ISSN (Online) : 0974-5645
ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 8(S1), 467–474, January 2015*
DOI: 10.17485/ijst/2015/v8iS1/59421

The Association of Blood Heavy Metal Concentration and Components of Metabolic Syndrome in Korean Male Adults

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Abstract

The purpose of this study was to analyse the association between blood heavy metal concentration (lead, mercury, cadmium) and components of metabolic syndrome (Mets) in Korean male adults. Data were extracted from the 5th Korea National Health and Nutrition Examination Survey (KNHANES) 2010. Participants were 965 Korean male adults aged 20 years and over. The data were analysed by using SPSS/Win 20.0. The means of blood lead, mercury and cadmium concentration in participants were 2.94μg/dl, 5.98μg/L, and 1.10μg/L, respectively. The means of Fasting Blood Glucose (FBG), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), serum Triglyceride (TG), serum High-density Lipoprotein Cholesterol (HDL-C) and Waist Circumference (WC) were 100.23mg/dl, 123.43mmHg, 81.23mmHg, 161.84mg/dl, 49.64mg/dl and 84.35cm, respectively. After adjusting for demographical characteristics (age, education, income, residential area, occupation, drinking, and smoking), increase of FBS and DBP were associated with the serum cadmium (OR = 1.465) and lead (OR = 1.147), respectively. Mercury was associated with increase of WC (OR = 1.051) and Mets (OR = 1.048). Based on the outcomes of this study, it is necessary to develop intervention strategies for reducing the lead, mercury and cadmium exposure and monitor continuous blood heavy metal concentration.

Keywords: Cadmium, Lead, Metabolic Syndrome, Mercury

1. Introduction

The heavy metals lead, mercury and cadmium are widely dispersed in the environment, and at excessive levels, are toxic to humans[1]. Chronic exposure to these substances may also be hazardous[2]. While most of the heavy metals absorbed into the human body through diverse channels, such as the digestive organs and the respiratory organs, might be excreted from the body during the process of metabolism or evacuation, some of them, which are accumulated within several tissues, affect hormonal metabolism and vessels, cause hypertension, diabetes, and cancer, and damage national health[3]. Lead and cadmium might be accumulated not only in nerves, the kidneys, the endocrine system, and the genital organs to damage organs and cause abnormal hormonal metabolism but also in the cardiovascular system to cause atherosclerosis and hypertension[4]. Mercury, which is accumulated in the body in the organic form not excreted easily from the body due to the long half-life, causes malfunction of vascular endothelial cells, increase free oxygen radicals, and induce proliferation of vascular smooth muscle cells[5, 6]. Therefore, constant exposure to mercury may cause death of myocardial infarction, coronary heart disease, and cardiovascular disease[2].

It has been reported that the risk factors of cardiovascular disease include smoking, dyslipidemia, hypertension, diabetes, old age, and obesity; while it was defined as X-syndrome or insulin resistance because each of the factors occurred due to insulin resistance and caused metabolic abnormalities, many researchers found that when they accompanied each other, they were more

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likely to cause coronary disease or cardiovascular disease. These factors are more likely to cause coronary disease or cardiovascular disease when they are accompanied by abdominal obesity. In 2001, U.S. NCEP ATP III (National Cholesterol Education Program Adult Treatment Panel III) defined metabolic syndrome as a case satisfying three or more among abdominal obesity (waist circumference), hypertension, high serum triglyceride(TG) level, abnormal high-density lipoprotein cholesterol (HDL-C), and a abnormal fasting blood glucose (FBS) level and tries to prevent metabolic syndrome and reduce the incidence of cardiovascular disease[8].

While many researchers have examined the blood heavy metal level and its effects on the human body among workers from the perspective of occupational disease associated with industrial health, there is little research on the effects of the daily exposure to environmental pollution on health and its correlation with metabolic syndrome among general people. Since low-concentration heavy metals to which the body is constantly exposed are accumulated in the body and can damage health, it is very important to examine the exposure level and assess its risk level constantly.

