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Convergent association between socioeconomic status and the blood concentrations of mercury, lead, and cadmium in the Korean adult population: based on the sixth Korea National Health and Nutritional Examination Surveys (KNHANES 2013-2015)

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한국성인의 사회경제적수준과 혈중 중금속 농도의 융합적 분석

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Abstract The purpose of this study was to investigate the association between socioeconomic status and blood heavy metal concentration in Korean adult population using the Korea National Health and Nutritional Examination Survey(KNHANES 2013-2015). Multiple logistic regression analysis was used to determine the association between socioeconomic status and the blood heavy metal concentration. Positive association was found between education and income level and blood concentration of mercury while those of lead and cadmium were negatively associated education and income level in Korean adult population (*P* for trend 〈0.001). At the point of an increase in the prevalence of heavy metal concentrations in the blood, a national public health policy will be needed to address the inequity of health due to socioeconomic factors.

Key Words : Convergence, Mercury, Lead, Cadmium, Heavy metal, SES

요 약 본 연구는 사회경제적 상태의 지표인 교육수준 및 소득수준과 수은, 납, 카드뮴의 혈중 중금속 농도간의 관련성을 살펴보고자 하였다. 국민건강영양조사 2013-2015년 자료를 이용하여 성별에 따른 사회경제적상태와 혈중 중금속 농도간의 관련성을 분석하기 위해 로지스틱회귀분석을 실시하였다. 분석결과 한국성인의 교육과 소득수준이 높을수록 혈중 수은의 농도는 증가하는 경향이 나타났고, 혈중 납과 카드뮴의 농도는 감소하는 경향을 보였다 (*P* for trend 〈0.001). 혈중 중금속 농도의 유병률이 증가하고 있는 시점에서 사회경제적수준에 따른 건강불평등을 해결하기 위한 국가차원의 공중보건학적 정책이 필요할 것으로 사료된다.

주제어 : 융합, 수은, 납, 카드뮴, 중금속, 사회경제적수준

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1. Introduction

Recently, heavy metal contamination in the body has become a serious hazards to health. In Korea, environmental diseases are increasing with the industrial development, mass production of chemicals including heavy metals, and air pollution from the increased traffic. Changes in lifestyle cause higher incidence and mortality of chronic diseases such as cardiovascular disease[1-4]. Increasing the heavy metal concentration in the body causes various diseases. Heavy metals absorbed by the body through various ways such as digestive organs and circulatory organs are mostly excreted. However, it is the portion that are deposited in the tissues and blood, that causes various diseases including hormonal metabolic disorders, high blood pressure, diabetes, cancer, osteoporosis, and kidney disease[5-11]. Mercury is used in many parts of the industry and builds up in the body through the ecosystem food chain. In particular, the mercury concentration in Asian blood is found to be two to three times higher than that of Americans, which was highly associated with the consumption of fish[12,13] and drinking alcohol[14]. Lead and Cadmium that builds up in nerves, kidneys, endocrine systems, genitals and in other areas of the body cause hormonal metabolic disorders, and deposition in the cardiovascular system cause thrombosis and high blood pressure[15]. In particular, blood lead concentration was high among smokers[16] and alcohol drinkers[17-19], and it has been found that air pollution form traffic[20] affects cadmium exposure in children aged 11 to 13 [12,14]. The increase in blood heavy metal concentration is mainly influenced by not only genetics but also environmental factors, and rapid changes in lifestyle are increasing the importance of the environmental factors[6,20]. Research on the effects of socioeconomic conditions on blood heavy metals concentration has been increasing recently[21-24]. Social and economic factors are known to be highly associated with diet, exercise, and health behaviors that affect the concentration of heavy metals in blood[25-28]. Higher the concentration of lead and cadmium in the blood was estimated for people in low socioeconomic status due to poor lifestyle such as smoking and drinking. Many studies have reported that lower socioeconomic level was associated with higher the level of lead and cadmium in the blood, and that higher socioeconomic level was associated with higher blood concentration of mercury[21,22]. A 34 year tracking survey conducted in Alameda County in the U.S. also reported that the lower the socioeconomic status, especially lower the level of education, the higher the blood lead and cadmium concentration[21]. A study conducted in the U.S. showed that blood lead concentration of African American in low education level was higher than American's in high education level, and low-income people's blood lead concentration was higher than high-income people[23]. However, most of the studies involved are mainly from the West, and studies focusing on social and economic conditions for Koreans are lacking.

The purpose of this study was to investigate the association between education and income levels which are the indicators of socioeconomic status (SES) to blood heavy metal concentration such as mercury, lead and cadmium using Korea National Health and Nutritional Examination Surveys (KNHANES).

