap water occupied 64.1% with securing the lion's share. As for meat intake, 56.5% of the Korean respondents, the largest share, said that they consumed meat at average of 2-3 servings per week. Among the Chinese subjects, the largest number of respondents said that they eat one serving or less of meat per week, posting 44.7%. Both Korean and Chinese subjects were found to have preference to fish. About 70% of each group said they like fish. In detail, fish intake of 2-3 servings per week was the highest among the Korean student. In China, over 50.0% answered that they consume one serving or less of per week, occupying the largest share within the group. Information about pas-

Table 1. Study subjects in Korea and China according to location.

		Risk area (n, %)	general area (n, %)	Total (n, %)
Korea	Male	46 (36.8)	29 (23.2)	75 (60.0)
	Female	25 (20.0)	25 (20.0)	50 (40.0)
	Total	71 (56.8)	54 (43.2)	125 (100.0)
China	Male	66 (17.7)	90 (24.2)	156 (41.9)
	Female	122 (32.8)	94 (25.3)	216 (58.1)
	Total	188 (50.5)	184 (49.5)	372 (100.0)

Table 2. Study subjects in Korea and China according to age.

Age		Risk area (n, %)	general area (n, %)	Total
Korea	6-9	41 (32.8)	19 (15.2)	60 (48.0)
	10-12	30 (24.0)	35 (28.0)	65 (52.0)
	Total	71 (56.8)	54 (43.2)	125 (100.0)
China	6-9	91 (24.7)	93 (25.2)	184 (49.9)
	10-13	95 (25.7)	90 (24.4)	185 (50.1)
	Total	186 (50.4)	183 (49.6)	369 (100.0)

Table 3. BMI of study subjects.

	Korea	China
Male	18.06±2.73 (63)	18.56±5.27 (112)
Female	16.59±2.35 (40)	17.83±4.84 (149)
Total	17.49±2.68 (103)	18.15±5.03 (261)

BMI=weight/height^2

sive smoke is seen in Table 5. Chinese students presented 87.4% in terms of passive smoke rate, compared to Korean counterparts with 79.8%.

Table 6 shows dental filling and vaccination information. About the question asking whether they have amalgam filling placed within 6 months, 40.4% of Korean subjects said yes. On the other hand, 6.2% of Chinese respondents said they have received amalgam. As for vaccination, 88.7% of Korean respondents and 95.0% of Chinese respondents said that they didn't receive vaccination within a year, respectively.

Table 4. Dietary conditions of study subjects in relation to food intake.

Food intake		Korea (n, %)	China (n, %)
Drinking water	Tap water	37 (36.6)	237 (64.1)
	Purified water	47 (45.5)	5 (1.4)
	Bottled water	11 (10.9)	–
	Underground water	3 (3.0)	125 (33.8)
	Others	3 (3.0)	2 (0.5)
Meat intake	One serving or less per week	38 (30.6)	159 (44.7)
	2-3 servings per week	70 (56.5)	126 (35.4)
	4-6 servings per week	16 (12.9)	40 (11.2)
	Everyday	–	31 (8.7)
Fish preference	Like	89 (71.2)	293 (82.5)
	Dislike	36 (28.8)	62 (17.5)
Fish intake	None	11 (9.2)	113 (35.1)
	One serving or less per week	38 (31.7)	161 (50.0)
	2-3 servings per week	60 (50.0)	38 (11.8)
	4-6 servings per week	9 (7.5)	8 (2.5)
	Everyday	2 (1.7)	2 (0.6)

Table 5. Study subjects exposed to passive smoking.

		Korea (n, %)	China (n, %)
Passive smoking exposure	Yes	99 (79.8)	250 (87.4)
	No	25 (20.2)	36 (12.6)

Hair Mercury Level

Table 7 shows hair mercury levels in Korean and Chinese subjects. Geometric mean concentration of mercury in Korean students posted 0.73 μg/g while the level of Chinese students was 0.12 μg/g, showing statistically meaningful difference. Table 8 below compares hair mercury levels in subjects living in risk areas and general areas. The mean concentration of Korean children living near incineration facilities was higher by recording 0.76 μg/g while the average concentration of their counterpart in Korea reached 0.69 μg/g. In case of Chinese children, those who are living near power plants showed higher level with posting 0.16 μg/g while the others recorded 0.10 μg/g. The test results showed statically meaningful difference ($P < 0.01$). The average concentration of male students and female students in Korea was 0.76 and 0.68 μg/g, respectively. In China, mean concentration in male students was 0.12 and the level of female chil-

Table 6. Subjects with amalgam filling in dental service and vaccination.

