

The relationship between metabolic syndrome and increase of metabolic syndrome score and serum vitamin D levels in Korean adults: 2012 Korean National Health and Nutrition Examination Survey

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The present study was conducted to assess the relationship between metabolic syndrome and metabolic syndrome score (MSS) and serum vitamin D levels in adults aged 20 or older ($n = 5,483$) using 2012 Korean National Health and Nutrition Examination Survey data, which represents national data in Korea. Key study results were as follows: First, serum 25-hydroxyvitamin D [25(OH)D] levels decreased significantly with an increase in MSS ($p = 0.004$), shown by serum 25(OH)D levels after adjusting the variables (age, gender, BMI, TC, HDL-C, FBS, SBP, and DBP, etc.). These were 17.30 ± 0.16 ng/ml for MSS 0, 17.13 ± 0.15 ng/ml for MSS 1, 17.02 ± 0.16 ng/ml for MSS 2, 16.60 ± 0.20 ng/ml for MSS 3, 16.55 ± 0.28 ng/ml for MSS 4, and 15.52 ± 0.50 ng/ml for MSS 5. Second, after adjusting the related variables, serum 25(OH)D levels were significantly lower ($p = 0.004$) in the metabolic syndrome group (16.49 ± 0.19 ng/ml) than the non-metabolic syndrome group (17.16 ± 0.09 ng/ml). In conclusion, metabolic syndrome and the increased levels of its components are inversely associated with the serum vitamin D concentration in Korean adults.

Key Words: 25-hydroxyvitamin D, metabolic syndrome, metabolic syndrome score

Recently, major causes of death for Koreans include cancer (27.6%), cardiac disease (9.9%), cerebrovascular disease (9.6%), diabetes (4.3%), and hypertension (2.0%),⁽¹⁾ and the prevalence of these chronic diseases has gradually increased since 1998.⁽²⁾ Metabolic syndrome is defined as a disease in which conditions such as hypertension, high blood sugar, plasma lipid abnormality, as well as abdominal obesity occur simultaneously with resistance to insulin and at least three of five coronary risk factors. These include elevated blood pressure, elevated fasting blood sugar (FBS), abdominal obesity, elevated triglycerides (TG), and reduced high-density lipoprotein cholesterol (HDL-C).⁽³⁾ These risk factors are known to increase cardiovascular diseases in particular⁽⁴⁾ and the incidence of cerebrovascular diseases, and they are highly associated with total mortality.⁽⁵⁾ While each risk factor influences coronary artery disease independently, having multiple risk factors simultaneously increases the risk of coronary artery disease exponentially.^(6,7) The prevalence of metabolic syndrome varies across countries, races, and regions.⁽⁸⁾ In the U.S.,

23.7% of adults aged 20 or older, and approximately 44% of those aged 50 or older, have metabolic syndrome, and a leading cause of metabolic syndrome has been found to be obesity due to lack of exercise.⁽⁹⁾ The prevalence of metabolic syndrome in Korea showed a steady increase from 25.3% in 1998, to 29.0% in 2001, and 32.6% in 2005.⁽¹⁰⁾ In particular, the prevalence rates for men and women aged 30 or older were 32.9 and 31.8%, respectively, and they tended to increase with age.⁽¹¹⁾

Vitamin D plays a major role in tissues (e.g., regulation of cellular proliferation/differentiation and immune function, anti-cancer actions) as well as in the metabolism of the skeletal system (e.g., skeletal growth and maintenance, calcium homeostasis maintenance, osteoporosis prevention and treatment).⁽¹²⁾ Vitamin D is a hormone precursor, vitamin D₂ is present in certain plants and animals such as mushrooms and mackerel, and vitamin D₃ is synthesized from 7-dehydrocholesterol in the skin by ultraviolet light.⁽¹³⁾ 25-hydroxyvitamin D [25(OH)D] usually functions as a storage due to its relatively long half-life of 2–3 weeks, and in terms of blood concentration, the total vitamin D status in the body is generally estimated through measurements of serum 25(OH)D.⁽¹⁴⁾ In terms of the functions of vitamin D, it is known to inhibit the development of osteoporosis and diabetes, maintain immune functions, prevent breast and prostate cancer, and treat rheumatism.^(15,16) Vitamin D deficiency is a risk factor for cartilage mineralization disorder, rickets developed due to the abnormal organization of the cartilage growth plate, cognitive function disorders, dementia, and depression.⁽¹⁷⁾

