The association between Blood Levels Mercury and Risk for Obesity in a General adult population: Results from the Korean National Health and Nutrition Examination Survey

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감사의 글

배움에 대한 설렘과 기대로 시작한 연세대학원 보건학과 석사과정 생활이 어느덧 졸업을 앞두고 있습니다. 부족하게나마 논문을 완성하고 나서야 학문의 어려움과 부족함을 알게 되었고 앞으로 배워가야 할 것들이 더 많다는 것을 알게 되었습니다. 본 논문을 완성하기 까지 도움을 주신 훌륭한 교수님들, 선배님들, 동기들 덕분에 타지에서의 대학원 생활이 힘들지 않았고 값진 시간을 함께 보낼 수 있었습니다.

논문이 완성될 수 있도록 학문적으로 정성껏 지도해 주시고, 항상 인자하신 모습으로 학생들에게 따뜻한 관심을 보여주시는 노재훈 보건대학원 원장님께 감사 드립니다. 진정한 학자의 모습을 보여주시고 좋은 논문이 될 수 있도록 꼼꼼히 지도해 주신 원종욱 교수님과 많이 부족하고 실수투성인 저를 가장 가까이서 지도하시며 연구적 기틀을 잡아주시고 따끔한 조언을 아끼지 않으셨던 윤진하 교수님, 한결 같은 믿음으로 격려해주시고 뒤에서 묵묵히 지켜보며 산업위생전문가로서의 길을 손수 인도하시는 수고를 아끼지 않으셨던 김치년 교수님께 감사 드립니다. 그리고 산업보건학에 입문하여 부족한 저에게 계속하여 이 길을 걸을 수 있도록 무조건적인 믿음과 기회를 주신 부산 가톨릭 대학교 백종민 교수님, 김기연 교수님께 감사 드립니다. 부족한 저를 많이 예뻐해 주시고 아낌없이 응원해주시며 배움의 여정이 지치지 않도록 물심양면으로 도와주시는 배문주 교수님, 늘 바쁜 생활 중에도 힘들 때 마다 찾아가면 반겨주시고 격려를 아끼지 않으시며 다양한 방면으로 큰 가르침을 주시는 직업환경의학과 이준희 선생님, 석홍덕 선생님, 이완형 선생님, 김영광 선생님에게도 깊은 감사의 마음을 올립니다. 연구소 생활 동안 늘 한결 같은 마음으로 아낌 없는 지원과 관심으로 힘이 되어주신 고옥재 선생님, 방문규 팀장님, 김용표 과장님, 김광희 실장님, 황정호 국장님께도 감사의 말씀을 드립니다.

2년 이라는 시간 동안 연구소에서 생활을 하면서 힘든 출장 일정과 어려운 상황 속에서 희로애락을 함께하며 힘이 되어준 산업보건 연구소 선배·동료 연구원들, 선배 우진 선생님, 항상 웃는 얼굴로 철없는 언니 말을 잘 들어주고 고맙게도 잘 따라주는 하나뿐인 내 동기 솔휘, 한 수 앞을 내다보는 긍정 보이 해안, 든든하고 믿음직한 성훈이, 함께 있어 더 소중한 보건학과 동기 선비, 지혜, 최영 선생에게 감사의 마음을 올립니다.

이 논문을 받고 가장 기뻐하셨을 하늘에 계신 저의 친할머니, 외할머니께 감사 드립니다. 생전에 손녀를 가장 많이 아끼고 예뻐해 주신 그 품을 기억하며 힘든 시간을 이겨낼 수 있게 해 주셔서 감사 드리며, 그 품을 기억하고 간직할 수 있게 해주셔서 감사합니다. 또 오늘이 있게 끝없는 사랑으로 보살펴주시고 항상 올바른 길로 걸어갈 수 있도록 인도하시는 부모님, 바르게 살기 위하여 노력하고 감사한 분들께 보답하는 마음을 잊지 않으려 노력하는 것은 지금까지 올바르게 키워주시려고 끊임없이 노력하신 부모님 덕분이며 감사 드리고 사랑합니다. 그리고 많은 것을 언니이게 양보하고 나보다 더 언니 같은 우리 가족의 활력소, 이 선생 아영에게도 고마움을 전합니다. 마지막으로 항상 한결 같은 마음으로 나를 아껴주고, 옆에서 응원해 주며, 서로 힘든 시기를 잘 이겨낸 너무 소중한 내 친구, 든든한 버팀목이 되어주어 고맙고, 사랑합니다.

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ABSTRACT

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Objective: The rising prevalence of overweight and obesity has been recognized as a serious, worldwide public health concern in the 21st century. Many studies have reported about risk for gain weight according to countless causes of obesity. The primary objective of this study was to estimate association between blood mercury levels and obesity in Korean adults.

Methods: We analyzed cross-sectional data from 9,923 participants (4,619 men and 5,304 women) who completed the Korean National Health and Nutrition Examination Survey (KNHANES), 2007–2013. The population was divided into 2 groups according to body mass index (BMI) and waist circumference (WC). Blood mercury levels were analyzed using a gold amalgam collection method and categorized by interquartiles stratified by sex and occupational status(manual and non-manual workers). The study population was evaluated by Student's t-tests, χ^2 tests and logistic regression.

Results: A multiple logistic regression analysis after adjusting for all covariates showed that blood mercury levels were significantly associated with overweight and abdominal obesity in all subjects. According to BMI criteria, the adjusted odds ratio of being in the highest blood mercury quartile was 1.92 (95% confidence interval [CI], 1.69–2.18) overall, 2.32 (95% CI, 1.93–2.80) in men, and 1.68 (95% CI, 1.42–1.99) in women.

According to WC criteria, the adjusted odds ratio of being in the highest blood mercury quartile was 1.97 (95% CI, 1.61–2.41) in men and 2.01 (95% CI, 1.69–2.40) in women compared with the lowest quartile. Additionally, a linear trend in overweight and abdominal obesity across increasing blood mercury levels was observed by *P* for trend test in multiple diagnostic criteria. After stratification by occupational status, the adjusted odds ratio of being in the highest blood mercury quartile was 2.06 (95% CI, 1.69–2.50) overall manual worker group, 2.42 (95% CI, 1.88–3.13) in men manual workers, and 1.86 (95% CI, 1.39–2.50) in women manual workers based on BMI categorize. According to WC criteria, the adjusted odds ratio of being in the highest blood mercury quartile was 2.07 (95% CI, 1.56–2.74) in men and 2.37 (95% CI, 1.75–3.20) in women compared with the lowest quartile in manual worker group In non-manual worker group, the adjusted odds ratio of being in the highest blood mercury quartile was 1.95 (95% CI, 1.44–2.63) overall non-manual worker group, 3.02 (95% CI, 2.02–4.52) in men, and 1.54 (95% CI, 1.02–2.30) in women based on BMI categorize. According to WC criteria, the adjusted odds ratio of being in the highest blood mercury quartile was 1.93 (95% CI, 1.31–2.86) in men and 2.25 (95% CI, 1.41–3.59) in women compared with the lowest quartile in manual worker group

Conclusion: We found meaningful associations between blood mercury level and weight gain in a dose-dependent manner. Moreover, we attempted to stratify by occupation (manual and non-manual workers), which no study has done previously. A meaningful association of blood mercury and obesity was confirmed in some of these subgroups.

Keywords Mercury · Obesity · Weight gain· Korean National Health and Nutrition Examination Survey

Ⅰ. INTRODUCTION

Obesity has been increasingly recognized as a serious, worldwide public health concern in the 21st century. The rising prevalence of overweight and obesity in several countries has been described as a global pandemic and has not stopped spreading. The number of individuals classified as overweight and obese has dramatically increased globally from 857 million to 2.1 billion individuals over 4 decades.[1] In Organization for Economic Co-operation and Development (OECD) countries, 18.4% of adults are classified as obese.[2]

Many studies in the literature have reported that overweight and obesity are major causes of comorbidities that can lead to further morbidity and mortality including non-communicable diseases such as type 2 diabetes, hypertension, certain types of cancer, heart disease, musculoskeletal disorders, and other leading causes of preventable death.[3-5] Furthermore, obesity can increase the mortality of cardiovascular disease (CVD), which is the leading cause of death in most countries around the world.[6,7] Indeed, a number of deaths are attributable to obesity. In the United States, 14% and 20% of all deaths from cancer in men and women, respectively, are attributable to excess weight or obesity.[5,8] The related annual medical expenditure of governments and individuals is substantial, rising by 209.7 billion dollars for reducing the obesity rate and obesity-related illness.[9] New regulations have been implemented to tackle obesity in the United States, Japan, and the United Kingdom. Considering the public health efforts on obesity, supervision tendency to obesity remains an important problem.[2,10]

A lifestyle of physical inactivity and individual food consumption patterns are known risk factors for obesity.[5] In a number of developing countries, an increasingly westernized lifestyle and diet have been associated with an increased prevalence of obesity.[11] Socioeconomic status (SES) also has a strong effect on the distribution of obesity. Some studies have reported that belonging to a lower SES class was associated with increased general obesity and central obesity.[12]

Environmental risk factors, including heavy metals, air pollution, and traffic-related urban pollution, constitute another cause of weight gain, which is not as well-known but important, and should not be ignored.[13-15] Among various environmental risk factors, especially, heavy metals have accumulated in the earth, because of rapid industrialization and urbanization for the last 3–4 decades. As a result, many toxic heavy metals have gradually redistributed from the earth's crust to the environment, thereby making it impossible for humans to escape the toxic heavy metals released through occupational and other environmental routes. Individuals can be exposed to mercury in the workplace (occupational pathway). For example, workers who handle medical equipment or broken medical equipment, who are involved in the extraction and recovery of mercury, or who work in a chloro-alkali factory might be exposed to mercury. Especially, dentists and others who work in dental clinics are exposed to mercury and in danger of short-term peak exposure.[16] Most people are unaware of their exposure to toxic heavy metals via their environment and daily lifestyle, but interest has been generated in toxic trace elements and their role in the human body.[17,18]

Although there are countless causes of obesity, we focused here on environmental exposure, especially of mercury. Mercury derived from natural and anthropogenic forms is widespread in the environment.[19] Because of mercury's volatile unpredictable behavior at the earth's surface, it acts as one of the complex factors in one of the most scientifically challenging biogeochemical cycles. Due to relatively high vapor pressures, its gas phase is important geochemically.[20] Since the increasing awareness of mercury's impact as an environmental pollutant worldwide, health professionals have made considerable efforts to protect the environment and human health from the release of mercury and its compounds.[21] Despite international action, recent data have proved that mercury concentration in the environment has increased 3-fold compared to pre-condition. [22]

A considerable amount of literature has been published on obesity. These studies have reported that socioeconomic disparities and eating disorders are associated with increased risk of weight gain. However, most studies used only one criterion, such as body mass index (BMI), waist circumference (WC), or waist to hip ratio (WHR) to diagnose obesity.[23,24] In this study, we used both BMI and WC data obtained from the Korean National Health and Nutrition Examination Survey (KNHANES).