		Korea (n, %)	China (n, %)
Amalgam filling (within 6 months)	Yes	50 (40.0)	21 (6.2)
	No	75 (60.0)	320 (93.8)
Vaccination	No	110 (88.7)	321 (95.0)
	Within 6 months	5 (4.0)	9 (2.7)
	Within 3 months	7 (5.6)	6 (1.8)
	Within one month	2 (1.6)	2 (0.6)

Table 7. Hair mercury level (μg/g) measured in Korea and China.

	N (%[a])	GM[b]	M ± SD[c]	Range	*P*-value
Korea	125 (100.0)	0.73	0.79 ± 0.35	0.27-2.24	.000**
China	372 (100)	0.12	0.15 ± 0.11	0.03-0.77	

**$P < 0.01$

[a]Percentage based on total population

[b]Geometric mean

[c]Arithmetic mean ± Arithmetic standard deviation

Table 8. Hair mercury level (μg/g) according to location.

Location		N (%[a])	GM[b]	M ± SD[c]	Range	*P*-value
Korea	Risk area	71 (56.8)	0.76	0.82 ± 0.33	0.27-2.24	.407
	Control area	54 (43.2)	0.69	0.76 ± 0.39	0.29-2.24	
China	Risk area	188 (50.5)	0.16	0.19 ± 0.13	0.04-0.77	.000**
	Control area	184 (49.5)	0.10	0.11 ± 0.06	0.03-0.52	

**$P < 0.01$

[a]Percentage based on total population; [b]Geometric mean; [c]Arithmetic mean ± Arithmetic standard deviation

Table 9. Hair mercury level (μg/g) according to gender.

Location		N (%[a])	GM[b]	M ± SD[c]	Range	*P*-value
Korea	Male	75 (60.0)	0.76	0.82 ± 0.35	0.27-2.24	.297
	Female	50 (40.0)	0.68	0.75 ± 0.36	0.29-2.24	
China	Male	156 (41.9)	0.12	0.15 ± 0.12	0.03-0.77	.400
	Female	216 (58.1)	0.12	0.14 ± 0.10	0.03-0.71	

[a]Percentage based on total population; [b]Geometric mean; [c]Arithmetic mean ± Arithmetic standard deviation

Table 10. Hair mercury level (μg/g) according to age.

Age		N (%[a])	GM[b]	M ± SD[c]	Range	*P*-value
Korea	6-9	41 (32.8)	0.77	0.85 ± 0.39	0.27-2.24	.990
	10-12	30 (24.0)	0.75	0.78 ± 0.21	0.43-1.44	
China	6-9	91 (24.7)	0.17	0.20 ± 0.15	0.04-0.77	.007**
	10-13	95 (25.7)	0.15	0.16 ± 0.10	0.05-0.62	

**$P < 0.01$

[a]Percentage based on total population; [b]Geometric mean; [c]Arithmetic mean ± Arithmetic standard deviation

Table 11. Hair mercury level (μg/g) according to drinking water.

Water type		N (%[a])	GM[b]	M ± SD[c]	Range	*P*-value
Korea	Tap water	37 (36.6)	0.67	0.72 ± 0.27	0.27-1.73	.465
	Purified water	47 (46.5)	0.78	0.85 ± 0.40	0.35-2.24	
	Bottled water	11 (10.9)	0.70	0.78 ± 0.42	0.29-1.67	
	Underground water	–	–	–	–	
	Others	–	–	–	–	
China	Tap water	237 (64.1)	0.12	0.15 ± 0.12	0.03-0.77	.102
	Purified water	–	–	–	–	
	Bottled water	–	–	–	–	
	Underground water	125 (33.8)	0.12	0.13 ± 0.08	0.03-0.52	
	Others	–	–	–	–	