Therefore, this study aims to examine blood lead, mercury, and cadmium concentrations and determine their association with Waist Circumference (WC), Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP), TG, HDL-C, and FBG among Korean adult males.

2. Method

2.1 Research Design and Sampling

The current study used a cross-sectional descriptive design. Data were extracted from the 5th Korea National Health and Nutrition Examination Survey (KNHANES) 2010. Participants were 965 Korean male adults aged 20 years and over who completed the health examination survey, including blood lead, mercury, and cadmium measurements.

2.2 Definition Metabolic Syndrome (Mets)

In accordance with 2005 revised NCEP- ATP III (National Cholesterol Education Program-Adult Treatment Panel III) and Asia – Pacific Obesity criteria for waist circumference, Mets was defined as the presence of three or more of the following: (1) Systolic Blood Pressure (SBP) ≥130mmHg or Diastolic Blood Pressure (DBP) ≥85mmHg, (2) Fasting Blood Glucose (FBG) ≥100mg/dl, (3) serum High density Lipoprotein Cholesterol (HDL-C) < 40mg/dl (male) (4) serum Triglyceride (TG) ≥150mg/dl, (5) Waist Circumference(WC) ≥ 90cm(male)[9].

2.3 Data Sampling of Mets and Analysis of Blood Samples

Blood pressure was measured while subjects were in a seated position following 5 minutes rest period with a mercury sphygmomanometer. WC was measured midway between the costal margin and iliac crest at the end of a normal expiration. Blood samples were collected in the morning following an overnight fast. The serum concentrations of FBG, TG, and HDL-C were measured using a Hitachi Automatic Analyser 7600(Japan). Blood cadmium and lead were measured by atomic absorption spectrometry method (AAnalyst 800, PerkinElmer, Singapore). Blood mercury level was measured by gold-amalgam collection method (DMA-80, Milestone, Italy). All blood samples analyses were performed by N medical institute.

2.4 Data Analysis

Data was analysed by using SPSS/Win 20.0 using descriptive analysis, ANOVA, t-test and binary logistic regression.

3. Results

3.1 Lead, Mercury and Cadmium Concentration According to General Characteristics

The general characteristics of the study population are shown in Table 1. Of the participants, 38.3%, 41.3% and 20.3% ranged from 20 to 39 years, 40 to 59 years, and over 60 years of age, respectively. As to residence type, 79% lived in urban and 45.5% lived in apartments. Of the participants, 37.0% was smoker and 36.0% was alcohol drinker (≥ twice a week).

The blood lead concentration was statistically significant difference in age ($F = 20.91$, $p<.001$), education level ($F = 4.22$, $p = .006$), income ($F = 3.84$, $p = .010$), house type ($t = -2.97$, $p = .003$), alcohol drinking ($F = 11.75$. $p<.001$), occupation ($F=5.12$, $p<.001$). The blood mercury concentration was statistically significant difference in age ($F = 35.57$, $p<.001$), education level

Table 1. Blood lead, mercury and cadmium concentration according to general characteristics (*N* = 965)