Some studies have reported that mercury in human serum leads to weight gain and general or central obesity[7,13,25-27], but the results of previously published studies have been inconsistent, and currently, there is no reliable evidence that high blood mercury levels lead to obesity.

Therefore, the primary objective of this study was to estimate blood mercury concentrations in adults in relation to weight gain evaluated by the diagnostic criteria BMI and WC.

Ⅱ. MATERIALS AND METHODS

1. Design and Data Collection

The KNHANES is a series of nationally representative population-based cross-sectional surveys on health and nutritional status involving a complex, stratified, multistage probability sample of Koreans that have been conducted by the Korea Centers for Disease Control and Prevention (KCDC).[28] The current study used the KNHANES IV–VI (2007–2013) survey data for analysis. From an initial 58,423 men and women, we excluded those younger than 20 years old and those lacking data on age, sex, sociodemographic factors (education level, occupational status, household income, and residential area), or health behavioral factors (smoking status, exercise level, alcohol consumption, total calorie intake, and calorie therapy). We further excluded those missing anthropometric measurements, non-responses for self-reported questionnaires, and missing data or no measurement of blood mercury concentration. All participants provided written informed consent. Ultimately, 9,923 participants (4,619 men and 5,304 women) met the inclusion criteria for this study (Fig. 1). This study was approved by the Institutional Review Board of the Graduate School of Public Health, Yonsei University, Seoul, Korea (2-1040939-AB-N-01-2015-138).

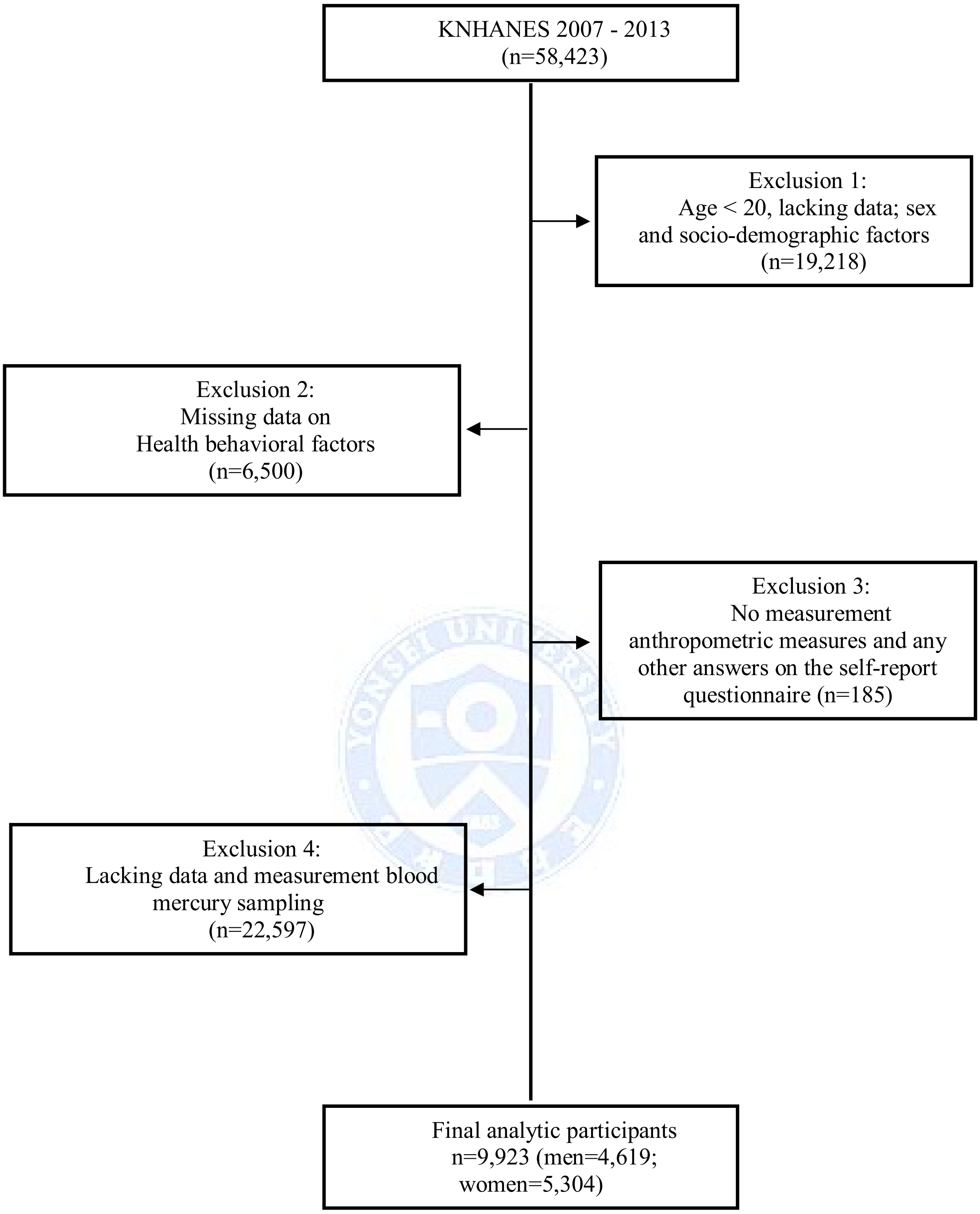

Figure. 1 Selection of study data

2. Obesity Diagnostic Criteria

BMI is usually used to evaluate overweight and obesity and WC to evaluate central obesity. However, there is a clear genetic and ethnic predisposition for obesity.[29] In 2000, the Asia Pacific regional guideline of the World Health Organization (WHO) and International Obesity Task Force (IOTF) proposed alternative criteria of overweight as a BMI of 23.0–24.9 kg/m2 and obesity as a BMI of ≥25.0 kg/m2; ethnically specific WC cutoff points for abdominal obesity were also defined: ≥90 and ≥80 cm for South Asian and Chinese men and women, respectively.[30] Some studies have reported the importance of overweight and overweight-related serious illness including heart disease, cancer, and chronic lower respiratory disease.[31,32]

To evaluate the relationship between blood mercury levels and weight gain in Korean adults, we used the overweight criteria of the WHO and IOTF for an Asian population. Blood mercury concentrations were categorized into quartiles (Q) and stratified by sex.

The anthropometric measures of height, weight, WC, and BMI were obtained by trained technicians. The participants' height was measured with an accuracy of 0.1 cm using a portable SECA stadiometer (Seca GmbH & Co. KG, Hamburg, Germany), with the participants standing up in bare feet. Body weight was measured to the nearest 0.1 kg using an electronic scale (GL-6000-20; CAS Co., Seoul, Korea). WC was measured to the nearest 0.1 cm at the narrowest point between the lowest rib and the uppermost lateral border of the right iliac crest. BMI is defined as a person's weight in kilograms divided by the square of height in meters (kg/m^2).

3. Measurement of Covariates

The covariates we selected were socio-demographic and behavioral factors that could affect obesity. Due to social disparities, people with lower SES, i.e., poor education and working in lower grade occupation are more likely to gain weight.[2,33] Belonging to manual worker group in adulthood was significantly associated with increased general obesity in older women.[34,35] Educational levels were classified as middle school or less, high school, and college or more. Household income was calculated using standardized classification by 5-year age groups and sex, and then the value was compared with the standard income level of Korean civilians. Total household income was divided into 4 categories. Type of residence was categorized into urban and rural areas according to administrative divisions of cities in Korea. Occupational status was categorized as manual, non-manual, or unemployed. Individuals in sales and services, agriculture, forestry, fishery, engineering, assembling, technical work, and manual labor were classified as manual workers. Managers, experts and related workers, and office workers were classified as non-manual workers. Individuals with no job, students, and housewives were classified as unemployed. Smoking status was classified as non-smoker (fewer than 100 cigarettes ever), former smoker (past smoker but not smoking at the time of the survey), and current smoker (currently smoking). Alcohol drinking was differentiated by sex with heavy drinking defined as at least 7 glasses of alcohol on 2 or more occasions per week for men and at least 5 glasses of alcohol on 2 or more occasions per week for women. Exercise activity levels were classified as none, moderate (between none and high), and high (≥20 minutes at least 3 times per week of activity that results in increased respirations). Information on total calorie intake and whether currently calorie therapy or not was obtained using a 24-hour dietary recall questionnaire administered by a trained nutritionist.

4. Analysis of Blood Mercury Concentration

To assess the concentrations of heavy metals in whole blood, 3-mL blood samples were collected in standard commercial evacuated tube containing sodium heparin (Vacutainer). A gold amalgam collection method (DMA 80; Milestone, Sorisole, Italy) was used to measure blood mercury concentrations. Blood mercury analyses were carried out at the Neodin Medical Institute (Seoul, Korea), a central laboratory certified by the Korean Ministry of Health and Welfare. For internal quality assurance and control, commercial reference material was used (Lyphochek® Whole Blood Metals Control; Bio-Rad, Hercules, CA, USA) with coefficients of variation of 1.59–4.86% in 4 reference samples. For external quality assurance and control, Neodin Medical Institute participates in both the German External Quality Assessment Scheme (G-EQUAS) run by Friedrich-Alexander University (Erlangen, Germany), which is a well-known protocol for measuring chemicals at low concentrations, and the Quality Assurance Program run by the Korea Occupational Safety and Health Agency (KOSHA). Neodin Medical Institute is also certified by the Ministry of Employment and Labor as one of the designated laboratories for special chemicals including heavy metals. The detection limit for blood mercury was 0.158 μg/L in the present study.[36]

5. Statistical Analysis

Statistical analyses were performed using SAS statistical software (version 9.4; SAS Institute Inc., Cary, NC, USA). The baseline characteristics of the study population were evaluated by Student's t-tests and $\chi 2$ tests. Because blood mercury levels differed by sex, the quartiles of blood mercury levels were stratified by sex. The association between blood mercury levels and overweight according to BMI and abdominal obesity according to WC were evaluated by 3 different logistic regressions. Subjects in Q1 of blood mercury levels were considered as the reference group for analyses. Model 1 was adjusted only for age. The second set of models added socio-demographic variables. The third set of models added health behavior variables as additional confounders A p-value <0.05 was considered statistically significant level both tail. We also performed p for trend tests to evaluate whether there was a linear trend in the weight gain in adults across increasing blood mercury concentrations.

Ⅲ. RESULTS

1. Basic characteristics of study subjects

Tables 1 and 2 present participant characteristics based on BMI and WC criteria, respectively; 2,911 men (63.0%) and 2,590 women (48.8%) were in the overweight group, and 1,204 men (26.1%) and 2,081 women (39.2%) were in the abdominal obesity group.