2. Materials and Methods

2.1 Study Participants

This study was based upon the data obtained in the first, second and third year of Korea National Health and Nutritional Examination Survey (KNHANES) Ⅵ (2013-2015). KNHANES which examined a health examination, a health interview, and a nutrition survey is conducted

annually, using the stratified multistage cluster sampling method that drew on a representative sample of the non-institutionalized civilian population in South Korea. We analyzed the data of (n=7,999) participants over aged 20 years old who completed the nutrition survey and the health examination survey, including blood metal measurements. All the participants in the survey received informed consent.

2.2 Demographic, anthropometric variables and socioeconomic status (SES)

We included age, gender, residence area(urban), physical exercise, alcohol drinking, smoking status as demographic variables and education level, and household monthly income level as socioeconomic indicators during the health interview survey and Waist circumference (WC), Body mass index (BMI) as anthropometric variables. Residence area was divided into two categories; Rural or urban. Rurality of residence is determined by health interview survey. Physical exercise was divided into two groups; non-exercise group, regular exercise group. Regular exercise group means those who exercise more than three times a week and more than 20 minutes for one time. Based on the frequency of monthly alcohol drinking, alcohol intake was classified into three groups; non-drinkers, mild to moderate drinkers, heavy drinkers. Those who drank more than once a month were defined as drinkers and those who drank more than three drinks a day were defined as heavy drinkers. Smoking status was categorized into three groups; non-smokers, ex-smokers, current-smokers. Those who smoked more than five packs for a lifetime defined as smokers. We distinguished ex-smokers from current-smokers based on the present smoking status. Education level was classified into four groups; Elementary school, middle school, high school, and college and higher. And monthly income level was divided into four groups according to quartiles: low, middle low, middle high, high. Waist circumference (WC) was measured at the narrowest point between the lower border of the rib cage and the iliac crest. Body mass index (BMI) was calculated using the following formula: weight (kg) / height^2 (m^2).

2.3 Measurement of Mercury, Lead, and Cadmium

To assess levels of heavy metals in whole blood, 3ml blood samples were obtained from the anticubital vein after the participants have been fastened for eight or more hours to determine the blood level of mercury (Hg), lead (Pb), and cadmium (Cd). Blood samples were processed appropriately, then immediately refrigerated, and transported by cold storage to the Central Testing Institute in Seoul, Korea. Blood samples were analyzed within 24 hours after transportation. Blood lead and cadmium were measured by graphite-furnace atomic absorption spectrometry with Zeeman background correction(Perkin Elmer A Analyst 600; Perkin Elmer, Turku, Finland). Blood total mercury levels were measured using a gold amalgam collection method with a DMA 80 (Milestone, Bergamo, Italy). For internal quality assurance and control, commercial reference materials were used (Lyphochek Whole Blood Metals Control; Bio-Rad, Hercules, CA, USA). The coefficients of variation were within 0.95-4.82 %, 2.65-6.50 %, and 1.59-4.86 % for blood cadmium, lead, and mercury, respectively in four reference samples. As part of external quality assurance and control, the institute passed both the German External Quality Assessment Scheme operated by Friedrich-Alexander University and the Quality Assurance Program operated by the Korea Occupational Safety and Health Agency. The method detection limits for blood cadmium, lead, and mercury in the present study were 0.056 μg/l, 0.12 μg/dl, and 0.158 μg/l, respectively. No sample for blood cadmium, lead, or mercury was the below detection limits.

2.4 Statistical analysis

All analyses were performed using the SAS (Version 9.2; SAS Institute, Cary, NC, USA). One way analysis of variance (ANOVA) was used to investigate the differences in demographic variables according to household income and education levels. A multiple logistic regression analysis was used to confirm the odds ratios (ORs) and 95% confidence intervals (CIs) for the blood level of heavy metal according to each demographic variable. Two-sided P-value 〈0.05 was considered statistically significant.

3. Result and discussion

The general characteristics of study participants according to gender are shown in Table 1. The participants consisted of 7,999 men (49.6%) and 4,033 (50.4%). The average age of men was 44 years old and women was 46 years old. The means of blood mercury, lead, and cadmium concentration for men were 5.93 μg/l, 2.85μg/dl, and 1.06μg/l, respectively and those for women were in 3.91μg/l, 2.08 μg/dl, and 1.24 μg/l, respectively. Men smoked much more and had a higher level of alcohol consumption than women, despite the fact that men exercised more regularly than women. In addition, it was shown that BMI, waist circumference, daily energy intake and fat intake of men were higher than women.

Table 2 represents the characteristics of study participants according to the household income and education level in both genders. Blood lead and cadmium concentrations were inverse proportion to the household income in both genders. However, blood mercury level was proportional to household income in both genders. Most men were current smokers, and the percentage of non-smokers was higher in those with a higher level of household income.