[a]Percentage based on total population; [b]Geometric mean; [c]Arithmetic mean ± Arithmetic standard deviation

dren was 0.12 μg/g (Table 9). In case of age difference, mean concentration level increased with decreased age. The level of children in Korea from 6-9 of age was 0.77 μg/g and that of children from 10-12 of age was 0.75 μg/g. In China, average of children from 6-9 of age was 0.17 μg/g and that of subjects from 10-13 of age was 0.15 μg/g (Table 10). The results of research about age of Chinese subjects showed statistically meaningful difference ($P < 0.01$).

Hair Mercury Level according to Dietary Conditions

Table 11 shows hair mercury levels according to drinking water. Most Korean respondents said that they drank purified water and largest share among the Chinese participants answered they drank tap water. Among the Korean subjects, the level of those who drink tap water recorded 0.67 μg/g while those drinking purified water and bottled water posted 0.78 μg/g and 0.70 μg/g, respectively. As for Chinese students, both groups drinking tap water and underground water recorded 0.12 μg/g. All in all, drinking water has nothing to do with hair mercury level. However, the level in Korean students drinking tap water was 0.67 μg/g, which is 6 times higher compared to the level of Chinese students drinking tap water with 0.12 μg/g. The result seems to be caused by difference in tap water provision conditions and other environmental conditions between the two countries.

Hair mercury levels according to meat intake are presented in Table 12. In Korea, children, who consume an average of 1 serving or less of meat per week, recorded 0.72 μg/g, those eating 2-3 servings per week recorded 0.73 μg/g and those eating 4-6 servings posted 0.82 μg/g. None answered that they ate meat every day. In China, children who consume 1 serving or less a week recorded 0.12 μg/g, those consuming 2-3 servings posted 0.12 μg/g, those eating 4-6 servings

Table 12. Hair mercury level (μg/g) according to meat intake.

		N (%[a])	GM[b]	M ± SD[c]	Range	*P*-value
Korea	Less than 1 serving per week	38 (30.6)	0.72	0.78 ± 0.37	0.40-2.24	.752
	2-3 servings per week	70 (56.5)	0.73	0.79 ± 0.36	0.27-2.24	
	4-6 servings per week	16 (12.9)	0.82	0.86 ± 0.29	0.43-1.46	
	Everyday	–	–	–	–	
China	Less than 1 serving per week	159 (44.7)	0.12	0.13 ± 0.09	0.03-0.52	.001**
	2-3 servings per week	126 (35.4)	0.12	0.14 ± 0.10	0.03-0.75	
	4-6 servings per week	40 (11.2)	0.15	0.18 ± 0.13	0.06-0.71	
	Everyday	31 (8.7)	0.17	0.21 ± 0.19	0.06-0.77	

**$P < 0.01$

[a]Percentage based on total population; [b]Geometric mean; [c]Arithmetic mean ± Arithmetic standard deviation

Table 13. Hair mercury level (μg/g) according to fish preference.

Fish preference		N (%[a])	GM[b]	M ± SD[c]	Range	*P*-value
Korea	Like	89 (71.2)	0.79	0.85 ± 0.38	0.29-2.24	.003**
	Dislike	36 (28.8)	0.61	0.65 ± 0.22	0.27-1.10	
China	Like	293 (82.5)	0.13	0.15 ± 0.12	0.03-0.77	.004**
	Dislike	62 (17.5)	0.11	0.12 ± 0.06	0.04-0.36	

**$P < 0.01$

[a]Percentage based on total population; [b]Geometric mean; [c]Arithmetic mean ± Arithmetic standard deviation

Table 14. Hair mercury level (μg/g) according to fish intake.