Table 1 participant's characteristics of Korean adult population by Body Mass Index (BMI) criteria

	Total (n=9,923)					
	Men (n=4,619)			Women (n=5,304)		
Characters	Normal	Overweight *	P-value †	Normal	Overweight	P-value
N (%)	1,708 (37.0)	2,911 (63.0)	<.0001	2,714 (51.2)	2,590 (48.8)	<.0001
Age(years)	45.7 ± 16.2	46.5 ± 14.5	0.0784	41.2 ± 14.3	50.0 ± 13.9	<.0001
Educational level, n (%)			0.0875			<.0001
Less than Middle school	450 (26.4)	726 (24.9)		600 (22.1)	1,227 (47.4)	
High school	688 (40.3)	1,120 (38.5)		1,026 (37.8)	856 (33.0)	
College and more	570 (33.4)	1,065 (36.6)		1,088 (40.1)	507 (19.6)	
House hold income, n (%)			<.0001			<.0001
1st quartile	296 (17.3)	368 (12.6)		344 (12.7)	561 (21.7)	
2nd quartile	457 (26.8)	739 (25.4)		655 (24.1)	770 (29.7)	
3rd quartile	512 (30.0)	838 (28.8)		806 (29.7)	676 (26.1)	
4th quartile	443 (25.9)	966 (33.2)		909 (33.5)	583 (22.5)	
Occupation, n (%)			<.0001			<.0001
Non-manual	385 (22.5)	849 (29.2)		684 (25.2)	337 (13.0)	
Manual	862 (50.5)	1,430 (49.1)		720 (26.5)	955 (36.9)	
Unemployed	461 (27.0)	632 (21.7)		1,310 (48.3)	1,298 (50.1)	
Residence area, n (%)			0.3570			<.0001
Urban	1,343 (78.6)	2,322 (79.8)		2.271 (83.7)	2,018 (77.9)	
Rural	365 (21.4)	589 (20.2)		443 (16.3)	572 (22.1)	
Smoking status, n (%)			<.0001			0.2130
Non-smoker	397 (23.2)	551 (18.9)		2,381 (87.8)	2,312 (89.3)	
Former smoker	352 (20.6)	757 (26.0)		107 (3.9)	91 (3.5)	
Current smoker	959 (56.2)	1,603 (55.1)		226 (8.3)	187 (7.2)	
Drinking status, n (%)			0.0002			<.0001
Never drink	242 (14.7)	384 (13.2)		803 (29.6)	961 (37.1)	
Moderate drink	1,171 (68.5)	1,874 (64.4)		1,770 (65.2)	1,525 (58.9)	
Heavy drink	295 (17.3)	653 (22.4)		141 (5.2)	104 (4.0)	
Exercise level, n (%)			0.0080			0.7758
None	971 (56.9)	1,555 (53.4)		1,961 (72.3)	1,857 (71.7)	
Moderate	631 (36.9)	1,111 (38.2)		602 (22.2)	595 (22.0)	
High	106 (6.2)	245 (8.4)		151 (5.6)	138 (5.3)	
Calorie intake (kcal/day)	2336.9 ± 954.7	2396.2 ± 951.3	0.0412	1737.6 ± 707.8	1665.7 ± 673.8	0.0002
Diet therapy, n (%)			<.0001			<.0001
Yes	216 (12.6)	713 (24.5)		567 (20.9)	860 (33.2)	
No	1,492 (87.4)	2,198 (75.5)		2,147 (79.1)	1,730 (66.8)	
With diet therapy(n=2,356), n (%)			0.5949			0.6130
<2500 (kcal/day)	148 (68.5)	500 (70.1)		509 (89.8)	785 (91.3)	
<4000 (kcal/day)	55 (25.5)	182 (25.5)		54 (9.5)	69 (8.0)	
≥4000 (kcal/day)	13 (6.0)	31 (4.4)		4 (0.7)	6 (0.7)	
Without diet therapy(n=7,567), n (%)			0.0547			0.0649
<2500 (kcal/day)	960 (64.3)	1,328 (60.4)		1,893 (88.2)	1,559 (90.1)	
<4000 (kcal/day)	447 (30.0)	731 (33.3)		230 (10.7)	161 (9.3)	
≥4000 (kcal/day)	85 (2.7)	139 (6.3)		24 (1.1)	10 (0.6)	
Anthropometric measures						
Height (cm)	170.3 ± 6.6	170.2 ± 6.5	0.5249	158.8 ± 5.9	156.3 ± 5.9	<.0001
Weight (kg)	61.2 ± 6.4	75.40 ± 9.6	<.0001	52.0 ± 5.1	63.6 ± 7.9	<.0001
Waist circumference (cm)	76.7 ± 5.9	88.9 ± 7.1	<.0001	71.2 ± 6.0	84.7 ± 7.8	<.0001
Body mass index (kg/m²)	21.0 ± 1.5	60.0 ± 2.4	<.0001	20.6± 1.6	26.0 ± 2.6	<.0001
Blood mercury (μg/L)						
Mean mercury (μg/L)	4.7 ± 3.1	6.1 ± 4.7	<.0001	3.5 ± 2.4	4.1 ± 2.8	<.0001
Geometric mean mercury (μg/L)	4.0 ± 0.6	4.9 ± 0.7	<.0001	3.0 ± 0.6	3.5 ± 0.6	<.0001

* Overweight was estimated with BMI > 23

† P-value by chi-square test and t-test, p<0.05

Grouped according to BMI criteria, household income, occupational status, drinking status, calorie intake, diet therapy, weight, WC, BMI, and mean blood mercury levels significantly differed in both men and women. Education level, residence area, and height were significant only in women, whereas smoking status and exercise level were significant only in men. Mean blood mercury concentrations were 6.08 μg/L in men and 4.07 μg/L in women.

Table 2 participant's characteristics of Korean adult population by Waist Circumference (WC) criteria

	Total (n=9,923)					
	Men (n=4,619)			Women (n=5,304)		
Characters	Normal	Abdominal obesity *	P-value †	Normal	Abdominal obesity	P-value
N (%)	3,415 (73.9)	1,204 (26.1)	<.0001	3,233 (60.8)	2,081 (39.2)	<.0001
Age(years)	45.2 ± 15.2	50.0 ± 14.6	<.0001	41.3 ± 13.9	52.0 ± 13.9	<.0001
Educational level, n (%)			0.0302			<.0001
Less than Middle school	838 (24.5)	338 (28.1)		730 (22.7)	1,097 (52.7)	
High school	1,367 (40.0)	441 (36.6)		1,237 (38.4)	645 (31.00)	
College and more	1,210 (35.5)	425 (35.3)		1,256 (38.9)	339 (16.3)	
House hold income, n (%)			0.1021			<.0001
1st quartile	490 (14.4)	174 (14.4)		378 (11.7)	527 (25.3)	
2nd quartile	890 (26.1)	306 (25.4)		809 (25.1)	616 (29.6)	
3rd quartile	1,024 (30.0)	326 (27.1)		959 (29.8)	523 (25.1)	
4th quartile	1,011 (29.6)	398 (33.1)		1,077 (33.4)	415 (19.9)	
Occupation, n (%)			0.6520			<.0001
Non-manual	903 (26.4)	331 (27.5)		798 (24.8)	223 (10.7)	
Manual	1,708 (50.0)	584 (48.5)		891 (27.6)	784 (37.7)	
Unemployed	804 (23.5)	289 (24.0)		1,534 (47.6)	1,074 (51.6)	
Residence area, n (%)			0.3074			<.0001
Urban	2,722 (79.7)	943 (78.3)		2,730 (84.7)	1,559 (74.9)	
Rural	693 (20.3)	261 (21.7)		493 (15.3)	522 (25.1)	
Smoking status, n (%)			0.0002			0.2318
Non-smoker	748 (21.9)	200 (16.6)		2,834 (87.9)	1,859 (89.3)	
Former smoker	791 (23.2)	318 (26.4)		130 (4.0)	68 (3.3)	
Current smoker	1,876 (54.9)	686 (57.0)		259 (8.0)	154 (7.4)	
Drinking status, n (%)			<.0001			<.0001
Never drink	456 (13.4)	170 (14.1)		954 (29.6)	810 (38.9)	
Moderate drink	2,312 (67.7)	733 (60.9)		2,106 (65.3)	1,189 (57.1)	
Heavy drink	647 (18.9)	301 (25.0)		163 (5.1)	82 (3.9)	
Exercise level, n (%)			0.0975			<.0001
None	1,836 (53.8)	690 (57.3)		2,252 (69.9)	1,566 (75.2)	
Moderate	1,317 (38.6)	425 (35.3)		777 (24.1)	420 (20.2)	
High	262 (7.7)	89 (7.4)		194 (6.0)	95 (4.6)	
Calorie intake (kcal/day)	2371.2 ± 950.2	2383.0 ± 961.0	0.7113	1728.9 ± 710.9	1661.7 ± 660.5	0.0005
Diet therapy, n (%)			<.0001			<.0001
Yes	619 (18.1)	310 (25.7)		755 (23.4)	672 (32.3)	
No	2,796 (81.9)	894 (74.3)		2,468 (76.6)	1,409 (67.7)	
With diet therapy(n=2,356), n (%)			0.3013			0.7494
<2500 (kcal/day)	427 (69.0)	221 (71.3)		681 (90.2)	613 (91.2)	
<4000 (kcal/day)	158 (25.5)	79 (25.5)		69 (9.1)	54 (8.0)	
≥4000 (kcal/day)	34 (5.5)	10 (3.2)		5 (0.7)	5 (0.7)	
Without diet therapy(n=7,567), n (%)			0.4475			0.1125
<2500 (kcal/day)	1,746 (62.5)	542 (60.6)		2,181 (88.4)	1,271 (90.2)	
<4000 (kcal/day)	887 (31.7)	291 (32.6)		261 (10.6)	130 (9.2)	
≥4000 (kcal/day)	163 (5.8)	61 (6.8)		26 (1.0)	8 (0.6)	
Anthropometric measures						
Height (cm)	169.9 ± 6.5	171.4 ± 6.4	<.0001	158.2 ± 6.0	156.6 ± 5.9	<.0001
Weight (kg)	66.3 ± 8.2	81.0 ± 10.5	<.0001	53.4 ± 5.9	64.4 ± 8.4	<.0001
Waist circumference (cm)	80.5 ± 6.2	95.6 ± 5.4	<.0001	71.5 ± 5.3	87.5 ± 6.3	<.0001
Body mass index (kg/m²)	23.0 ± 2.4	27.5 ± 2.7	<.0001	21.3 ± 2.2	26.2 ± 2.9	<.0001

Table 2 participant's characteristics of Korean adult population by Waist Circumference (WC) criteria

	Total (n=9,923)					
	Men (n=4,619)			Women (n=5,304)		
Characters	Normal	Abdominal obesity *	P-value †	Normal	Abdominal obesity	P-value
Blood mercury (μg/L)						
Mean mercury (μg/L)	5.2 ± 3.8	6.6 ± 5.2	<.0001	3.5 ± 2.2	4.2 ± 3.0	<.0001
Geometric mean mercury (μg/L)	4.3 ± 0.7	5.3 ± 0.7	<.0001	3.0 ± 0.6	3.6 ± 0.6	<.0001

* Abdominal obesity was estimated with WC ≥ 90cm for men and ≥ 80 cm for women
† P-value by chi-square test and t-test, p<0.05

Grouped according to WC cutoff point, there were significant differences in age, education, drinking status, diet therapy, anthropometric measures, and mean blood mercury levels in both men and women. Household income, occupational status, residence area, exercise level, and total calorie intake were significant only in women, whereas smoking status was significant only in men

Tables 3–6 present participant characteristics stratified by occupational status based on categorized BMI and WC. There were 3,967 manual workers (2,292 men and 1,675 women) and 2,255 non-manual workers (1,234 men and 1,021 women).