Table 1. General characteristics of study participants according to gender

	Men (n=3,966)	Women (n=4,033)	P^*
Age	44±0.3	46±0.3	〈0.001
Body mass index	24±0.1	23±0.1	〈0.001
Waist circumference	84±0.2	78±0.2	〈0.001
Mercury	5.93±0.12	3.91±0.06	〈0.001
Lead	2.85±0.02	2.08±0.02	〈0.001
Cadmium	1.06±0.01	1.24±0.01	〈0.001
Daily energy intake	2371±20.9	1648±12.6	〈0.001
Daily fat intake	19±0.2	17±0.2	〈0.001
Daily fish intake	88±2.5	51±0.3	〈0.001
Residence areas			0.543
Rural	20.3(1.4)	19.9(1.4)	
Smoking			〈0.001
Non-smoker	23.4(0.8)	90.6(0.6)	
Ex-smoker	29.7(0.9)	3.7(0.4)	
Current-smoker	46.8(0.9)	5.7(0.5)	
Drinking			〈0.001
Non	14.4(0.7)	34.7(1.0)	
Mild to moderate	67.2(0.9)	63.1(1.0)	
Heavy	18.4(0.7)	2.1(0.3)	
Exercise			〈0.001
Yes	27.2(0.8)	21.8(0.8)	
Medical security			0.029
Local medical insurance	38.7(1.0)	38(1.0)	
Job member	59.2(1.0)	58.7(1.0)	
Medicaid	2.1(0.3)	3.3(0.4)	
Commercial health insurance			0.665
Yes	73.1(0.9)	73.6(1.0)	
Public charge			〈0.001
Yes	4.5(0.3)	6.3(0.5)	
House type			0.022
Detached house	39.9(1.3)	40.1(1.4)	
Apartment	35.3(0.7)	35.2(0.8)	
Others	24.8(1.3)	24.7(1.3)	

All values are mean±s.e. or percentage (s.e.).
*Calculated by Student's t-test or Chi-square test.

Most of the participants were mild to moderate drinkers; however, the proportion of non-drinkers was higher in the lower income group in both genders, and a higher percentage of heavy drinkers were men. Apartment Living is the most common in both men and women as income level increased. On the other hand, Detached house Living was increased as income decreased in both genders.

Table 3 demonstrates the characteristics of subjects according to level of education in both genders. According to level of education in both genders, there was similar to the trend of household income.

Table 4 shows the relationship between income level and blood heavy metal concentration according to the demographic characteristics. Higher income people who lived in apartments indicated higher blood mercury concentration. In case of lead and cadmium more people of the high-income class who had higher blood lead and cadmium concentration lived in Detached house. All three metals showed relevance between income level and commercial health insurance. As the income level increased, the number of commercial health insurance subscribers also increased.

Table 5 depicts the ORs for the Heavy metals concentrations across the 4 categories of level of education and household income, using an elementary school or less level of education and the lowest household income as a reference, after controlling the effects of confounding factors on heavy metals concentrations. According to level of education, Among men, the adjusted OR of mercury was 1.86-fold higher in the college and higher than in the reference in model 3. and the adjusted ORs of lead and

Table 2. Characteristics of study participants according to categories of household income