Variables		n (%)	Lead (μg/dL) M(SD)	t or F(p)	Mercury (μg/L) M(SD)	t or F(p)	Cadmium (μg/L) M(SD)	t or F(p)
Age (year)	20–39[a]	370(38.3)	2,38(0.76)	35.57 (<.001) a>b,c	4.99(3.19)	20.91 (<.001) a, c < b	0.87(0.49)	49.43 (<.001) a < b, c
	40–59[b]	399(41.3)	3.28(2.25)		7.02(5.38)		1.22(0.61)	
	≥60[c]	196(20.3)	3,31(1.29)		5.70(4.14)		1.28(0.62)	
Education level	≤Elementary school	118(12.2)	3.63(2.05)	16.22 (<.001) a, b > c, d c > d	5.96(5.07)	4.22 (.006) c < d	1.41(0.68)	20.21 (<.001) a, b > c, d
	Middle school[b]	97(10.1)	3.46(1.52)		5.71(4.75)		1.27(0.53)	
	High school[c]	368(38.1)	2.95(2.12)		5.41(3.79)		1.07(0.57)	
	≥College[d]	371(38.4)	2.57(0.82)		6.56(4.74)		0.98(0.56)	
	missing	11((1.1)						
Income	Low[a]	240(24.9)	3.09(1.93)	1.11 (.345)	5.51(4.74)	3.84 (.010) a, b < d	1.19(0.67)	2.45 (.062)
	Middle low[b]	249(25.8)	2.92(1.50)		5.70(4.29)		1.07(0.56)	
	Middle high[c]	238(24.7)	2.81(1.44)		5.84(4.32)		1.05(0.55)	
	High[d]	229(23.7)	2.92(1.86)		6.79(4.44)		1.08(0.58)	
	missing	9(0.9)						
Residence area	Urban	767(79.5)	2.89(1.78)	−2.12 (.035)	5.94(4.52)	−0.50 (.615)	1.08(0.58)	−1.70 (.090)
	Rural	198(20.5)	3.12(1.25)		6.12(4.41)		1.17(0.64)	
House type	Apartment	526(54.5)	3.07(1.69)	2.70 (.007)	5.58(4.37)	−2.97 (.003)	1.17(0.63)	4.11 (<.001)
	Others	439(45.5)	2.78(1.67)		6.45(4.60)		1.01(0.54)	
Smoking	Non-smoker[a]	178(18.4)	2.56(1.43)	6.22 (.002) a < b, c	5.29(4.02)	2.55 (.079)	0.72(0.32)	99.34 (<.001) a <b, c b < c
	Past smoker[b]	327(33.9)	2.94(1.68)		6.10(4.20)		0.96(0.48)	
	Smoker[c]	454(37.7)	3.09(1.77)		6.15(4.84)		1.35(0.64)	
Alcohol Drinking	Non-dinker[a]	112(11.6)	2.79(1.02)	11.75 (<.001) a, b, c < d	4.86(2.91)	11.45 (<.001) a, b < c, d	1.05(0.51)	13.92 (<.001) a, b < c, d c < d
	≤ once a month[b]	205(21.2)	2.48(0.92)		4.91(3.08)		0.92(0.48)	
	2–4 times a month[c]	301(31.2)	2.86(1.82)		6.05(4.84)		1.07(0.58)	
	≥ twice a week[d]	347(36.0)	3.32(1.99)		6.90(5.06)		1.24(0.66)	
Occupation	Manager,specialists[a]	151(15.6)	2.59(0.85)	5.12 (<.001) a<e a, b, c < d d, e > g	6.83(4.56)	7.69 (<.001) a, b > e, f, g c, d > g	1.02(0.56)	5.16 (<.001) a, b < d, f d, f > g
	White-collar[b]	127(13.2)	2.79(2.26)		7.17(5.15)		0.98(0.48)	
	Service sales[c]	123(12.7)	2.74(1.28)		6.63(5.37)		1.10(0.58)	
	Agriculture,fisheries[d]	90(9.3)	3.49(1.21)		6.78(4.84)		1.31(0.62)	
	Technician[e]	196(20.3)	3.26(2.44)		5.38(3.80)		1.14(0.57)	
	Simple labor[f]	69(7.2)	3.18(1.44)		4.72(2.81)		1.29(0.71)	
	Unemployed[g]	189(19.6)	2.72(1.16)		4.70(3.72)		1.02(0.62)	
	missing	20(2.1)						

[*] Post hoc: Scheffe's test

($F = 16.22$, $p < .001$), house type ($t = 4.11$, $p = .007$), alcohol drinking ($F = 11.45$, $p < .001$), occupation ($F = 7.69$, $p < .001$). The blood cadmium concentration was statistically significant difference in age ($F = 49.43$, $p < .001$), education level ($F = 20.21$, $p < .001$), residence area ($t = –2.12$, $p = .035$), house type ($t = 2.70$, $p = .007$), smoking ($F = 99.34$, $p<.001$), alcohol drinking ($F = 13.92$, $p < .001$), occupation ($F = 5.16$, $p < .001$) (Table 1).