Table 3 General characteristics for manual workers by Body Mass Index (BMI) criteria

	Manual workers (n= 3,967)					
	Men (n=2,292)			Women (n=1,675)		
Characters	Normal	Overweight *	P-value †	Normal	Overweight	P-value
N (%)	862 (37.6)	1,430 (62.4)	0.0006	720 (43.0)	955 (57.0)	0.0006
Age(years)	47.0 ± 14.4	47.7 ± 13.1	0.2732	46.4 ± 13.0	51.4 ± 11.2	<.0001
Educational level, n (%)			0.8423			<.0001
Less than Middle school	292 (33.9)	489 (34.2)		290 (40.28)	572 (59.90)	
High school	395 (45.8)	639 (44.7)		318 (44.17)	322 (33.72)	
College and more	175 (20.3)	302 (21.1)		112 (15.56)	61 (6.39)	
House hold income, n (%)			0.0060			0.0011
1st quartile	129 (15.0)	153 (10.7)		106 (14.72)	206 (21.57)	
2nd quartile	269 (31.2)	445 (31.1)		218 (30.28)	301 (31.52)	
3rd quartile	267 (31.0)	439 (30.7)		212 (29.44)	248 (25.97)	
4th quartile	197 (22.8)	393 (27.5)		184 (25.56)	200 (20.94)	
Residence area, n (%)			0.5488			0.0107
Urban	609 (70.6)	1,027 (71.8)		520 (72.22)	634 (66.39)	
Rural	253 (29.4)	403 (28.2)		200 (27.78)	321 (33.61)	
Smoking status, n (%)			0.0042			0.4347
Non-smoker	157 (18.2)	254 (17.8)		640 (88.89)	852 (89.21)	
Former smoker	170 (19.7)	367 (25.6)		16 2.22)	29 (3.04)	
Current smoker	535 (62.1)	809 (56.6)		64 (8.89)	74 (7.75)	
Drinking status, n (%)			0.0792			0.0306
Never drink	107 (12.4)	187 (13.1)		217 (30.14)	344 (36.02)	
Moderate drink	582 (67.5)	903 (63.1)		457 (63.47)	563 (58.95)	
Heavy drink	173 (20.1)	340 (23.8)		46 (6.39)	48 (5.03)	
Exercise level, n (%)			0.1322			0.3496
None	477 (55.3)	774 (54.1)		525 (72.92)	681 (71.31)	
Moderate	335 (38.9)	541 (37.9)		158 (21.94)	234 (24.50)	
High	50 (5.8)	115 (8.0)		37 (5.14)	40 (4.19)	
Calorie intake (kcal/day)	2413.8 ± 982.6	2464.9 ± 953.6	0.2193	1701.7 ± 626.9	1678.3 ± 630.0	0.4498
Diet therapy, n (%)			<.0001			<.0001
Yes	82 (9.5)	297 (20.8)		114 (15.8)	266 (27.9)	
No	780(90.5)	1,133 (79.2)		606 (84.2)	689 (72.1)	
With diet therapy (n=759), n (%)			0.1347			0.2560
<2500 (kcal/day)	54 (65.9)	207 (69.7)		105 (92.1)	242 (91.0)	
<4000 (kcal/day)	21 (25.6)	80 (26.9)		8 (7.0)	24 (9.0)	
≥4000 (kcal/day)	7 (8.5)	10 (3.4)		1 (0.9)	0 (0.0)	
Without diet therapy (n=3,208), n (%)			0.1215			0.9234
<2500 (kcal/day)	478 (61.3)	641 (56.6)		546 (90.1)	624 (90.6)	
<4000 (kcal/day)	249 (31.9)	406 (35.8)		57 (9.4)	61 (8.8)	
≥4000 (kcal/day)	53 (6.8)	86 (7.6)		3 (0.5)	4 (0.6)	
Anthropometric measures						
Height (cm)	169.6 ± 6.4	169.7 ± 6.4	0.9263	157.1 ± 6.0	155.9 ± 5.6	<.0001
Weight (kg)	60.6 ± 6.2	74.8 ± 9.2	<.0001	51.68 ± 5.13	63.35 ± 7.55	<.0001
Waist circumference (cm)	76.6 ± 5.7	88.8 ± 6.8	<.0001	72.45 ± 5.81	84.98 ± 7.37	<.0001

Table 3 General characteristics for manual workers by Body Mass Index (BMI) criteria

	Manual workers (n= 3,967)					
	Men (n=2,292)			Women (n=1,675)		
Characters	Normal	Overweight *	P-value †	Normal	Overweight	P-value
Body mass index (kg/m²)	21.0 ± 1.4	25.9 ± 2.3	<.0001	20.93 ± 1.54	26.03 ± 2.48	<.0001
Blood mercury (μg/L)						
Mean mercury (μg/L)	4.8 ± 3.0	6.0 ± 4.5	<.0001	3.81 ± 2.77	4.32 ± 3.19	0.0004
Geometric mean mercury (μg/L)	4.0 ± 0.6	4.9 ± 0.7	<.0001	3.18 ± 0.63	3.63 ± 0.61	<.0001

* Overweight was estimated with BMI > 23

† P-value by chi-square test and t-test, p<0.05

For men manual workers grouped according to BMI category, household income, smoking history, weight, WC, BMI, and blood mercury concentration were significantly higher in the overweight group than in the normal group. Women manual workers in the overweight group were significantly older than those in the normal group. There were also significant differences in the frequency distribution by education level, household income, residential area, alcohol consumption, and anthropometric measures. Additionally, women manual workers in the overweight group had a significantly higher mean and geometric mean level of mercury than those in the normal group (Table 3).

Table 4 General characteristics for non-manual workers by Body Mass Index (BMI) criteria

	Non manual workers (n= 2,255)					
	Men (n=1,234)			Women (n=1,021)		
Characters	Normal	Overweight *	P-value †	Normal	Overweight	P-value
N (%)	385 (31.2)	849 (68.8)	<.0001	684 (67.0)	337 (33.0)	<.0001
Age(years)	39.5 ± 10.9	42.0 ± 10.9	0.0002	33.0 ± 9.0	38.5 ± 10.7	<.0001
Educational level, n (%)			0.1054			<.0001
Less than Middle school	5 (11.3)	29 (3.4)		10 (1.5)	19 (5.6)	
High school	96 (31.1)	213 (25.1)		166 (24.3)	100 (29.7)	
College and more	284 (31.9)	607 (71.5)		508 (74.2)	218 (64.7)	
House hold income, n (%)			0.0027	0.0308		
1st quartile	17 (4.4)	30 (3.5)		23 (3.3)	14 (4.2)	
2nd quartile	69 (17.9)	128 (15.1)		119 (17.4)	76 (22.5)	
3rd quartile	141 (36.6)	245 (28.9)		222 (32.5)	121 (35.9)	
4th quartile	158 (41.1)	446 (52.5)		320 (46.8)	126 (37.4)	
Residence area, n (%)			0.2519			0.0486
Urban	344 (89.4)	739 (87.0)		594 (86.8)	277 (82.2)	
Rural	41 (10.6)	110 (13.0)		90(13.2)	60 (17.8)	
Smoking status, n (%)			0.0008			0.7763
Non-smoker	108 (28.1)	157 (18.5)		605 (88.4)	299 (88.7)	
Former smoker	91 (23.6)	229 (27.0)		32 (4.7)	18 (5.4)	
Current smoker	186 (48.3)	463 (54.5)		47 (6.9)	20 (5.9)	
Drinking status, n (%)			0.0259			0.0361
Never drink	44 (11.4)	80 (9.4)		127 (18.6)	85 (25.2)	
Moderate drink	271 (70.4)	557 (65.6)		523 (76.4)	233 (69.2)	
Heavy drink	70 (18.2)	212 (25.0)		34 (5.0)	19 (5.6)	
Exercise level, n (%)			0.1974			0.0975
None	193 (50.1)	395 (46.5)		479 (70.0)	217 (64.4)	
Moderate	167 (43.4)	375 (44.2)		174 (25.4)	96 (28.5)	
High	25 (6.5)	79 (9.3)		31 (4.6)	24 (7.1)	
Calorie intake (kcal/day)	2459.1 ± 895.5	2463.6 ± 936.4	0.9373	1867.1 ± 819.0	1777.7 ± 718.9	0.0748
Diet therapy, n (%)			<.0001			<.0001
Yes	51 (13.3)	252 (29.7)		175 (25.6)	141 (41.8)	
No	334 (86.7)	597 (70.3)		509 (74.4)	196 (58.2)	
With diet therapy (n=619), n (%)			0.6683			0.6121
<2500 (kcal/day)	33 (64.7)	168 (66.7)		151 (86.3)	124 (88.0)	
<4000 (kcal/day)	14 (27.5)	72 (28.6)		22 (12.6)	14 (9.9)	
≥4000 (kcal/day)	4 (7.8)	12 (4.7)		2 (1.1)	3 (2.1)	
Without diet therapy (n=1,636), n (%)			0.8749			0.4099
<2500 (kcal/day)	199 (59.6)	354 (59.3)		420 (82.5)	168 (85.7)	
<4000 (kcal/day)	116 (34.7)	204 (34.2)		77 (15.1)	26 (13.3)	
≥4000 (kcal/day)	19 (5.7)	39 (6.5)		12 (2.4)	2 (1.0)	
Anthropometric measures						
Height (cm)	172.6 ± 5.5	171.6 ± 6.0	0.0079	160.9 ± 5.5	158.9 ± 5.3	<.0001
Weight (kg)	63.2 ± 5.7	76.7 ± 9.3	<.0001	52.5 ± 5.3	65.2 ± 7.8	<.0001
Waist circumference (cm)	76.7 ± 5.5	88.6 ± 7.1	<.0001	69.2 ± 5.5	82.3 ± 7.2	<.0001

Table 4 General characteristics for non-manual workers by Body Mass Index (BMI) criteria

	Non manual workers (n= 2,255)					
	Men (n=1,234)			Women (n=1,021)		
Characters	Normal	Overweight *	P-value †	Normal	Overweight	P-value
Body mass index (kg/m²)	21.2 ± 1.4	26.0 ± 2.4	<.0001	20.3 ± 1.6	25.8 ± 2.6	<.0001
Blood mercury (μg/L)						
Mean mercury (μg/L)	5.1 ± 2.9	7.0± 5.1	<.0001	3.3 ± 1.8	3.6 ± 2.0	0.0187
Geometric mean mercury (μg/L)	4.4 ± 0.6	5.8 ± 0.7	<.0001	3.0 ± 0.5	3.2 ± 0.5	0.0123

* Overweight was estimated with BMI > 23
† P-value by chi-square test and t-test, p<0.05

In the non-manual worker group, there were significant differences in age, household income, smoking and alcohol status, anthropometric measures, and blood mercury levels in men, and similar to women manual workers, there were significant differences in age, education, household income, residential area, drinking status, anthropometric measures, and blood mercury level, but not in smoking status, exercise level, and total calorie intake in women (Table 4).