	Men (n=3,966)					Women (n=4,033)				
	Lowest	Medium-lowest	Medium-highest	Highest	P*	Lowest	Medium-lowest	Medium-highest	Highest	P*
Age	54.1±1	43.7±0.5	40.8±0.4	42.3±0.4	<0.001	57.8±0.9	45.8±0.6	41.8±0.5	41.6±0.5	<0.001
Body mass index	23.5±0.2	24±0.1	24±0.1	24.5±0.1	<0.001	24.2±0.2	23.6±0.1	23±0.1	22.5±0.1	<0.001
Waist circumference	83.7±0.5	84.1±0.4	83.9±0.3	85.2±0.3	0.007	81.8±0.5	79±0.4	77±0.3	75.4±0.3	<0.001
Mercury	5.38±0.2	5.26±0.13	5.91±0.24	6.84±0.19	<0.001	3.68±0.13	3.7±0.09	3.99±0.11	4.21±0.09	<0.001
Lead	3.15±0.07	2.94±0.05	2.74±0.05	2.73±0.04	<0.001	2.26±0.05	2.07±0.03	2.02±0.03	2.01±0.06	0.003
Cadmium	1.28±0.04	1.07±0.02	1.02±0.02	0.98±0.02	<0.001	1.45±0.04	1.23±0.02	1.16±0.02	1.16±0.02	<0.001
Daily energy intake	2107.6±56.4	2343.2±42.1	2429.8±37.2	2460.4±36.6	<0.001	1459.7±29.3	1642.4±23.9	1715.1±24.4	1728.5±23.6	<0.001
Daily fat intake	14.8±0.4	18.2±0.4	20±0.3	20±0.3	<0.001	13.8±0.5	16.5±0.3	17.7±0.3	18.5±0.3	<0.001
Daily fish intake	63.8±5	81±4.5	96.3±5.3	98.7±4.6	<0.001	36.2±2.5	48.2±3	55.8±2.8	60±2.7	<0.001
Residence areas					<0.001					<0.001
Rural	27.6(2.9)	21(2)	19.8(1.8)	16.9(1.8)	0.009	28.2(2.7)	20.2(2)	16.5(1.7)	17.5(1.9)	
Smoking										0.089
Non-smoker	20.7(2.1)	20.4(1.5)	24.1(1.5)	26.7(1.4)		88.7(1.6)	89.1(1)	91.6(1)	92.8(0.9)	
Ex-smoker	29.2(2.3)	28.8(1.7)	29.3(1.5)	31.6(1.5)		3.6(0.9)	4.5(0.7)	3.6(0.8)	3.2(0.6)	
Current-smoker	50.1(2.6)	50.8(1.8)	46.7(1.8)	41.8(1.7)		7.6(1.4)	6.5(0.8)	4.8(0.7)	4.1(0.7)	
Drinking					<0.001					<0.001
Non	24.4(2.3)	15.1(1.4)	11.7(1.1)	10.2(1)		49.4(2.7)	36.5(1.9)	28.8(1.7)	27.8(1.6)	
Mild to moderate	58.8(2.6)	63.9(1.9)	71.7(1.5)	70.5(1.5)		47.7(2.7)	62(1.8)	67.9(1.8)	71.4(1.6)	
Heavy	16.8(1.9)	21(1.6)	16.6(1.3)	19.2(1.4)		2.9(0.8)	1.5(0.4)	3.3(0.7)	0.9(0.3)	
Exercise					<0.001					0.857
Yes	19.9(2.1)	27.9(1.7)	26.4(1.5)	31.4(1.6)		21.3(2.1)	21.2(1.5)	22.5(1.5)	22.9(1.6)	
Medical security					<0.001					<0.001
Local medical insurance	41.2(2.6)	44.9(1.8)	37.5(1.8)	32.4(1.7)		41.9(2.5)	41.7(1.8)	40(1.8)	29.2(1.8)	
Job member	48.8(2.6)	52.8(1.8)	62.3(1.8)	67.5(1.7)		45.2(2.5)	56.2(1.8)	59.7(1.8)	70.3(1.8)	
Medicaid	10(1.5)	2.2(0.5)	0.2(0.2)	0.1(0.1)		12.8(1.6)	2.2(0.5)	0.3(0.1)	0.5(0.3)	
Commercial health insurance					<0.001					<0.001
Yes	37.9(2.6)	70.3(1.7)	84.1(1.3)	83.3(1.5)		44.8(2.6)	72.9(1.8)	81.7(1.4)	88.3(1.3)	
Public charge					<0.001					<0.001
Yes	15.1(1.8)	5.9(0.9)	2.1(0.6)	1.5(0.5)		17.5(1.7)	5.6(0.8)	3.1(0.7)	2.2(0.6)	
House type					<0.001					<0.001
Detached house	56.2(2.9)	45.8(2.2)	35(1.9)	31.7(2)		58.3(2.7)	39.4(2.1)	36.9(2.1)	31.1(2.1)	
Apartment	19.3(1.9)	24.4(1.4)	38.6(1.6)	49.7(1.9)		16.9(1.8)	30.4(1.8)	37.3(1.6)	51.3(2)	
Others	24.5(2.6)	29.8(2.1)	26.4(1.9)	18.7(1.6)		24.8(2.3)	30.2(2.1)	25.9(1.9)	17.6(1.7)	

All values are mean±s.e. or percentage (s.e.).
*Calculated by Student's t-test or Chi-square test.

cadmium were 0.57 and 0.56-fold lower in the college and higher than in the reference in model 3 separately. Among women, the adjusted OR of Mercury was 1.47-fold higher in those whose level of education was middle school in model 3. However, no significant association was found between education level and Mercury concentration. The adjusted ORs of lead and cadmium were 0.55 and 0.39-fold lower in the college and higher than in the reference in model 3 separately. Concerning the level of lead and cadmium, are negatively associated higher exposures for lower education level in both genders. According to level of household income, Among men, the adjusted OR of Mercury in model 3 was 1.50-fold greater in those whose level of household income was medium-highest and 2.35-fold greater in those whose level of household income was highest. Among women, the adjusted OR of Mercury in model 3 was

Table 3. Characteristics of study participants according to categories of education level