3.2 Blood Levels of Lead, Mercury and Cadmium and Components of Metabolic Syndrome of Participants

The means of blood lead, mercury and cadmium concentration in participants were 2.94μg/dl, 5.98μg/L, and 1.10μg/L, respectively. The means of FBG, SBP, DBP, TG, HDL-C and WC were 100.23mg/dl, 123.43mmHg, 81.23mmHg, 161.84mg/dl, 49.64mg/dl and 84.35cm, respectively (Table 2).

3.3 Blood Lead, Mercury and Cadmium Concentration by Metabolic Syndrome and its Components

The group with Mets was significantly higher in the blood levels of lead ($t = 2.54$, $p = .011$), mercury ($t = 4.46$, $p <. 001$), cadmium ($t = 3.77$, $p < .001$) than non Mets group. As for the components of metabolic syndrome, the blood lead, mercury, and cadmium concentrations were statistically significantly higher in the group with FBS of ≥100 mg/dl than in that with <100 mg/dl, in the group SBP of ≥130 mmHg than in that with <130 mmHg, and in the group with TG of ≥150 mg/dl than in that with <150 mg/dl. The group with DBP of ≥85 mmHg had higher lead and mercury concentrations than that with <85 mmHg and the group with WC of 90 cm had a significantly higher mercury concentration than that with <90 cm (Table 3).

Table 2. Blood lead, mercury and cadmium concentration and components of metabolic syndrome ($N = 965$) in participants

Variables	M(SD)	Min–Max
B-HMC		
Lead(μg/dL)	2.94(1.69)	1.0–27.0
Mercury(μg/L)	5.98(4.49)	1.0–41.0
Cadmium(μg/L)	1.10(0.59)	0–4.0
Components of Mets		
FBS(mg/dl)	100.23(26.34)	69–325
SBP(mmHg)	123.43(15.71)	85–189
DBP(mmHg)	81.23(10.53)	49–125
S-TG(mg/dl)	161.84(152.18)	22–2474
S-HDL(mg/dl)	49.64(12.40)	18–116
WC(cm)	84.35(8.89)	59–132

B-HMC: Blood Heavy Metal Concentration, Mets: Metabolic syndrome, FBS: Fasting blood glucose, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, S-TG: Serum triglyceride, S-HDL:Serum High density lipoprotein, WC: Waist circumference

3.4 Odds Ratios (95% CI) for Components of Metabolic Syndrome by Blood Lead, Mercury and Cadmium Concentration

According to binary logistic regression analyses (Table 4), increase of FBS and DBP were associated with the serum cadmium ($OR = 1.465$) and lead ($OR = 1.147$), respectively. Mercury was associated with increase of WC ($OR = 1.051$) and Mets ($OR = 1.047$) after adjusting for demographical characteristics (age, education, income, residential area, occupation, drinking, and smoking).

4. Discussion

The heavy metals as lead, mercury, and cadmium are widely distributed in the environment where we live, and human beings are exposed to heavy metals by air, soil, water, food, and diverse products containing them. Overexposure to heavy metals can not only does harm to human beings but also are accumulated and act as toxins, instead of being metabolized in the body.