	Fish intake	N (%[a])	GM[b]	M ± SD[c]	Range	*P*-value
Korea	None	11 (9.2)	0.59	0.60 ± 0.14	0.33-0.82	.038*
	1 serving or less per week	38 (31.7)	0.67	0.73 ± 0.30	0.29-1.73	
	2-3 servings per week	60 (50.0)	0.78	0.84 ± 0.36	0.27-2.24	
	4-6 servings per week	9 (7.5)	0.91	1.04 ± 0.60	0.60-2.24	
	Every day	2 (1.7)	0.84	0.85 ± 0.15	0.74-0.95	
China	None	113 (35.1)	0.11	0.13 ± 0.09	0.03-0.52	.040*
	1 serving or less per week	161 (50.0)	0.14	0.17 ± 0.12	0.05-0.77	
	2-3 servings per week	38 (11.8)	0.14	0.17 ± 0.15	0.04-0.75	
	4-6 servings per week	8 (2.5)	0.11	0.13 ± 0.12	0.06-0.40	
	Every day	2 (0.6)	0.23	0.24 ± 0.05	0.20-0.28	

*$P < 0.05$

[a]Percentage based on total population; [b]Geometric mean; [c]Arithmetic mean ± Arithmetic standard deviation

of meat posted 0.15 μg/g. Children who consume meat everyday recorded 0.17 μg/g. As meat intake frequency increased, geometric mean concentration of mercury also increased. Chinese subjects showed statistically meaningful difference ($P < 0.01$) while Korean counterparts didn't.

Table 13 shows hair mercury levels according to fish preference. Among Korean subjects, those who like to eat fish posted 0.79 μg/g while those who dislike fish recorded 0.61 μg/g in terms of hair mercury level. As for China, each groups posted 0.13 and 0.11 μg/g, respectively. The study results in case of both Korean and Chinese students indicated statistically meaningful difference ($P < 0.01$).

Table 14 indicates levels according to fish intake. In case of Korean children, those who don't eat fish recorded 0.59 μg/g in terms of hair mercury level. And the group who consume one time serving or less per week recorded 0.67 μg/g, those eating 2-3 servings a week posted 0.78 μg/g, and the group eating 4-6 services of fish posted 0.91 μg/g. And those consuming fish everyday recorded 0.84 μg/g. Among Chinese students, mean hair mercury level of children who don't eat fish stood at 0.11 μg/g and those who consume 1 serving or less per week posted 0.11 μg/g while those eating 2-3 servings recorded 0.14 μg/g. Children eating 4-6 servings of fish recorded 0.11 μg/g and those consuming fish every day posted 0.23 μg/g.

Table 15. Hair mercury level (μg/g) according to passive smoke.

Passive smoke experience		N (%[a])	GM[b]	M ± SD[c]	Range	*P*-value
Korea	Yes	25 (20.0)	0.73	0.83 ± 0.47	0.35-2.24	.649
	No	99 (80.0)	0.73	0.79 ± 0.32	0.27-2.24	
China	Yes	250 (87.4)	0.13	0.15 ± 0.10	0.04-0.77	.861
	No	36 (12.6)	0.11	0.14 ± 0.14	0.03-0.63	

[a]Percentage based on total population; [b]Geometric mean; [c]Arithmetic mean ± Arithmetic standard deviation

Table 16. Hair mercury level (μg/g) according to amalgam filling.

Amalgam filling		N (%[a])	GM[b]	M ± SD[c]	Range	*P*-value
Korea	Yes	50 (40.0)	0.763	0.84 ± 0.42	0.27-2.24	.198
	No	75 (60.0)	0.710	0.76 ± 0.31	0.29-1.73	
China	Yes	21 (6.2)	0.123	0.15 ± 0.12	0.05-0.63	.950
	No	320 (93.8)	0.125	0.15 ± 0.11	0.03-0.77	

[a]Percentage based on total population; [b]Geometric mean; [c]Arithmetic mean ± Arithmetic standard deviation

Table 17. Hair mercury level (μg/g) according to vaccination.