Table 5 General characteristics for manual workers by Waist Circumference (WC) criteria

	Manual workers (n= 3,967)					
	Men (n=2,292)			Women (n=1,675)		
Characters	Normal	Abdominal obesity *	P-value †	Normal	Abdominal obesity	P-value
N (%)	1,708 (74.5)	584 (25.5)		891 (53.2)	784 (46.8)	
Age(years)	46.7 ± 13.8	49.5 ± 12.8	<.0001	46.3 ± 12.4	52.6 ± 11.2	<.0001
Educational level, n (%)			0.1116			<.0001
Less than Middle school	564 (33.0)	217 (37.2)		367 (41.2)	495 (63.2)	
High school	791 (46.3)	243 (41.6)		392 (44.0)	248 (31.6)	
College and more	353 (20.7)	124 (21.2)		132 (14.8)	41 (5.2)	
House hold income, n (%)			0.1276			<.0001
1st quartile	213 (12.5)	69 (11.8)		123 (13.8)	189 (24.1)	
2nd quartile	540 (31.6)	174 (29.8)		280 (31.4)	239 (30.5)	
3rd quartile	537 (31.4)	169 (28.9)		256 (28.7)	204 (26.0)	
4th quartile	418 (24.5)	172 (29.5)		232 (26.1)	152 (19.4)	
Residence area, n (%)			0.6829			<.0001
Urban	1,223 (71.6)	413 (70.7)		666 (74.7)	488 (62.2)	
Rural	485 (28.4)	171 (29.3)		225 (25.3)	296 (37.8)	
Smoking status, n (%)			0.0462			0.1872
Non-smoker	323 (18.9)	88 (15.1)		782 (87.8)	710 (90.6)	
Former smoker	384 (22.5)	153 (26.2)		27 (3.0)	18 (2.3)	
Current smoker	1,001 (58.6)	343 (58.7)		82 (9.2)	56 (7.1)	
Drinking status, n (%)			0.0015			0.0358
Never drink	223 (13.1)	71 (12.2)		275 (30.9)	286 (36.5)	
Moderate drink	1,134 (66.4)	351 (60.1)		560 (62.9)	460 (58.7)	
Heavy drink	351 (20.5)	162 (27.7)		56 (6.2)	38 (4.8)	
Exercise level, n (%)			0.5918			0.1886
None	922 (54.0)	329 (56.3)		643 (72.2)	563 (71.8)	
Moderate	660 (38.6)	216 (37.0)		200 (22.5)	192 (24.5)	
High	126 (7.4)	39 (6.7)		48 (5.3)	29 (3.7)	
Calorie intake (kcal/day)	2445.7 ± 962.2	2445.9 ± 972.9	0.9956	1693.4± 625.9	1682.7± 631.9	0.7272
Diet therapy, n (%)			<.0001			<.0001
Yes	244 (14.3)	135 (23.1)		168 (18.9)	212 (27.0)	
No	1,464 (85.7)	449 (76.9)		723 (81.1)	572 (73.0)	
With diet therapy (n=759), n (%)			0.5325			0.3915
<2500 (kcal/day)	168 (68.9)	93 (68.9)		155 (92.3)	192 (90.6)	
<4000 (kcal/day)	63 (25.8)	38 (28.2)		12 (7.1)	20 (9.4)	
≥4000 (kcal/day)	13 (5.4)	4 (2.9)		1 (0.6)	0 (0.0)	
Without diet therapy (n=3,208), n (%)			0.5664			0.7707
<2500 (kcal/day)	866 (59.2)	253 (56.3)		653 (90.3)	517 (90.4)	
<4000 (kcal/day)	494 (33.7)	161 (35.9)		67 (9.3)	51 (8.9)	
≥4000 (kcal/day)	104 (7.1)	35 (7.8)		3 (0.4)	4 (0.7)	
Anthropometric measures						
Height (cm)	169.2 ± 6.4	171.1 ± 6.1	<.0001	156.6 ± 5.9	156.2 ± 5.7	0.1885
Weight (kg)	65.7 ± 8.1	80.6 ± 9.5	<.0001	53.3 ± 5.9	64.0 ± 8.0	<.0001
Waist circumference (cm)	80.5 ± 6.2	95.3 ± 4.9	<.0001	72.7 ± 5.0	87.4 ± 6.0	<.0001

Table 5 General characteristics for manual workers by Waist Circumference (WC) criteria

	Manual workers (n= 3,967)					
	Men (n=2,292)			Women (n=1,675)		
Characters	Normal	Abdominal obesity *	P-value †	Normal	Abdominal obesity	P-value
Body mass index (kg/m²)	22.9 ± 2.4	27.5 ± 2.4	<.0001	21.7 ± 2.1	26.2 ± 2.8	<.0001
Blood mercury (μg/L)						
Mean mercury (μg/L)	5.2 ± 3.6	6.6 ± 4.9	<.0001	3.8 ± 2.6	4.5 ± 3.4	<.0001
Geometric mean mercury (μg/L)	4.3 ± 0.6	5.4 ± 0.7	<.0001	3.2 ± 0.6	3.8 ± 0.6	<.0001

* Abdominal obesity was estimated with WC ≥ 90cm for men and ≥ 80 cm for women
† P-value by chi-square test and t-test, $p<0.05$

For men manual workers grouped according to WC category, there were significant differences in the frequency distribution by smoking and alcohol status between the abdominal obesity and normal groups. Men manual workers in the abdominal obesity group were significantly older and had significantly higher anthropometric measures and mean and geometric mean blood mercury concentrations than those in the normal group, but education level, household income, residential area, exercise level, and total calorie intake were not different. Women manual workers in the abdominal obesity group were significantly older and had significantly higher weight and BMI and blood mercury concentrations than those in the normal group (Table 5).

Table 6 General characteristics for non-manual workers by Waist Circumference (WC) criteria

	Non manual workers (n= 2,255)					
	Men (n=1,234)			Women (n=1,021)		
Characters	Normal	Abdominal obesity *	P-value †	Normal	Abdominal obesity	P-value
N (%)	903 (73.2)	331 (26.8)		798 (78.2)	223 (21.8)	
Age(years)	40.5 ± 10.7	43.1 ± 11.4	0.0003	33.3 ± 9.1	40.0 ± 11.3	<.0001
Educational level, n (%)			0.2070			<.0001
Less than Middle school	21 (2.3)	13 (3.9)		10 (1.3)	19 (8.5)	
High school	221 (24.5)	88 (26.6)		197 (24.7)	69 (31.0)	
College and more	661 (73.2)	230 (69.5)		591 (74.0)	135 (60.5)	
House hold income, n (%)			0.3159			0.0651
1st quartile	32 (3.5)	15 (4.5)		27 (3.4)	10 (4.5)	
2nd quartile	144 (16.0)	53 (16.0)		143 (17.9)	52 (23.3)	
3rd quartile	295 (32.7)	91 (27.5)		263 (33.0)	80 (35.9)	
4th quartile	432 (47.8)	172 (52.0)		365 (45.7)	81 (36.3)	
Residence area, n (%)			0.4930			0.0046
Urban	796 (88.2)	287 (86.7)		694 (87.0)	177 (79.4)	
Rural	107 (11.8)	044 (13.3)		104 (13.0)	46 (20.6)	
Smoking status, n (%)			0.0139			0.7227
Non-smoker	212 (23.5)	053 (16.0)		704 (88.2)	200 (89.7)	
Former smoker	233 (25.8)	087 (26.3)		39 (4.9)	11 (4.9)	
Current smoker	458 (50.7)	191 (57.7)		55 (6.9)	12 (5.4)	
Drinking status, n (%)			0.2569			0.2144
Never drink	90 (10.0)	34 (10.3)		158 (19.8)	54 (24.2)	
Moderate drink	617 (68.3)	211 (63.7)		601 (75.3)	155 (69.5)	
Heavy drink	196 (21.7)	86 (26.0)		39 (4.9)	14 (6.3)	
Exercise level, n (%)			0.3879			0.8048
None	425 (47.1)	163 (49.2)		540 (67.7)	156 (70.0)	
Moderate	406 (45.0)	136 (41.1)		214 (26.8)	56 (25.1)	
High	72 (7.9)	32 (9.7)		44 (5.5)	11 (04.9)	
Calorie intake (kcal/day)	2462.8 ± 941.6	2460.7 ± 873.4	0.9726	1847.7 ± 798.9	1801.4 ± 749.1	0.4384
Diet therapy, n (%)			0.0189			<.0001
Yes	206 (22.8)	97 (29.3)		223 (27.9)	93 (41.7)	
No	697 (77.2)	234 (70.7)		575 (72.1)	130 (58.3)	
With diet therapy (n=619), n (%)			0.2102			0.1318
<2500 (kcal/day)	133 (64.6)	68 (70.1)		192 (86.1)	83 (89.3)	
<4000 (kcal/day)	59 (28.6)	27 (27.8)		29 (13.0)	7 (7.5)	
≥4000 (kcal/day)	14 (6.8)	2 (2.1)		2 (0.9)	3 (3.2)	
Without diet therapy (n=1,636), n (%)			0.6449			0.8815
<2500 (kcal/day)	420 (60.3)	133 (56.9)		478 (83.1)	110 (84.6)	
<4000 (kcal/day)	235 (33.7)	85 (36.3)		85 (14.8)	18 (13.9)	
≥4000 (kcal/day)	42 (6.0)	16 (6.8)		12 (2.1)	2 (1.5)	
Anthropometric measures						
Height (cm)	171.5 ± 5.7	172.9 ± 6.3	0.0004	160.4 ± 5.5	159.7 ± 5.5	0.1155
Weight (kg)	68.6 ± 7.4	83.0 ± 10.3	<.0001	53.7 ± 6.0	67.3 ± 8.5	<.0001
Waist circumference (cm)	81.0 ± 5.9	95.5 ± 5.6	<.0001	69.4 ± 5.4	86.3 ± 5.5	<.0001

Table 6 General characteristics for non-manual workers by Waist Circumference (WC) criteria

	Non manual workers (n= 2,255)					
	Men (n=1,234)			Women (n=1,021)		
Characters	Normal	Abdominal obesity *	P-value †	Normal	Abdominal obesity	P-value
Body mass index (kg/m²)	23.3 ± 2.3	27.7 ± 2.6	<.0001	20.0 ± 2.4	26.4 ± 3.0	<.0001
Blood mercury (μg/L)						
Mean mercury (μg/L)	6.0 ± 4.1	7.5 ± 5.7	<.0001	3.3 ± 1.7	3.9 ± 2.2	0.0001
Geometric mean mercury (μg/L)	5.0 ± 0.6	6.1 ± 0.7	<.0001	2.9 ± 0.5	3.4 ± 0.5	<.0001

* Abdominal obesity was estimated with WC ≥ 90cm for men and ≥ 80 cm for women
† P-value by chi-square test and t-test, $p<0.05$

In men non-manual workers, there were significant differences in age, smoking status, anthropometric measures, and blood mercury concentration. In women non-manual workers, there were significant differences between the abdominal obesity and normal group in age, education level, residential area, weight, WC, BMI, and blood mercury level. Unlike women manual workers, there were no significant differences in household income or alcohol status in the non-manual worker group (Table 6).