In this study, the average blood lead, mercury, and cadmium concentrations were estimated to be 2.94 (±1.69) μg/dL, 5.98 (±4.49) μg/L, and 1.10 (±0.59) μg/L, respectively, among the participants. While the blood cadmium concentration was slightly lower than the level, 1.55 μg/L, estimated by the Korea Centers for Disease Control and Prevention in 2005[3], the blood mercury concentration was higher than the level in 2005 (4.34 μg/L) and that between 2009 and 2011 (3.08 μg/L)[10]. The blood lead concentration was lower than the average level of 3.25 μg/dL estimated in males by Park[11]. The average blood lead, mercury, and cadmium concentrations are about three times, six times, and three times higher than the estimations by the U.S. Health and Nutrition Examination (2009-2010): 1.12 μg/dL, 0.86 μg/L, and

Table 3. Blood lead, mercury and cadmium concentration by metabolic syndrome and its components (N = 965)

Variables	n	Lead(μg/dL)		Mercury(μg/L)		Cadmium(μg/L)	
		Mean(SD)	t(p)	Mean(SD)	t(p)	Mean(SD)	t(p)
Fasting blood glucose							
≥100mg/dl	303	3.18(1.94)	2.94 (.003)	6.75(5.27)	3.62 (<.001)	1.25(0.65)	5.46 (<.001)
<100mg/dl	662	2.83(1.56)		5.62(4.05)		1.03(0.56)	
Systolic blood pressure							
≥130mmHg	229	3.40(2.16)	4.77 (<.001)	6.66(5.26)	2.67 (.008)	1.26(0.60)	4.57 (<.001)
<130mmHg	736	2.80(1.49)		5.76(4.21)		1.05(0.59)	
Diastolic blood pressure							
≥85mmHg	329	3.21(2.30)	3.66 (<.001)	6.55(4.87)	2.87 (.004)	1.15(0.57)	1.83 (.067)
<85mmHg	636	2.80(1.25)		5.68(4.26)		1.07(0.61)	
Serum triglyceride							
≥150mg/dl	380	3.13(2.08)	2.84 (.005)	6.65(5.06)	3,67 (<.001)	1.19(0.61)	3.92 (<.001)
<150mg/dl	585	2.81(1.37)		5.54(4.03)		1.04(0.58)	
Serum High density lipoprotein							
<40mg/dl	198	2.82(1.41)	−1.13 (.258)	6.04(4.37)	.230 (.818)	1.14(0.61)	1.038 (.299)
≥40mg/dl	767	2.97(1.76)		5.96(4.53)		1.09(0.59)	
Waist circumference							
≥90cm	239	2.97(1.82)	.332 (.740)	6.97(5.58)	3.96 (<.001)	1.13(0.56)	.883 (.377)
<90cm	726	2.93(1.65)		5.65(4.03)		1.09(0.61)	
Metabolic syndrome							
Yes	547	3.06(1.89)	2.54 (.011)	6.53(4.94)	4.46 (<.001)	1.16(0.62)	3.77 (<.001)
No	418	2.78(1.37)		5.24(3.71)		1.02(0.57)	

0.32 μg/L, respectively[12]. These levels are also higher than findings from the 2007 to 2008 Canadian Health and Nutrition Examination, as reported by Suzy and Ellen[28]: 1.50 μg/dL, 0.91 μg/L, and 0.42 μg/L, respectively; in particular, the mercury concentration is significantly higher than that of Germany: 0.5 μg/L[10]. The U.S. Center for Disease Control (CDC) recommends the blood lead level to be 10 μg/dL for children and has made no recommendation for adults. U.S. EPA(Environmental Protection Agency) recommends the blood mercury concentration of ≤5.8 μg/L as the level doing no harm to the human body[3]; since the level of 5.98 μg/L in this study is above the recommendation, intensive control and monitoring is especially required for males. The blood cadmium concentration was lower than the WHO recommendation of ≤5 μg/L.

In addition, smokers had higher blood lead and cadmium concentrations than non-smokers; the group having alcohol intake twice or more a week had higher blood lead, mercury, and cadmium concentrations than any other group in this study. This result is similar to Batariova, Spevakova, & Benes[14] that smokers had a 2.5 to 5 times higher blood cadmium concentration than non-smokers. Among alcohol drinks, 101 μg lead is contained in 1 L wine and 22 μg lead in 1 L beer and 0.70 μg/g to 2.01 μg/g in tobaccos[13,29]. As it has been reported domestically and internationally that drinking and smoking are correlated with the increased blood lead concentration[15–18], smoking and alcohol intake, which can increase the risk of exposure to heavy metals, need to be restricted.