	Men (n=3,966)					Women (n=4,033)				
	Elementary School or Less	Middle School	High School	College and higher	P^*	Elementary School or Less	Middle School	High School	College and higher	P^*
Age	62.5±0.6	54.7±0.8	38.8±0.4	40±0.3	<0.001	63.9±0.5	51.6±0.6	39.6±0.4	34.4±0.3	<0.001
Body mass index	23.5±0.2	24.1±0.2	24±0.1	24.5±0.1	<0.001	24.6±0.1	24.2±0.2	23±0.1	22±0.1	<0.001
Waist circumference	84.7±0.4	85.8±0.5	83.5±0.3	85±0.3	0.870	83.4±0.4	80.5±0.5	76.6±0.3	73.7±0.3	<0.001
Mercury	3.46±0.08	3.25±0.07	2.78±0.04	2.59±0.03	<0.001	2.38±0.04	2.36±0.05	1.97±0.03	1.8±0.06	<0.001
Lead	5.9±0.41	6.17±0.26	5.35±0.12	6.54±0.16	0.139	3.89±0.13	4.39±0.16	3.98±0.08	3.65±0.09	0.081
Cadmium	1.38±0.04	1.23±0.03	1.02±0.02	0.93±0.02	<0.001	1.54±0.03	1.43±0.04	1.18±0.02	0.92±0.02	<0.001
Daily energy intake	2028.4±49.6	2249.5±49.7	2438.8±34	2452.6±35.1	<0.001	1486.1±22.3	1665.6±37.4	1660.5±21	1777.6±23.7	<0.001
Daily fat intake	13.3±0.4	15.6±0.5	20.1±0.3	20.3±0.3	<0.001	11.9±0.4	14.5±0.4	18.3±0.3	20.6±0.3	<0.001
Daily fish intake	61.8±4.7	75.9±5.8	85.2±3.6	106.1±4.9	<0.001	35.3±2.3	51.4±4.9	56.6±2.2	59.4±2.9	<0.001
Residence areas					<0.001					<0.001
Rural	33.8(3.1)	29.2(2.8)	19.5(1.7)	12.9(1.4)		28.9(2.3)	25.6(3.1)	16.8(1.6)	12.8(1.6)	
Smoking					<0.001					0.001
Non-smoker	14.7(1.9)	16.2(2)	25.1(1.2)	26.9(1.4)		92.2(1.2)	91.7(1.5)	88(1)	91.9(0.9)	
Ex-smoker	39.9(2.6)	38.6(2.6)	25.7(1.3)	28.3(1.4)		2.5(0.6)	1.8(0.8)	4.6(0.6)	4.5(0.8)	
Current-smoker	45.4(2.7)	45.2(2.7)	49.1(1.4)	44.8(1.5)		5.3(1)	6.5(1.3)	7.3(0.9)	3.6(0.6)	
Drinking					<0.001					<0.001
Non	30.1(2.5)	16.5(2)	9.6(0.8)	11.1(1)		54.8(2.2)	32.4(2.7)	26.5(1.4)	25.4(1.6)	
Mild to moderate	50(2.6)	63.8(2.6)	70.8(1.3)	72.5(1.5)		44.4(2.1)	64.6(2.7)	69.9(1.5)	73.4(1.6)	
Heavy	19.9(2.2)	19.7(2.2)	19.6(1.2)	16.4(1.2)		0.7(0.3)	3(1)	3.6(0.6)	1.2(0.4)	
Exercise					<0.001					0.079
Yes	21(2.2)	25.9(2.6)	31.8(1.4)	24.5(1.4)		22.5(1.9)	23.2(2.3)	23.3(1.2)	18.5(1.4)	
Medical security					<0.001					<0.001
Local medical insurance	40(2.7)	45(2.8)	43.2(1.5)	30.5(1.5)		36.2(2)	46.4(3.1)	43(1.6)	30(1.6)	
Job member	55.2(2.7)	50.7(2.9)	55.2(1.5)	68.7(1.5)		57.5(2)	51.3(3.1)	53.8(1.7)	69.2(1.6)	
Medicaid	4.8(1.1)	4.3(1)	1.5(0.4)	0.9(0.3)		6.3(1.1)	2.3(0.7)	3.2(0.5)	0.8(0.3)	
Commercial health insurance					<0.001					<0.001
Yes	45.7(2.8)	62.6(2.8)	75(1.3)	84.3(1.2)		48.3(2.2)	77.7(2.4)	81(1.3)	88.2(1.1)	
Public charge					<0.001					<0.001
Yes	11.1(1.7)	6.3(1.3)	4.5(0.7)	1.8(0.4)		11.2(1.3)	6.8(1.4)	5.6(0.8)	2.4(0.5)	
House type					<0.001					<0.001
Detached house	52.6(3)	52.5(2.9)	40.7(1.8)	29.7(1.7)		53.6(2.2)	45.9(3.2)	34.7(1.8)	31.2(2)	
Apartment	21.3(2)	21.5(2.1)	31.9(1.3)	49.5(1.6)		23.7(1.6)	27(2.3)	38.7(1.4)	45.3(1.7)	
Others	26.2(2.7)	26(2.8)	27.5(1.8)	20.8(1.6)		22.7(1.9)	27.1(2.9)	26.6(1.7)	23.5(1.8)	

All values are mean±s.e. or percentage(s.e.).
*Calculated by Student's t-test or Chi-square test.