In the past, research on vitamin D was largely confined to diseases related to bone metabolism, such as osteoporosis or osteomalacia. However, interest in vitamin D is increasing due to recent research findings that vitamin D deficiency increases hypertension, high pulse pressure, obesity, hyperlipidemia, diabetes, etc., which increases the chance of cardiovascular disease.^(18–21)

Recently, research on vitamin D and metabolic syndrome, which is known to increase cardiovascular disease, is being conducted all over the world. However, the association of metabolic syndrome and vitamin D is still being debated because the findings vary across studies. That is, some report that metabolic syndrome

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and its components are associated with vitamin D.^(22–24) Some state that metabolic syndrome was not associated with vitamin D but that the components of metabolic syndrome are associated with vitamin D.⁽²⁵⁾ Finally, some report that neither metabolic syndrome nor its components was associated with vitamin D.^(26,27) The Republic of Korea is experiencing an increasing prevalence of diseases such as metabolic syndrome, cardiovascular diseases, and vitamin D deficiency. However, research on the association between metabolic syndrome and vitamin D in Korean adults is scarce.

Therefore, the present study aimed to investigate the association between metabolic syndrome and vitamin D in adults aged 20 or older using the fifth Korea National Health and Nutrition Examination Survey (KNHANES) data, which is representative of Korea.⁽²⁸⁾

Methods

Study subjects. This study was based on data from the KNHANES V-3, 2012. The KNHANES is a cross-sectional survey conducted nationwide by the Division of Korean National Health and Welfare. The KNHANES V-3 (2012) was performed from January 2012 to December 2012. In the KNHANES V-3 (2012), 8,058 individuals over age 1 were sampled for the survey. Among them, of the 6,221 subjects who participated in the KNHANES V-3, we limited the analyses to adults aged ≥ 20 years. We excluded 738 subjects whose data were missing for important analytic variables, such as serum 25(OH)D levels and the mental health questionnaire. Finally, 5,483 subjects were included in the statistical analysis. The KNHANES was approved by the Institutional Review Board of the Centers for Disease Control and Prevention in Korea. All participants in the survey signed an informed written consent form.

General characteristics and blood chemistry. Research subjects were classified by gender and by age into 20–29, 30–39, 40–49, 50–59, 60–69, 70–79, and 80 years or older. Anthropometric measurements included measurement of height, weight, body mass index (BMI), and waist measurement (WM) and final measurements of systolic blood pressure (SBP) and diastolic blood pressure (DBP). Blood chemistry included measurement of total cholesterol (TC), high density lipoprotein cholesterol (HDL-C), triglyceride (TG), fasting blood sugar (FBS), 25(OH)D.

Serum 25(OH)D assessment. Blood samples were collected through an antecubital vein after 10–12 h of fasting to assess serum levels of biochemical markers. Serum levels of 25(OH)D were measured with a radioimmunoassay (25-hydroxy-vitamin D ¹²⁵I RIA Kit; DiaSorin, Stillwater, MN) using a 1470 Wizard Gamma Counter (PerkinElmer, Turku, Finland). To minimize the analytical variation, serum 25(OH)D levels were analyzed by the same institute, which carried out a quality assurance program through the analysis period. Serum 25(OH)D was classified as vitamin D deficiency [25(OH)D < 15 ng/ml] or vitamin D sufficiency [25(OH)D ≥ 15 ng/ml].⁽¹⁷⁾