There are significant differences by age: the older, the higher concentration of heavy metals due to the differences in their accumulation in the body and delayed excretion caused by malfunction of organs with age[19]. Besides, there were statistically significant differences in the blood lead concentration by education, region, and residence type, in the blood mercury concentration by education, income, and residence type, and in the blood cadmium concentration by education, income, region, and residence type; this result is consistent with

Table 4. Odds ratios (95% CI) for components of metabolic syndrome by blood lead, mercury and cadmium concentration (N = 965)

Variables	Components of Metabolic Syndrome			
	Crude OR(95% CI)	p	Adjusted OR*(95% CI)	p
Fasting blood glucose (≥100mg/dl)				
Lead(μg/dL)	1.050(.968–1.140)	.236	.991(.904–1.085)	.838
Mercury(μg/L)	1.038(1.006–1.070)	.019	1.030(.966–1.065)	.087
Cadmium(μg/L)	1.616(1.270–2.058)	<.001	1.465(1.086–1.978)	.013
Systolic blood pressure (≥130mmHg)				
Lead(μg/dL)	1.154(1.047–1.272)	.004	1.072(.983–1.169)	.118
Mercury(μg/L)	1.027(.994–1.061)	.106	1.025(.990–1.063)	.166
Cadmium(μg/L)	1.459(1.126–1.891)	.004	1.111(.805–1.533)	.523
Diastolic blood pressure (≥85mmHg)				
Lead(μg/dL)	1.167(1.052–1.294)	.004	1.147(1.032–1.275)	.011
Mercury(μg/L)	1.038(1.007–1.070)	.016	1.021(.989–1.055)	.202
Cadmium(μg/L)	1.024(.803–1.307)	.847	1.246(.934–1.662)	.134
Serum triglyceride (≥150mg/dl)				
Lead(μg/dL)	1.090(.998–1.192)	.056	1.065(.973–1.165)	.174
Mercury(μg/L)	1.045(1.013–1.078)	.005	1.023(.990–1.056)	.171
Cadmium(μg/L)	1.309(1.036–1.655)	.024	1.165(.881–1.542)	.284
Serum High– density lipoprotein cholesterol (<40mg/dl)				
Lead(μg/dL)	.885(.765–1.024)	.100	.883(.754–1.034)	.123
Mercury(μg/L)	1.004(.968–1.040)	.839	1.005(.967–1.045)	.781
Cadmium(μg/L)	1.188(.896–1.576)	.232	.916(.649–1.292)	.616
Waist circumference (≥90cm)				
Lead(μg/dL)	.994(.906–1.091)	.900	.953(.856–1.063)	.389
Mercury(μg/L)	1.054(1.021–1.088)	.001	1.051(1.016–1.086)	.004
Cadmium(μg/L)	.998(.766–1.301)	.991	.955(.695–1.314)	.778
Metabolic syndrome				
Lead(μg/dL)	1.062(.969–1.164)	.199	1.012(.928–1.104)	.790
Mercury(μg/L)	1.066(1.029–1.106)	<.000	1.048(1.010–1.087)	.013
Cadmium(μg/L)	1.361(1.070–1.730)	.012	1.130(.848–1.505)	.405

*Adjusting for age, education, income, residential area, house type, occupation, alcohol drinking, and smoking

the finding of many researchers that those who are older, whose household income is lower, who are less educated, and who are smokers have a higher blood lead concentration[11,18], suggesting the need of intensive control for the susceptible population. The metabolic syndrome group had statistically significantly higher blood lead, mercury, and cadmium concentrations than the non-metabolic syndrome group; overseas researchers also reported that lead, mercury, and cadmium accumulated in the body could facilitate insulin resistance, hyperglycemia, hypertension, abdominal obesity, and dyslipidemia[20,22]. They are risk factors that cause metabolic syndrome and increase the risk of causing cardio- and cerebro-vascular disease with close association with each other in a group; for this reason, metabolic syndrome having three or more risk factors is drawing attention as a principal risk factor of cardiovascular disease than that having a single factor.