1.74-fold greater in those whose level of household income was medium-highest and 2.34-fold greater in those whose level of household income was highest. However, no significant association was found between income level and lead and cadmium concentrations. Concerning the level of lead and cadmium, are negatively associated higher exposures for lower income level in both genders. We also analyzed the effects of other confounding factors on the level of heavy metals. The blood mercury, lead, and cadmium concentration increased with age (people ≥20 aged) in both genders. Current smokers had a higher mercury level than non-smokers(OR, 1.34; 95% C.I., 1.022-1.759) and heavy drinkers had a higher mercury level than non-drinkers in both gender (OR, 2.39; 95% C.I., 1.630-3.496 in men; OR, 3.71; 95% C.I., 1.705-8.073 in women). Weak associations with the dietary habits (fish consumption) were also observed. The adjusted

Table 4. The relationship between household income level and heavy metals concentration according to the demographic factors

	Men					Women				
	Lowest	Medium-lowest	Medium-highest	Highest	P^*	Lowest	Medium-lowest	Medium-highest	Highest	P^*
Mercury										
Medical security					0.009					0.052
Local medical insurance	37.9(2)	41.6(1.8)	35.9(1.8)	39.4(1.9)		34.3(1.9)	39.1(2)	37.2(1.8)	41.8(2.1)	
Job member	58.7(1.9)	56.3(1.8)	62.2(1.8)	59.7(1.9)		61(1.9)	57.7(2)	60.1(1.8)	55.8(2.1)	
Medicaid	3.4(0.6)	2.1(0.5)	1.9(0.4)	0.9(0.3)		4.7(0.9)	3.2(0.8)	2.7(0.6)	2.3(0.7)	
Commercial health insurance					〈0.001					〈0.001
Yes	61.8(2)	75.3(1.6)	76.4(1.6)	79.9(1.6)		64.2(2.2)	73.2(1.9)	80.0(1.6)	77.9(1.7)	
Public charge					0.001					0.669
Yes	7(1.0)	5.3(0.8)	4.4(0.7)	2.4(0.6)		6.7(1)	7.1(1.0)	6.1(0.9)	5.5(1)	
House type					〈0.001					0.003
Detached house	43(2.4)	38.4(2.2)	38.8(2.1)	39.2(2.1)		46.6(2.6)	36.5(2.1)	36.1(2.1)	41(2.3)	
Apartment	27.5(1.6)	36.7(1.7)	37.6(1.7)	40(1.9)		31.1(1.9)	35.7(1.8)	37.7(1.7)	36.4(2.0	
Others	29.5(2.3)	25(2.0	23.5(1.9)	20.7(1.7)		22.3(2.1)	27.8(2.0)	26.2(2.0)	22.6(1.9)	
Lead										
Medical security					0.214					0.130
Local medical insurance	36.3(1.9)	37(1.9)	39.2(1.9)	42.4(1.9)		32.9(1.9)	38.1(2)	40.2(1.9)	40.8(2)	
Job member	61.2(1.9)	61.4(1.9)	58.3(1.9)	55.6(1.9)		63.7(1.9)	58.7(2)	56.5(2)	55.9(2)	
Medicaid	2.5(0.6)	1.6(0.5)	2.4(0.6)	2(0.5)		3.3(0.8)	3.2(0.6)	3.3(0.9)	3.4(0.7)	
Commercial health insurance										0.157
Yes	74.1(1.7)	75.2(1.7)	72.3(1.8)	80.8(1.8)	0.296	74.9(2)	75.4(1.9)	74.5(1.9)	69.9(2)	
Public charge										0.048
Yes	5.6(0.9)	4.1(0.9)	4.4(0.7)	5.1(0.8)	0.572	4(0.8)	7.5(1.2)	6.5(1)	7.2(1)	
House type					〈0.001					〈0.001
Detached house	34.9(2.1)	37.6(2.1)	41.3(2.2)	46.3(2.1)		35.3(2.2)	36.6(2.2)	41.1(2.1)	47.4(2.2)	
Apartment	38.3(1.8)	41(1.7)	32.7(1.6)	28.9(1.6)		41.3(1.8)	37.6(1.8)	34.5(1.7)	27.4(1.6)	
Others	26.8(1.9)	21.4(1.9)	26(2)	24.8(1.9)		23.4(1.9)	25.8(2.1)	24.4(1.7)	25.2(2)	
Cadmium										
Medical security					0.033					0.571
Local medical insurance	36.4(1.9)	37(1.9)	40.5(1.9)	40.8(1.9)		35.1(1.9)	37.5(1.9)	39.2(1.9)	40.4(2)	
Job member	62.2(1.9)	61.3(1.8)	57.2(1.9)	55.9(1.9)		61.6(1.9)	59.7(2)	57.4(2)	56(2.1)	
Medicaid	1.4(0.4)	1.7(0.5)	2.3(0.5)	3.2(0.6)		3.3(0.9)	2.8(0.6)	3.4(0.8)	3.6(0.7)	
Commercial health insurance					0.002					0.001
Yes	75.2(1.7)	76.1(1.6)	73.7(1.7)	67.4(1.8)		79.7(1.7)	73.9(1.9)	73.0(1.9)	68.2(2)	
Public charge					0.016					0.262
Yes	3.3(0.7)	4.1(0.8)	5(0.8)	6.8(1)		6(1.1)	5.3(0.8)	6.1(1)	7.9(1)	
House type					〈0.001					0.157
Detached house	35(2.1)	39.4(2)	38.4(2)	47.1(2.2)		35.6(2.1)	41.3(2.4)	41.3(2.2)	42.2(2.2)	
Apartment	40.3(1.8)	39.1(1.7)	35.4(1.6)	26.4(1.5)		39.6(1.8)	34.3(1.7)	34(1.7)	32.8(1.8)	
Others	24.7(2)	21.6(1.7)	26.2(1.9)	26.5(2)		24.8(2)	24.4(2)	24.8(1.9)	24.9(2)	