		N (%[a])	GM[b]	M ± SD[c]	Range	*P*-value
Korea	Not within one year	110 (88.7)	0.73	0.79 ± 0.35	0.27-2.24	.260
	3 months ago	5 (4.0)	0.67	0.71 ± 0.26	0.49-1.02	
	One month ago	7 (5.6)	0.76	0.83 ± 0.41	0.43-1.67	
	15 days ago	2 (1.6)	1.20	1.27 ± 0.60	0.85-1.70	
China	Not within one year	321 (95.0)	0.12	0.15 ± 0.11	0.03-0.77	.840
	3 months ago	9 (2.7)	0.13	0.15 ± 0.09	0.06-0.31	
	One month ago	6 (1.8)	0.15	0.19 ± 0.17	0.06-0.51	
	15 days ago	2 (0.6)	0.13	0.13 ± 0.00	0.13-0.13	

[a]Percentage based on total population; [b]Geometric mean; [c]Arithmetic mean ± Arithmetic standard deviation

Intake of fish was found to be related to hair mercury level and the results showed statistically meaningful difference ($P < 0.05$).

Hair Mercury Level according to Passive Smoke

To identify relations between passive smoke and hair mercury level, we were focused on children who had a smoker among their family members. In Korea, geometric mean concentration of mercury of the two groups posted same value of 0.73 μg/g. Among Chinese subjects, those who are exposed to passive smoke recorded 0.13 μg/g, compared to their counterparts of 0.11 μg/g. Accordingly, passive smoke was not related to hair mercury level (Table 15).

Hair Mercury Level according to Amalgam Filling

The level of Korean children who have amalgam dental filling placed within 6 months stood at 0.76 μg/g while the level of the other group in Korea posted 0.71 μg/g. Among Chinese students, both groups recorded 0.12 μg/g.

Hair Mercury Level according to Vaccination

Table 17 shows hair mercury level according to vaccination. As for vaccination, those who received vaccination more than a year ago recorded 0.73 μg/g. And the level of those who got vaccination three months ago recorded 0.67 μg/g. One month after vaccination, the level was 0.76 μg/g and, 15 days after, the level was 1.20 μg/g. In China, those who received vaccination more than a year ago recorded 0.12 μg/g and the level was 0.13 μg/g among those who received vaccination about three months ago. The level of children at one month after receiving injection stood at 0.15 μg/g while the level within 15 days was 0.13 μg/g.

Relations between BMI and Hair Mercury Level

Biological factors such as gender, age, and BMI affect metabolism and concentration of heavy metals in the body. Barbosa[30] reported that evaluation of

Table 18. Correlation between BMI and hair mercury level.

			BMI	Hair mercury level
Korea	Male	BMI	1	
		Hair mercury level	.284*	1
	Female	BMI	1	
		Hair mercury level	−.101	1
	Total	BMI	1	
		Hair mercury level	.195*	1
China	Male	BMI	1	
		Hair mercury level	.195*	
	Female	BMI	1	
		Hair mercury level	−.069	1
	Total	BMI	1	
		Hair mercury level	.061	1

*$P < 0.05$

Table 19. Multiple regression analysis of hair mercury levels for mercury exposure factors.

Variables	Korea		China	
	Regression coefficient	Standard error	Regression coefficient	Standard error
Intercept	−0.864	0.282	−2.216	0.315
Location	−	−	0.471	0.084
Age	−	−	−0.045	0.027
BMI	0.023	0.015	0.009	0.009
Passive smoke	−0.172	0.098	−0.097	0.118
Fish preference	0.239	0.092	0.186	0.117
Fish intake	−	−	0.078	0.096
Vaccination	0.112	0.133	−	−
R-square	0.117 ($P < 0.028$)		0.216 ($P < 0.000$)	

Table 20. Gender distribution of target area.

Country	Area	Male	Female
Korea	Risk area[a]	46	25
	General area[b]	29	25
China	Risk area[c]	66	122
	General area[d]	90	94
Total		231	267

[a]Near the incineration facility in K and P, Korea
[b]Control areas in K and P, Korea
[c]Near the thermal power plant in M, China
[d]Control areas in M, China

Table 21. Conditions of analyzer for hair mercury level.