2. Odds ratio of obesity by based on BMI and WC value according to increasing blood mercury quartiles (general population)

Tables 7 and 8 present the results of logistic regression analyses based on BMI and WC in general population

Table 7. Results of unadjusted and adjusted odds ratio (95% CI) assess to relationship between blood mercury level and overweight using logistic regressions

	Blood mercury level category				P for trend
	1st quartile	2nd quartile	3rd quartile	4th quartile	
OVER ALL					
Range of blood mercury	< 2.49 μg/L	2.49 - 3.68 μg/L	3.68 - 5.56 μg/L	5.56 μg/L ≤	
Subjects (n=9,923)	2,473	2,466	2,493	2,491	
Overweight† [n(%)]	1,120 (20.36)	1,240 (22.54)	1,466 (26.65)	1,675 (30.45)	
Odds ratio (95% CI)					
Unadjusted	1.00	1.22* (1.09 - 1.36)	1.72** (1.54 - 1.93)	2.48** (2.21 - 2.78)	<.0001
Model 1	1.00	1.15* (1.03 - 1.29)	1.52** (1.35 - 1.70)	1.93** (1.71 - 2.17)	<.0001
Model 2	1.00	1.16* (1.03 - 1.30)	1.53** (1.36 - 1.72)	1.96** (1.73 - 2.22)	<.0001
Model 3	1.00	1.14* (1.01 - 1.28)	1.52** (1.35 - 1.71)	1.92** (1.69 - 2.18)	<.0001
MEN					
Range of blood mercury	< 3.00 μg/L	3.00 - 4.48 μg/L	4.48 - 6.78 μg/L	6.78 μg/L ≤	
Subjects (n=4,619)	1,154	1,148	1,161	1,156	
Overweight† [n(%)]	602 (20.68)	687 (23.60)	759 (26.07)	863 (29.65)	
Odds ratio (95% CI)					
Unadjusted	1.00	1.36* (1.15 - 1.61)	1.73** (1.46 - 2.04)	2.70** (2.26 - 3.22)	<.0001
Model 1	1.00	1.36* (1.15 - 1.61)	1.72** (1.46 - 2.04)	2.69** (2.25 - 3.21)	<.0001
Model 2	1.00	1.32* (1.12 - 1.56)	1.61** (1.36 - 1.91)	2.44** (2.03 - 2.93)	<.0001
Model 3	1.00	1.27* (1.08 - 1.51)	1.57** (1.32 - 1.86)	2.32** (1.93 - 2.80)	<.0001

Table 7. Results of unadjusted and adjusted odds ratio (95% CI) assess to relationship between blood mercury level and overweight using logistic regressions

	Blood mercury level category				P for trend
	1st quartile	2nd quartile	3rd quartile	4th quartile	
WOMEN					
Range of blood mercury	< 2.21 μg/L	2.21 - 3.16 μg/L	3.16 - 4.55 μg/L	4.55 μg/L ≤	
Subjects (n=5,304)	1,307	1,342	1,326	1,329	
Overweight† [n(%)]	540 (20.85)	614 (23.71)	679 (26.22)	757 (29.23)	
Odds ratio (95% CI)					
Unadjusted	1.00	1.19* (1.02 - 1.39)	1.49** (1.27 - 1.73)	1.88** (1.61 - 2.19)	<.0001
Model 1	1.00	1.21* (1.03 - 1.43)	1.47** (1.25 - 1.73)	1.63** (1.39 - 1.92)	<.0001
Model 2	1.00	1.26* (1.07 - 1.48)	1.53** (1.30 - 1.81)	1.70** (1.44 - 2.01)	<.0001
Model 3	1.00	1.24* (1.05 - 1.47)	1.52** (1.29 - 1.80)	1.68** (1.42 - 1.99)	<.0001

Model 1 adjusted for age

Model 2: Model 1 plus adjusted for sociodemographic factors (education, occupation, house hold income, and residence).

Model 3: Model 2 plus adjusted for health behavioral factors (smoking, alcohol drinking, and exercise level and calorie intake & therapy).

* $p<0.05$

** $p < .0001$

† Overweight was estimated with BMI > 23

Table 7 presents the relation between blood mercury levels and overweight based on BMI using logistic regression with different models. Fully adjusted for age, socio-demographic factors, and health behavioral factors, the odds ratio (OR) (95% confidence interval [CI]) for the highest vs. reference blood mercury level was 1.92 (1.69–2.18) in the overall general population, 2.32 (1.93–2.80) in men, and 1.68 (1.42–1.99) in women. In all models, a linear trend in overweight in adults across increasing blood mercury levels was revealed by a p for trend test (p-trend < 0.0001).

Table 8. Results of unadjusted and adjusted odds ratio (95% CI) assess to relationship between blood mercury level and abdominal obesity using logistic regressions

	Blood mercury level category				P for trend
	1st quartile	2nd quartile	3rd quartile	4th quartile	
MEN					
Range of blood mercury	< 3.00 μg/L	3.00 - 4.48 μg/L	4.48 - 6.78 μg/L	6.78 μg/L ≤	
Subjects (n=4,619)	1,154	1,153	1,157	1,155	
Abdominal Obesity † [n(%)]	213 (17.69)	295 (24.50)	299 (24.83)	397 (32.97)	
Odds ratio (95% CI)					
Unadjusted	1.00	1.51** (1.24 - 1.85)	1.54** (1.26 - 1.87)	2.31** (1.91 - 2.80)	<.0001
Model 1	1.00	1.50** (1.23 - 1.84)	1.49** (1.22 - 1.83)	2.17** (1.79 - 2.63)	<.0001
Model 2	1.00	1.49** (1.22 - 1.82)	1.47* (1.20 - 1.80)	2.11** (1.72 - 2.57)	<.0001
Model 3	1.00	1.45* (1.18 - 1.78)	1.41* (1.14 - 1.73)	1.97** (1.61 - 2.41)	<.0001
WOMEN					
Range of blood mercury	< 2.21 μg/L	2.21 - 3.16 μg/L	3.16 - 4.55 μg/L	4.55 μg/L ≤	
Subjects (n=5,304)	1,324	1,331	1,323	1,326	
Abdominal Obesity † [n(%)]	403 (19.37)	486 (23.35)	550 (26.43)	642 (30.85)	
Odds ratio (95% CI)					
Unadjusted	1.00	1.31* (1.11 - 1.54)	1.62** (1.38 - 1.90)	2.14** (1.82 - 2.51)	<.0001
Model 1	1.00	1.38* (1.16 - 1.65)	1.67** (1.40 - 1.98)	1.90** (1.60 - 2.25)	<.0001
Model 2	1.00	1.46** (1.22 - 1.74)	1.78** (1.49 - 2.12)	2.02** (1.69 - 2.40)	<.0001
Model 3	1.00	1.45** (1.21 - 1.73)	1.78** (1.49 - 2.12)	2.01** (1.69 - 2.40)	<.0001

Model 1 adjusted for age

Model 2: Model 1 plus adjusted for sociodemographic factors (education, occupation, house hold income, and residence).

Model 3: Model 2 plus adjusted for health behavioral factors (smoking, alcohol drinking, and exercise level and calorie intake and diet therapy).

* p<0.05

** p < .0001

† Abdominal obesity was estimated with WC ≥ 90cm for men and ≥ 80 cm for women

The results of logistic regression analyses based on WC are shown in Table 8. Fully adjusted, the association between blood mercury levels and abdominal obesity also did not dwindle, the OR (95% CI) for the highest vs. reference blood mercury level was 1.97 (1.61–2.41) in men and 2.01 (1.69–2.40) in women. Similarly, based on BMI, a linear trend in obesity in adults across increasing blood mercury levels was revealed by a p for trend test in all models (p-trend < 0.0001).

3. Odds ratio of obesity by based on BMI and WC value according to increasing blood mercury quartiles stratified by occupational status and gender

Tables 9, 11 and Figures 2, 3 present the results of logistic regression analyses based on BMI and WC categorized by occupational status and gender.

Table 9. Results of unadjusted and adjusted odds ratio (95% CI) assess to relationship between blood mercury level and overweight using logistic regressions (manual workers)

	Blood mercury level category				
	1st quartile	2nd quartile	3rd quartile	4th quartile	P for trend
OVER ALL					
Range of blood mercury	< 2.67 μg/L	2.67 - 4.03 μg/L	4.03 - 5.94 μg/L	5.94 μg/L ≤	
Subjects (n=3,967)	987	995	992	993	
Overweight† [n(%)]	495 (20.75)	582 (24.40)	623 (26.12)	685 (28.72)	
Odds ratio (95% CI)					
Unadjusted	1.00	1.40* (1.17 - 1.67)	1.67** (1.40 - 2.00)	2.21** (1.84 - 2.65)	<.0001
Model 1	1.00	1.37* (1.14 - 1.64)	1.61** (1.34 - 1.94)	2.06** (1.70 - 2.49)	<.0001
Model 2	1.00	1.37* (1.15 - 1.65)	1.61** (1.34 - 1.93)	2.07** (1.71 - 2.50)	<.0001
Model 3	1.00	1.39* (1.16 - 1.67)	1.63** (1.35 - 1.96)	2.06** (1.69 - 2.50)	<.0001
MEN					
Range of blood mercury	< 3.08 μg/L	3.08 - 4.52 μg/L	4.52 - 6.69 μg/L	6.69 μg/L ≤	
Subjects (n=2,292)	571	569	576	576	
Overweight† [n(%)]	295 (20.63)	350 (24.48)	364 (25.45)	421 (29.44)	
Odds ratio (95% CI)					
Unadjusted	1.00	1.49* (1.18 - 1.89)	1.60* (1.26 - 2.03)	2.54** (1.98 - 3.25)	<.0001
Model 1	1.00	1.49* (1.18 - 1.89)	1.60** (1.26 - 2.03)	2.53** (1.97 - 3.24)	<.0001
Model 2	1.00	1.49* (1.18 - 1.89)	1.57* (1.24 - 2.00)	2.47** (1.92 - 3.17)	<.0001
Model 3	1.00	1.45* (1.14 - 1.85)	1.54* (1.21 - 1.97)	2.42** (1.88 - 3.13)	<.0001