All values are mean±s.e. or percentage(s.e.).
*Calculated by Student's t-test or Chi-square test.

OR of fish consumption was 1.001; 95% C.I., 1.001-1.002 in men and the adjusted OR of fish consumption was 1.003; 95% C.I., 1.001-1.004 in women. Finally, Current smokers had a higher lead and cadmium level than non-smokers in both genders and mild to moderate drinkers had a higher lead level than non-drinkers (OR, 1.96; 95% C.I., 1.374-2.805) in men; OR, 1.305; 95% C.I., 1.027-1.659 in women).

This study showed that education and income as indicators of SES were associated with lead, cadmium, and mercury concentration in blood. The blood levels of lead and cadmium were higher when educational levels were lower and the blood concentrations of mercury increased as levels of education were higher in men. It showed that women have a similar trend with men but there was no statistical significance in the case of mercury.

The blood levels of mercury were higher when incomes levels were higher and the blood concentrations of lead and cadmium showed the

Table 5. Odds ratios and 95% confidence intervals of the level of Heavy metals among Korean adults across categories of SES

		Men			Women		
		Mercury	Lead	Cadmium	Mercury	Lead	Cadmium
Model 1[a]							
	Education						
	Elementary school or less	ref			ref		
	Middle school	1.44 (0.99-0.09)	0.92 (0.65-1.30)	1.02 (0.74-1.4)	1.58 (1.12-2.23)	1.16 (0.84-1.61)	0.91 (0.66-1.24)
	High school	1.40 (0.98-2.00)	0.81 (0.6-1.10)	0.77 (0.58-1.03)	1.74 (1.21-2.48)	0.67 (0.49-0.92)	0.77 (0.56-1.05)
	College and higher	2.50 (1.77-3.54)	0.51 (0.37-0.71)	0.51 (0.37-0.68)	1.54 (1.02-2.33)	0.49 (0.34-0.72)	0.39 (0.27-0.58)
	P for trend	〈0.001	〈0.001	〈0.001	0.04	〈0.001	〈0.001
	Household income						
	Lowest	ref			ref		
	Medium-lowest	1.19 (0.82-1.70)	1.20 (0.87-1.65)	0.744 (0.56-0.99)	1.31 (0.96-1.79)	1.05 (0.77-1.44)	1.01 (0.72-1.38)
	Medium-highest	1.72 (1.19-2.47)	0.96 (0.70-1.31)	0.667 (0.5-0.891)	1.86 (1.35-2.55)	1.09 (0.79-1.51)	0.93 (0.69-1.27)
	Highest	2.52 (1.78-3.57)	0.80 (0.58-1.10)	0.624 (0.46-0.84)	2.56 (1.85-3.55)	0.94 (0.68-1.30)	1.03 (0.75-1.41)
	P for trend	〈0.001	0.02	〈0.001	〈0.001	0.75	0.92
Model 2[c]							
	Education						
	Elementary school or less	ref			ref		
	Middle school	1.50 (1.01-2.25)	1.07 (0.74-1.54)	1.01 (0.68-1.45)	1.82 (1.27-2.60)	1.19 (0.84-1.68)	0.89 (0.64-1.24)
	High school	1.50 (1.03-2.18)	0.83 (0.59-1.16)	0.69 (0.49-0.98)	1.74 (1.18-2.57)	0.7 (0.51-1.01)	0.73 (0.53-1.02)
	College and higher	2.44 (1.68-3.56)	0.47 (0.33-0.67)	0.51 (0.35-0.74)	1.77 (1.12-2.79)	0.55 (0.36-0.81)	0.43 (0.29-0.64)
	P for trend	〈0.001	〈0.001	〈0.001	0.02	0.01	0.01
	Household income						
	Lowest	ref			ref		
	Medium-lowest	1.18 (0.80-1.74)	1.14 (0.80-1.63)	0.741 (0.51-1.06)	1.19 (0.86-1.64)	1.04 (0.76-1.43)	1.04 (0.74-1.47)
	Medium-highest	1.65 (1.10-2.45)	0.88 (0.62-1.26)	0.723 (0.51-1.02)	1.88 (1.35-2.62)	1.04 (0.74-1.46)	0.97 (0.70-1.35)
	Highest	2.68 (1.84-3.89)	0.69 (0.48-1.01)	0.667 (0.46-0.95)	2.53 (1.78-3.60)	0.88 (0.63-1.23)	1.09 (0.77-1.54)
	P for trend	〈0.001	0.01	0.05	〈0.001	0.42	0.69
Model 3[c]							
	Education						
	Elementary school or less	ref			ref		
	Middle school	1.41 (0.93-2.14)	1.04 (0.72-1.51)	1.052 (0.72-1.53)	1.47 (1.02-2.11)	1.18 (0.83-1.68)	0.86 (0.61-1.22)
	High school	1.27 (0.86-1.87)	0.88 (0.62-1.24)	0.73 (0.51-1.05)	1.34 (0.89-2.01)	0.72 (0.50-1.02)	0.69 (0.49-0.96)
	College and higher	1.86 (1.25-2.75)	0.57 (0.36-0.75)	0.56 (0.37-0.82)	1.21 (0.76-1.93)	0.55 (0.36-0.84)	0.39 (0.26-0.59)
	P for trend	0.01	〈0.001	0.01	0.50	0.01	〈0.001
	Household income						
	Lowest	ref			ref		
	Medium-lowest	1.14 (0.77-1.69)	1.19 (0.84-1.70)	0.77 (0.53-1.12)	1.11 (0.80-1.55)	1.03 (0.74-1.41)	1.05 (0.75-1.48)
	Medium-highest	1.50 (1.01-2.24)	1.01 (0.70-1.46)	0.825(0.57-1.17)	1.74 (1.24-2.45)	1.07 (0.76-1.51)	1.04 (0.74-1.44)
	Highest	2.35 (1.60-3.43)	0.83 (0.56-1.22)	0.78 (0.54-1.13)	2.34 (1.62-3.37)	0.96 (0.68-1.36)	1.28 (0.91-1.81)
	P for trend	〈0.001	0.10	0.35	〈0.001	0.94	0.13