Condition	
Method	Gold Amalgam Method
Range	0.001-1,000 ng
Moving gas	purified dry air, 0.5 L/min
Sample type	solid
Sample volume	10 mg
Additive	M[a]+S[b]+M+B[c]+M
Heating mode	standard solution mode 1 sample mode 3

[a]M (MHT): sodium hydroxide : calcium carbonate = 1 : 1 (W : W)
[b]S (Sample): sample
[c]B (BHT): aluminum oxide

mercury in hair should be linked to BMI data because biological factors such as BMI helped change toxic heavy metals into a variety of forms within the body. Accordingly, this research collected BMI information about the subjects. Table 21 shows relations between BMI and hair mercury level of 48 Korean participants and 124 Chinese participants, excluding those who didn't record BMI information in the questionnaire. Overall, BMI was found to be closely related to hair mercury levels. In particular, male student groups showed statistically meaningful difference ($P < 0.05$).

To identify factors affecting hair mercury levels in Korean and Chinese primary school students, multiple regression analysis was conducted as seen Table 19. Figure 1 shows relations between measured value and predicted value obtained through the multiple regression analysis results. In case of Korean students, BMI, passive smoke, fish preference and vaccination were the factors affecting hair mercury levels, recording 11.7% of contribution rate. Among Chinese subjects, location, age, BMI, passive smoke fish preference and fish intake were the factors with 21.6% of contribution.

Discussion

The reason behind higher mercury level in Korean children compared to their Chinese counterpart was caused by geographical position. Korea is surrounded by sea, providing Korean subjects with more chances of food intake. Study of Akagi[24], Murata[25] and Ip[22] reported that mercury concentration for residents near seashore was 0.99 μg/g, 1.64 μg/g and 2.20 μg/g, respectively, in their studies. The results are higher than those about residents located away from the seashore. Pesch[26] and Haćˊ[27] reported 0.18 and 0.37 μg/g, respectively in their studies about mercury level for residents located away from the seashore. Korea and China have no guideline for hair mercury level. When adopting the guideline of HBM of Germany, both Korean and Chinese student groups of risk areas posted concentration level below the guideline level of 5 μg/g. According to Agusa[1], the geometric mean concentration of mercury of incineration facilities and

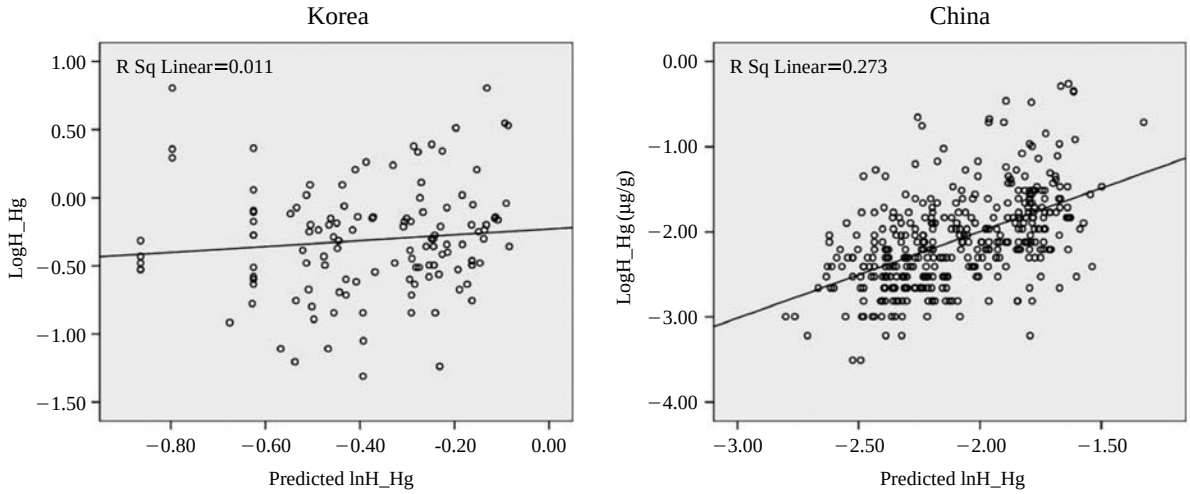

Figure 1. Relations between measured value and predicted value.