Table 9. Results of unadjusted and adjusted odds ratio (95% CI) assess to relationship between blood mercury level and overweight using logistic regressions (manual workers)

	Blood mercury level category				
	1st quartile	2nd quartile	3rd quartile	4th quartile	P for trend
WOMEN					
Range of blood mercury	< 2.30 μg/L	2.30 -3.37 μg/L	3.37 -5.00 μg/L	5.00 μg/L ≤	
Subjects (n=1,675)	414	423	419	419	
Overweight† [n(%)]	196 (20.52)	241 (25.24)	254 (26.60)	264 (27.64)	
Odds ratio (95% CI)					
Unadjusted	1.00	1.47* (1.12 - 1.93)	1.71* (1.30 - 2.25)	1.89** (1.43 - 2.49)	<.0001
Model 1	1.00	1.47* (1.11 - 1.95)	1.69* (1.27 - 2.23)	1.86** (1.40 - 2.46)	<.0001
Model 2	1.00	1.49* (1.12 - 1.97)	1.69* (1.27 - 2.25)	1.85** (1.39 - 2.47)	<.0001
Model 3	1.00	1.50* (1.12 - 1.99)	1.73* (1.29 - 2.31)	1.86** (1.39 - 2.50)	<.0001

Model 1 adjusted for age

Model 2: Model 1 plus adjusted for sociodemographic factors (education, house hold income, and residence).

Model 3: Model 2 plus adjusted for health behavioral factors (smoking, alcohol drinking, and exercise level and calorie intake and diet therapy).

* p<0.05

** p < .0001

† Overweight was estimated with BMI > 23

Table 9 presents the relation between blood mercury levels and overweight based on BMI using logistic regression with different models in the manual worker group. Fully adjusted for age, socio-demographic factors, and health behavioral factors, the OR (95% CI) for the highest vs. reference blood mercury level was 2.06 (1.69–2.50) in the overall manual worker group, 2.42 (1.88–3.13) in men manual workers, and 1.86 (1.39–2.50) in women manual workers. In all models, a linear trend in overweight in adults across increasing blood mercury levels was revealed by a p for trend test (p-trend < 0.0001).

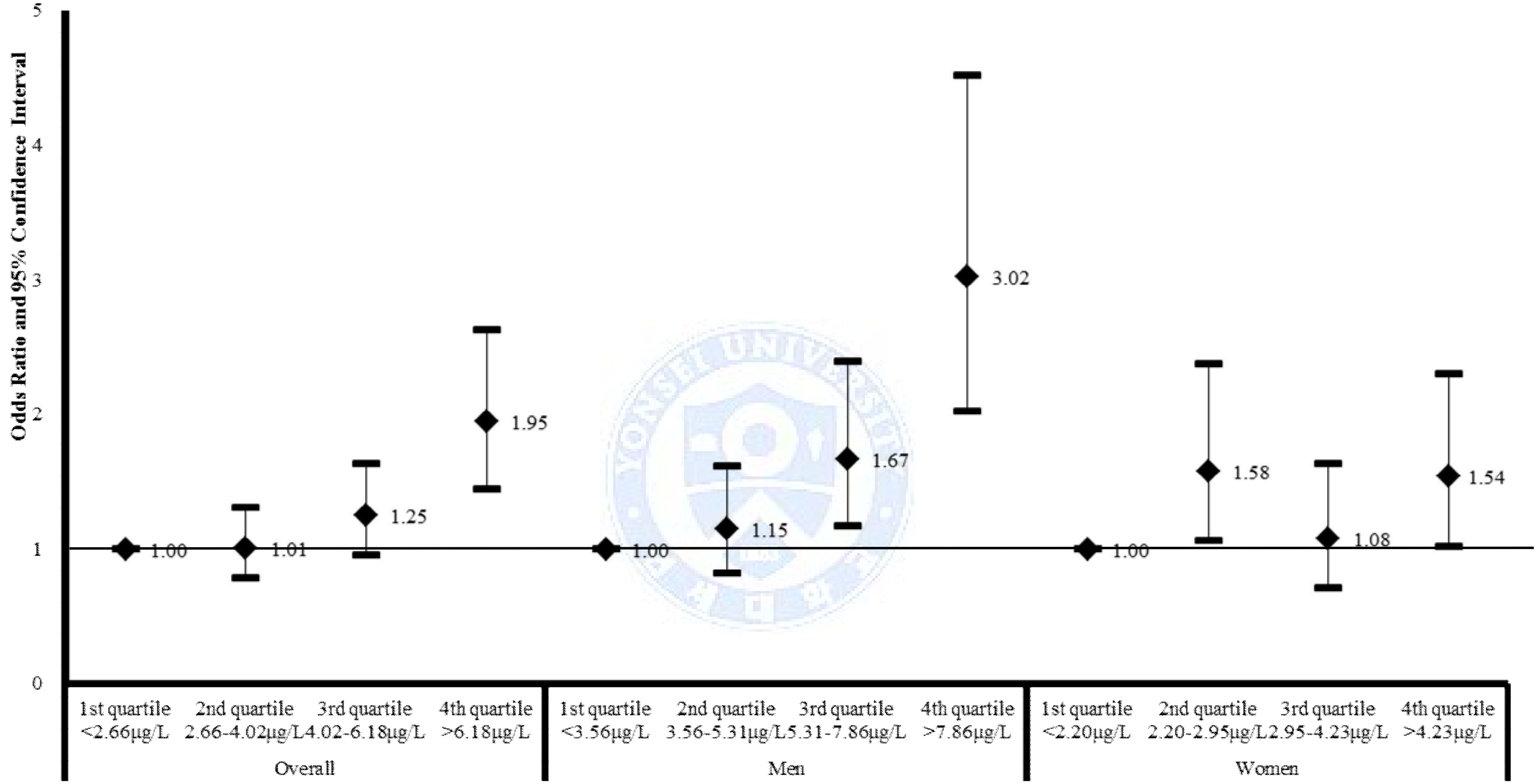

Figure 2 Odds ratio for overweight based on BMI criteria (Non-manual workers)

Figure 2 presents the relation between blood mercury levels and overweight based on BMI using logistic regression with different models in the non-manual worker group. Fully adjusted for age, socio-demographic factors, and health behavioral factors, the OR (95% CI) for the highest vs. reference blood mercury level was 1.95 (1.44–2.63) in the overall non-manual worker group, 3.02 (2.02–4.52) in men non-manual workers, and 1.54 (1.02–2.30) in women non-manual workers (but only Q2 and Q4 were significant). In all models, a linear trend in overweight in adults across increasing blood mercury levels was revealed by a p for trend test (p-trend < 0.0001).

Table 11. Results of unadjusted and adjusted odds ratio (95% CI) assess to relationship between blood mercury level and abdominal obesity using logistic regressions (manual workers)

Manual worker	Blood mercury level category				P for trend
	1st quartile	2nd quartile	3rd quartile	4th quartile	
MEN					
Range of blood mercury	< 3.08 μg/L	3.08 - 4.52 μg/L	4.52 - 6.69 μg/L	6.69 μg/L ≤	
Subjects (n=2,292)	571	569	576	576	
Abdominal Obesity † [n(%)]	104 (17.81)	134 (22.95)	145 (24.83)	201 (34.42)	
Odds ratio (95% CI)					
Unadjusted	1.00	1.38* (1.03 - 1.84)	1.51* (1.13 - 2.00)	2.40** (1.83 - 3.16)	<.0001
Model 1	1.00	1.37* (1.02 - 1.82)	1.47* (1.11 - 1.96)	2.29** (1.74 - 3.02)	<.0001
Model 2	1.00	1.36* (1.02 - 1.82)	1.45* (1.09 - 1.93)	2.24** (1.70 - 2.95)	<.0001
Model 3	1.00	1.31 (0.98 - 1.75)	1.35* (1.01 - 1.81)	2.07** (1.56 - 2.74)	<.0001
WOMEN					
Range of blood mercury	< 2.30 μg/L	2.30 - 3.37 μg/L	3.37 - 5.00 μg/L	5.00 μg/L ≤	
Subjects (n=1,675)	414	423	419	419	
Abdominal Obesity † [n(%)]	142 (18.11)	190 (24.23)	220 (28.06)	232 (29.59)	
Odds ratio (95% CI)					
Unadjusted	1.00	1.56* (1.18 - 2.06)	2.11** (1.60 - 2.79)	2.37** (1.79 - 3.14)	<.0001
Model 1	1.00	1.61* (1.20 - 2.15)	2.16** (1.62 - 2.90)	2.43** (1.81 - 3.25)	<.0001
Model 2	1.00	1.65* (1.23 - 2.21)	2.19** (1.63 - 2.94)	2.37** (1.76 - 3.18)	<.0001
Model 3	1.00	1.65* (1.23 - 2.22)	2.21** (1.64 - 2.98)	2.37** (1.75 - 3.20)	<.0001

Model 1 adjusted for age

Model 2: Model 1 plus adjusted for sociodemographic factors (education, house hold income, and residence).

Model 3: Model 2 plus adjusted for health behavioral factors (smoking, alcohol drinking, and exercise level and calorie intake and diet therapy).

* p<0.05

** p < .0001

† Abdominal obesity was estimated with WC ≥ 90cm for men and ≥ 80 cm for women

The results of logistic regression analyses based on WC are shown in Table 11. Though, fully adjustment, the association between blood mercury levels and abdominal obesity also did not dwindle both sex in manual worker group, the OR (95% CI) for the highest vs. reference blood mercury level was 2.07 (1.56–2.74) in men manual workers and 2.37 (1.75–3.20) in women manual workers. Similarly, based on BMI, a linear trend in obesity in adults across increasing blood mercury levels was revealed by a p for trend test in all models (p-trend < 0.0001).