As for the components of metabolic syndrome, the blood lead, mercury, and cadmium concentrations were statistically significantly higher in the group with FBS of ≥100 mg/dl, SBP of ≥130 mmHg, and TG of ≥150 mg/dl than other groups. The group with DBP of ≥85 mmHg had higher lead and mercury concentrations than that with <85 mmHg and the group with WC of 90 cm had a significantly higher mercury concentration than that with <90 cm.

Logistic regression analysis was made to identify the risk factors of heavy metals affecting metabolic syndrome and its components adjusting for age, education, income, region, occupation, smoking, and alcohol intake and found that risk factors of heavy metals that might increase FBS, DBP, and WC were cadmium, lead, and mercury, respectively, and that the risk factor of metabolic syndrome was mercury, suggesting the special need to control the exposure to mercury for Korean men. This result was similar to Chang, Chen, Su, Liao, Guo, and Lee[20] that mercury was correlated with metabolic syndrome. It was also similar to You et al[24]. that the waist-hip ratio (WHP) associated with cardiovascular disease was statistically significantly correlated with the increase in the blood mercury concentration. A higher mercury concentration leads to higher blood pressure, malfunction of vascular endothelial cells, increased free oxygen radicals, and abnormal lipid metabolism[5,25,26]. The Kuopio Ischemic Heart Disease Risk Factor (KIHD) cohort study that followed persons in their forties or older until they got older than sixty found that exposure to mercury could cause death of myocardial infarction, coronary heart disease, and vascular disease and that it was particularly associated with heart disease for the aged, not for infants or children[7], suggesting the need to train habits of reducing exposure to mercury in a daily life and to control the exposure. As for the non-occupational exposure group, the principal channel of exposure to mercury is through food, which gets contaminated by heavy metals during processing sometimes; meanwhile, the accumulation of heavy metals in food mainly due to such environmental factors as the quality of water and atmosphere causes the body to be exposed to mercury through eating[27]. The Ministry of Environment in South Korea established the First Comprehensive Mercury Control Plans between 2006 and 2010 to identify the properties of mercury excretion and take the measures to reduce mercury on the basis of the excretion criteria and control plans. The ministry announced the Second Comprehensive Mercury Control Plans in December 2010 to make integrated management of the entire process for mercury, reinforce mercury control in the discharge facilities, reinforce environmental monitoring, and prevent vulnerable and susceptible populations from being damaged by mercury and to try to achieve the goal of reducing the rate of exceeding the national blood mercury concentration standard (5.8 μg/L, as recommended by USEPA) from 26.2% in 2008 to 15% by 2015[25]. Efforts to reduce the national blood mercury concentration through cooperation with lots of experts should be made. Experts in the fields of environment and public health need to provide the people with information about harmfulness of heavy metals, including mercury, and to monitor them constantly. They also need to establish and implement an environment and health promotion plan to minimize the likelihood of being damaged by heavy metals by developing educational materials about prevention of exposure to heavy metals and by improving living habits, such as quitting smoking and moderation in drinking.

5. Conclusion

Blood cadmium and lead levels were risk factors of FBS and DBP among Mets' components. Especially, blood mercury level was risk factor for WC and Mets. The blood levels of lead, mercury and cadmium in Korea male adults are higher than those of people in the United States, Germany and Canada. According to this result, it is necessary to develop intervention strategies for reducing the lead, mercury and cadmium exposure and monitor continuous blood heavy metal concentration and educate tobacco and alcohol cessation through life style change.

This study had some limitation. Because this result was obtained by cross-sectional design, the associations between increases in Mets or its components and blood heavy metals levels require further study.

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