fishing village was 2.8 and 2.3 μg/g, respectively. On the other hand, Bose-O'reilly[28] reported that the level of gold mining areas was higher with 2.27 μg/g, compared to the control areas of 1.23 μg/g. Those studies found that incineration facilities and gold mines affect mercury level in children. And according to the results of this research, Korean and Chinese children living near incineration facilities or thermal power plants are also affected by mercury release from the facilities. Akagi[24] conducted a similar research targeting primary school students in the Philippines and found no gender difference. And gender difference did not appear in the study of Kim[10], that of Agusa[1] and that of Olivere[29], which are consistent with the results of this research. Study results of Barbosa[30], Pinheiron[31] and de Sá[32] indicated age was not closely related to the hair mercury levels, with being consistent to the results of our research about Korean students. Pinheiro[9], however, showed that young children were more venerable to mercury exposure. In his study, 65% of the group aged from 2-6 exceeded 10 μg/g, the limits guided by WHO while, among subjects aged from 7-12, only 50% surpassed the level. On the other hand, Yasutake[33], Agusa[1] and Kang[34] found out that hair mercury level increased as age increased. Accordingly, more studies are required to reveal relations between age and mercury level. Björnberget[35] reported in 2003 that chicken meat intake of pregnant women might lead to mercury exposure of fetus. In the study, mercury concentration was found to grow as meat intake increased. However, considering only meat intake frequency is not enough to find out relations between meat intake and mercury level in the body. In the future, further detailed study considering exact amount of meat intake and frequency is required. Among the Korean subjects, the largest share said they ate 2-3 servings of fish per week with securing 50% out of total. As fish intake frequency increases, mercury level increased too. As for China, those eating one serving or less of fish per week accounted for 50% of entire group, securing the largest share. Chinese students have less chance of eating fish due to the geographical characteristic.

Dunn[36], Al-Mafed[37] and Ip[22] respectively reported that hair mercury level increases were mainly caused by fish intake. The studies also indicated that hair mercury level increased as fish intake grew, which is consistent with the results of our research. According to the study of Mcdowell[38], the subjects who didn't eat fish posted 0.08 μg/g in hair mercury level and the level increased to 0.14 μg/g in case of one or two servings and to 0.16 μg/g in case of three servings or more. Akagi[24] also identified that fish intake made a great contribution to increases in hair mercury level. Our research results showed that mean concentration of mercury in hair climbed up according to rises in fish preference and intake, identifying statistically meaningful difference. Mortada[17] conducted a similar study on adults and found out that the level of smokers was 0.25 μg/g while that of nonsmokers was 0.21 μg/g. Batista[39] also provided a consistent result. All in all, smoking has a limited impact on hair mercury level. Mortada[17] compared mercury levels in blood, urine, hair and nails of adults in Egypt and found out that mercury levels increased after having amalgam filling. However, hair mercury level changed from 0.24 μg/g to 0.23 μg/g. In addition, Kim[40] conducted a similar research on subjects aged from 1-15 and found out no significant difference. According to the study of Counter[11] suggested that dental amalgam filling

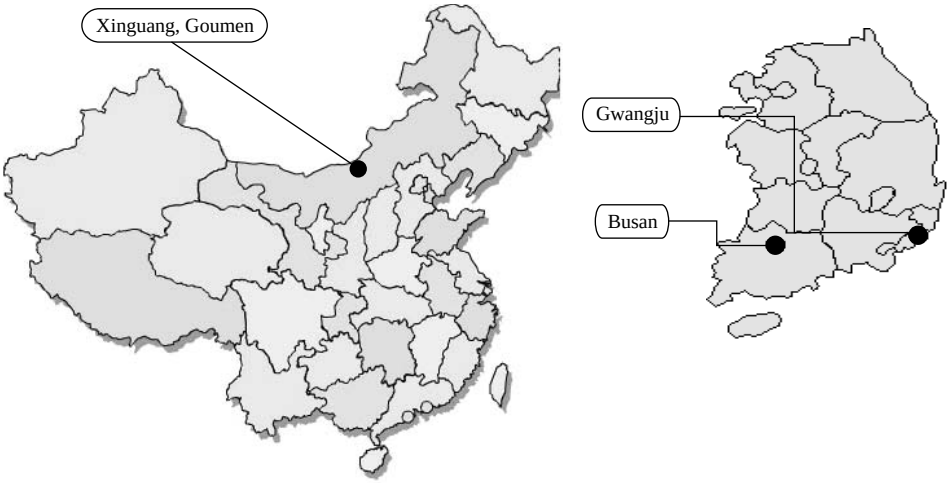

Figure 2. Target areas in Korea and China in this study.