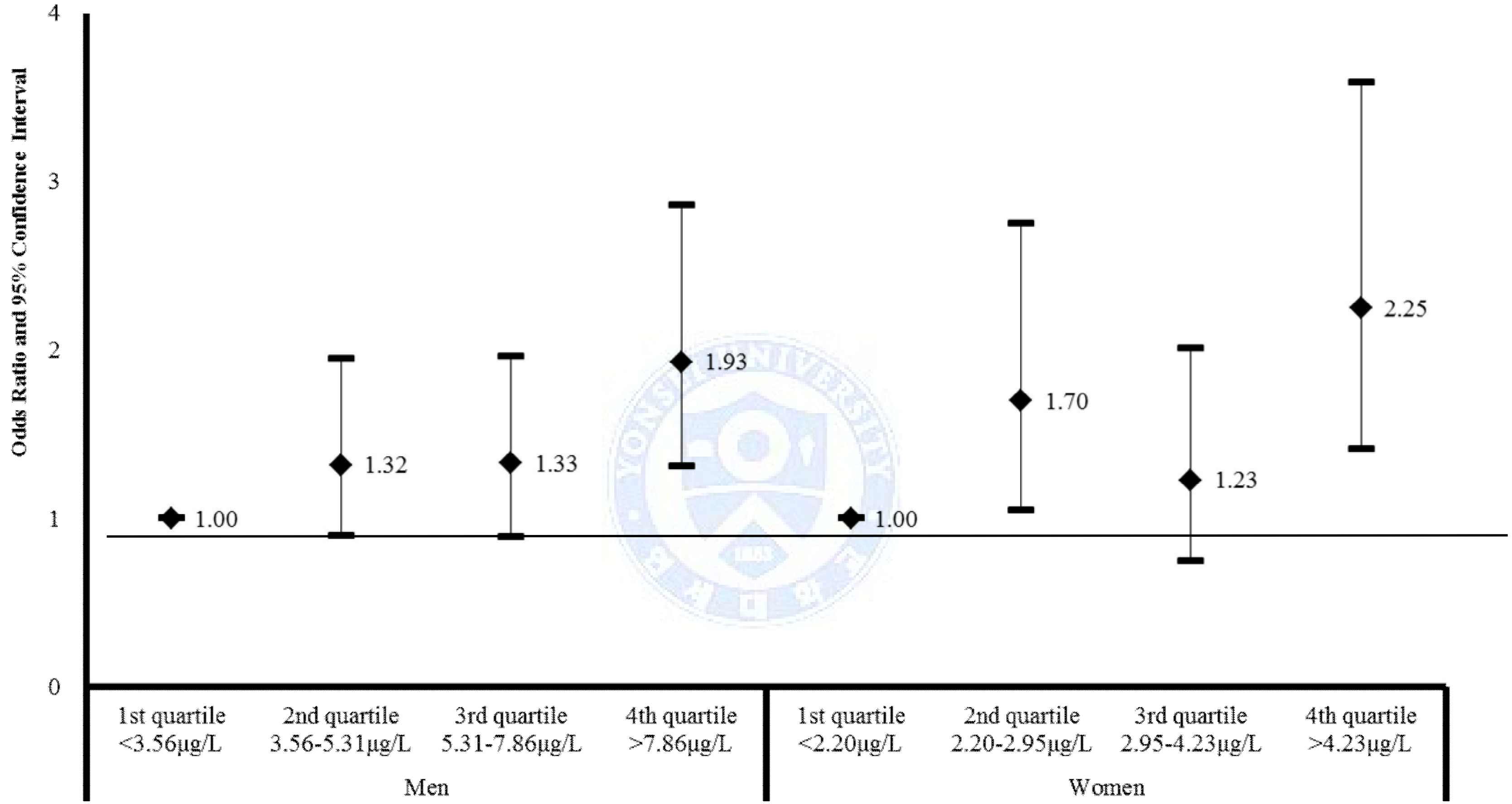

Figure 3 Odds ratio for overweight based on WC criteria (Non-manual workers)

The results of logistic regression analyses based on WC in the non-manual worker group are shown in Figure 3. The OR (95% CI) for the highest vs. reference blood mercury level was 1.93 (1.31–2.86) in men non-manual workers and 2.25 (1.41–3.59) in women non-manual workers, and only Q4 was significant in both men and women.

Ⅳ. DISCUSSION

To the best of our knowledge, this is the first attempt to investigate the association between the environmental exposure level of mercury and weight gain using multiple diagnostic criteria. After adjusting for possible potential confounders, we found a positive association between blood mercury concentration and overweight and abdominal obesity in a large population-based set of Korean data, which are representative of the Korean population. Additionally, we observed a meaningful trend of obesity increasing across increasing blood mercury quartiles.

Owing to our large sample size, we were able to conduct detailed subgroup analyses by sex and occupational status (manual and non-manual workers) that confirmed that the association between blood mercury concentration and obesity was consistently present within some of these subgroups (manual workers, shown in Tables 8 and 11). Additionally, we observed meaningful trends that gradually increased according to the blood mercury quartile through the odds of rising obesity within the subgroups.

Previous studies have examined the association between blood mercury concentration and obesity but with inconsistent results.[7,13,25-27] Some investigations demonstrated a significant association between blood mercury level and obesity in Korean adults.[25-27] Similarly, a previous study showed a significant association between hair mercury levels and BMI.[13] Conversely, another study showed no notable relation between blood mercury concentrations and obesity.[7] Those studies adjusted for only SES or food consumption, but not for other potential confounding factors such as occupational status. Furthermore, there were fewer study subjects than in our study population, which decreased their statistical power.

Some studies have postulated possible mechanisms for the association between blood mercury and weight gain. According to the current knowledge, mercury may play an important role in the development of obesity by causing not only adipose tissue endocrine dysfunction but also dysregulation of lipid metabolism and glucose metabolism.[27,37,38] Furthermore, obesity induced by environmental exposure to mercury lends support to potential pathology mechanisms explaining the relationship between chronic mercury exposure and risk of CVDs.[13,39,40] Thus, it is important to tighten the environmental restrictions on mercury exposure

Although the blood mercury levels in Q2 and Q3 (in women) in our study were lower than the lowest acceptable concentration (5.8 μg/L) which adverse effects are not likely, as recommended by the U.S. Environmental Protection Agency (EPA), we found an obvious risk for obesity in low-level environmental exposure to mercury. Thus, we need to reduce environmental mercury exposure in the general population and develop a strong surveillance system.[19]

In the current study, we estimated the relationship between weight gain and blood mercury levels in a Korean general adult population using different obesity criteria. According to our results, environmental exposure to mercury, even low-level exposure, might be a serious public health problem. Therefore, efforts should be made to establish a more acceptable standard exposure level of mercury from the environment.

There are several limitations to the current study. First, our study used a cross-sectional study design, which does not allow estimating a cause-effect relationship between parameters. Second, the mercury in hair, toenails, and urine reflect long-term exposure, but we used total blood mercury as an exposure biomarker for mercury in this study. Although the blood mercury level reflects relatively short-term exposure during several months, it has been widely used in epidemiologic studies as a marker and for monitoring the mercury exposure of populations at risk and for comparison with other populations.[19] Third, the nutrition data of study participants were obtained by using a 24-hour dietary recall questionnaire, thereby engendering potential recall bias. Despite these limitations, the major strengths of this study are that it assessed a large sample size, so that the results are representative of Korean adults. Second, the study populations consisted of ethnically homogenous Koreans, although the effects of mercury exposure on weight gain have not been found to differ among racial groups. Third, we evaluated overweight and obesity based on 2 different criteria, BMI and WC, whereas numerous published studies have used only a single criterion. Moreover, even after adjusting for occupation and many other confounder variables, we still found a significant association between blood mercury levels and overweight and abdominal obesity. Finally, we attempted to stratify by occupation (manual and non-manual workers), which no study has done previously. A meaningful association of blood mercury and obesity was confirmed in some of these subgroups.

Ⅴ. CONCLUSION

We found meaningful associations between blood mercury level and weight gain in a dose-dependent manner, thereby enhancing our understanding of the effect of blood mercury levels on the increasing trend of weight gain. The specific mechanism that blood mercury leads to obesity has not yet been reported. Further experimental studies, cohort studies, and clinical and epidemiologic studies are necessary to overcome the limitations of this study. Additionally, international awareness and continuous management for protecting populations against environmental exposure are required.

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ABSTRACT (IN KOREAN)

혈중 수은과 비만의 관련성에 대한 연구
- 2007-2013 년 국민건강영양조사 자료를 중심으로 -

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서론: 21세기에 과체중과 비만의 유병률은 전 세계적으로 증가하고 있고 보건학적인 측면에서 심각한 문제로 인식되고 있다. 수 많은 비만을 야기하는 원인과 비만의 위험성에 대한 연구가 많이 되어왔다. 본 연구의 목적은 혈중 중금속 중 수은과 비만과의 연관성에 대해 알아보고자 한다.

방법: 2007년부터 2013년 까지 국민건강영양조사 자료를 바탕으로 성인 중 혈중 중금속 농도 결과가 있는 대상자 9,923명 (남자 4,619명, 여자 5,304명)을 연구대상자로 선정하여 성별과 직업으로 층화하였다. 체질량지수(BMI)와 허리둘레(WC)를 비만 진단 기준으로 설정하였고 혈중 중금속은 아말감 방법으로 분석하여 그 결과를 사분위 수로 나누었다. 통계적 방법은T-test, 카이제곱, 다중 로지스틱 회귀분석을 사용하였다.

결과: 일반 인구 집단과 육체적 노동자 집단에서 혈중 수은농도의 4 분위수가 증가할수록 과체중과 비만의 위험이 유의하게 증가하였다. 일반인구 집단에서 가장 높은 혈중 수은농도가 가장 낮은 혈중 수은 농도를 가진 사람보다

과체중의 위험교차비가 전체대상자에서 1.92 (95% confidence interval [CI], 1.69–2.18)이었고, 남성에게서 2.32 (95% CI, 1.93–2.80), 여성에서1.68 (95% CI, 1.42–1.99)로 유의하게 증가하였고, 비만의 위험교차비가 남성에게서 1.97 (95% CI, 1.61–2.41)였고, 여성에서 2.01 (95% CI, 1.69–2.40)로 유의하게 증가하였다. 육체적 노동자 집단에서는 가장 높은 혈중 수은농도가 가장 낮은 혈중 수은 농도를 가진 사람보다 과체중의 위험교차비가 전체 대상자에서 2.06 (95% CI, 1.69–2.50)이었고, 남성에게서 2.42 (95% CI, 1.88–3.13) 그리고 여성에서 1.86 (95% CI, 1.39–2.50)로 유의하게 증가하였다. 비만의 위험교차비는 남성에게서 2.07 (95% CI, 1.56–2.74)였고 여성에서 2.37 (95% CI, 1.75–3.20)로 통계적으로 유의하였다. 비육체적 노동자 집단에서는 가장 높은 혈중 수은농도를 가진 사람이 가장 낮은 혈중 수은 농도를 가진 사람보다 과체중과 비만의 위험교차비가 통계적으로 유의하였으나 더 낮은 혈중 수은 농도에서는 유의하지 않았다.

고찰: 본 연구는 한국 성인의 혈중 수은 농도와 과체중/비만과의 관계에서 유의한 관련성을 보았다. 더불어 직업군을 층화하여 분석한 결과 육체적 노동자에서 혈중 수은 농도와 과체중/비만과의 유의한 관련성을 보았다.

핵심되는 말: 혈 중 수은, 과체중, 비만, 국민건강영양조사