All values are odds ratios with 95% confidence intervals. [a]Adjusted for age, BMI, residence areas, smoking, drinking, exercise.
[b]Additionally adjusted for daily fish intake
[c]Additionally adjusted education for household income, household income for education
ref(reference)

opposite tendency as compared with mercury in men. It showed that women have a similar trend with men but there was statistical significance in the case of mercury. This result agrees with other studies that have also reported the same results. Low SES was found to be related to high lead and cadmium blood concentrations while higher blood concentrations of mercury was found when the SES is high[21,25,26,29,30]. It is also reported that this tendency of blood level Mercury being high when the SES is high is associated with the consumption of fish [12,13,21,22,31,33]. This agrees with the results from this study, that higher income level and education level is related to higher consumption of fish showing higher mercury concentration in blood. Furthemore, Few studies have examined association between Lead and Cadmium poisoning and the poor lifestyle such as smoking and drinking at low SES [16-20,34]. This study found the Current smokers had a higher lead and cadmium level than non-smokers in both genders. The previous studies showed that the number of smoker and smoking at home were positively correlated with lead and cadmium concentrations in hair[20,34]. This study showed that as income level increased, blood mercury level was higher among people who lived in the apartments and blood lead and cadmium levels were higher among people who lived in the Detached house and this was consistent with the studies that reported SES such as maternal smoking, outdoor activity level of the mother, and quality of their apartments are related to blood lead concentrations[29]. Also in this study, blood cadmium level was higher when the education level was lower. Some studies point out that the blood cadmium level was correlated with maternal education level and teenage children with college graduates have higher levels of cadmium in their blood than those with elementary school graduates[35]. Other study showed that higher maternal education level is associated with consumption of vegetables and that a mother with higher education level consumed more vegetables[35]. In this study however, did not consider relationship between maternal education level and the maternal vegetable dietary so further studies related to maternal education level and maternal vegetable dietary is required.

In this study, it was significant that even if cross-sectional study to infer a cause-and-effect relationship is difficult, it was an opportunity to highlight the importance of socioeconomic health disparities by examining the relevance for the socioeconomic status and blood concentrations of heavy metals, using the Korean National Health and Nutritional Examination Survey.

In conclusion, this study showed that education and income as indicators of socioeconomic status were inversely associated with lead and cadmium concentration, and were linked with higher lead levels in Korean adult population. At the point of an increase in the prevalence of heavy metal concentrations in the blood, it is believed that a national public health policy will be needed to address the inequity of health due to socioeconomic factors.

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