was mostly composed of inorganic mercury and amalgam filling was the main cause of Hg^0 exposure. Mercury concentration in hair refers to organic mercury[26]. Accordingly, to identify mercury exposure caused by amalgam filling, study on mercury levels in urine must be considered, which reflects organic mercury in the body. Both in Korean and Chinese student groups, mercury level reached the highest point about one month after vaccination. Considering that half time of mercury in hair is 65 days[11], mercury which was moved from body to hair reached a peak at about one month after vaccination and declined. Goldman[41] suggested that children were exposed to Ethylmercury within Thimerosal, which was utilized for sterilization and preservation of vaccine. Ethylmercury was known to prevent nerve development and language function while causing autism. EPA of the US banned use of Thimerosal in July 1999 but, in developing countries, use of the chemical is still common[11]. Korea and China are not an exception. According to the study conducted by NIER in 2006, as much as 843.55 μg/L of mercury was contained in the vaccine which is available in the market as of now. And up to 0.42 μg of mercury exposure is expected per one time injection. As children are more sensitive and light-weighted, they are more venerable to mercury-containing vaccine. These studies suggest that Thimerosal use for vaccine must be banned.

Materials and Methods

This study followed 125 primary school students in Korea (Gwangju and Busan) and 373 primary school students in China (Xinguang village, Goumen town) from November 2006 to September 2007. It identifies subjects living in risk areas and the others of control areas. Table 20 shows gender distribution of risk areas and that of control area while Figure 2 shows target areas of the study. In Korea, two waste incineration facilities with annual capacity of 0.1 million were selected as the risk areas. As for China, risk areas were locations near thermal power plants with capacity of 0.2 billion kW while control area were the locations outside of an 80 km radius of the thermal power plants. To identify factors which might affect hair mercury concentration levels, questionnaire was independently developed by NIER (refer to Index) and was answered by parents.

Analysis of Mercury in Hair

For analysis, about 3 g of hair, which was 5 cm away from the scalp skin at occipital region, was taken. As for boys whose hair was short, full-length hair was taken. Hair samples were stored in polyethylene bag, which was stored in desiccators up until the analysis. 2 g was cut from the hair sample and cleaned up with acetone and 2-3% of a neutral detergent. In detail, hairs were washed with 3rd distilled water for two times and then washed with neutral detergent two times. After that, the samples were washed out three times with 3rd distilled water. And then acetone was added for washing. Hair was washed with acetone two times and then was washed with 3rd distilled water two times. Finally, we dried it to a constant weight in a dryer at 105°C and then dried it to room temperature in desiccators. Mercury content was analyzed by Gold Amalgam Method using Mercury Analyzer (SP-3DS, Nippon Instrument Co, Japan). Mercury within the hair sample was evaporated with high temperature. Mercury vapor was collected through gold amalgam collection method and absorbance at 253.7 nm was measured to evaluate concentration. The method is able to quantify mercury amount in sample rapidly

and accurately without wet oxidation.

To construct calibration curve, 0.01% L-cysteine was prepared. Place 3rd distilled water in 1,000 mL flask and 10 mg of L-cysteine and 2 mL of HNO_3 were added. Standard sample was diluted to 50, 100, 150 and 200 ppb to construct calibration curve. As for the hair sample, add MHT into the sample boat. And then prepared sample, MHT, BHT and MHT were added one after another. As for hair sample, exact volume of 10 mg was added and analyzed with automatic analyzer.

Statistical Analysis

To analyze biomarker analysis and questionnaire, SPSS (Ver. 13.0) was utilized. As for concentration distribution, t-test and ANOVA analysis was conducted. Multiple regression analysis was adopted to identify relations of factors affecting mercury level.

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