Metabolic Syndrome and Metabolic Syndrome Score (MSS). Metabolic syndrome was defined using the diagnostic criteria of the Revised National Cholesterol Education Program Adult Treatment panel III (Revised NCEP-ATP III) based on common clinical measures, including TG, HDL-C, blood pressure, FBS, and WM. TG over 150 mg/dl was set as the criteria for elevated TG. The criteria for reduced HDL-C were HDL-C of less than 40 and 50 mg/dl for males and females, respectively. FBS over 100 mg/dl was set as the criteria for elevated FBS. SBP over 130 mmHg or DBP over 85 mmHg were set as the criteria for elevated blood pressure. The criteria for abdominal obesity were abdominal measurements of over 90 and 80 cm for males and females, respectively, according to the Asia-Pacific criteria.⁽²⁹⁾

The presence of defined abnormalities in any three of these five measures constitutes a diagnosis of metabolic syndrome. The met-

abolic syndrome score (MSS) indicates the presence of abdominal obesity, elevated blood pressure, elevated FBS, elevated TG, or reduced HDL-C. Subjects without any of the five risk factors received an MSS 0, and those with one, two, three, four, and five of the risk factors received an MSS score of 1, 2, 3, 4, and 5, respectively.⁽³⁰⁾

Data analysis. The collected data were statistically analyzed using SPSS WIN (ver. 18.0). The distributions of the participant characteristics were converted into percentages, and the successive data were presented as averages with standard deviations. The average difference in serum 25(OH)D for control subjects and the clinical elements of metabolic syndrome were calculated using an analysis of variance and independent *t* tests. The average difference in serum 25(OH)D for metabolic syndrome and MSS was calculated using an analysis of variance and an analysis of covariance. Furthermore, a logistic regression analysis was performed on the odds ratio (OR) values of the vitamin D deficiency [25(OH)D < 15 ng/ml]. The significance level for all of the statistical data was set as $p < 0.05$.

Results

General characteristics of research subjects. General characteristics of the research subjects are shown in Table 1. The mean age of all subjects was 51.90 ± 16.73 years, and 42.5% were males and 57.5% were females. According to the classification of risk factors for coronary artery disease and the MSS guidelines, 1,476 (26.9%), 1,426 (26.0%), 1,184 (21.6%), 830 (15.1%), 443 (8.1%), and 124 (2.3%) subjects were classified as MSS 0, MSS 1, MSS 2, MSS 3, MSS 4, and MSS 5, respectively, while the prevalence rate of metabolic syndrome was 1,397 of the 5,483 patients (25.5%). The mean value of serum 25(OH)D was 16.99 ± 5.63 ng/ml, and of the 5,483 subjects, 2,182 (39.8%) had a vitamin D deficiency [25(OH)D < 15 ng/ml]. The average BMI and WM were 23.75 ± 3.43 kg/m² and 81.25 ± 9.81 cm, respectively. The mean values of TC, TG, and HDL-C were 189.81 ± 36.05 mg/dl, 130.12 ± 89.50 mg/dl, and 51.64 ± 12.61 mg/dl, respectively. The mean value of FBS was 106.2 ± 27.2 mg/dl. The mean values of SBP and DBP were 119.91 ± 17.24 mmHg and 75.66 ± 10.50 mmHg, respectively.

Serum 25(OH)D levels by subject characteristics. Serum 25(OH)D levels by subject characteristics are shown in Table 2. Serum 25(OH)D levels were higher ($p < 0.001$) in older participants and lower ($p < 0.001$) among women (16.27 ± 5.55 ng/ml) than men (17.94 ± 5.59 ng/ml). They were higher ($p = 0.015$) in the obese group (17.02 ± 5.83 ng/ml) than the normal-weight group (16.51 ± 5.17 ng/ml) and higher ($p = 0.021$) in the high TC group (17.21 ± 5.37 ng/ml) than the normal TC group (16.51 ± 5.17 ng/ml). In terms of components of metabolic syndrome, serum 25(OH)D levels were lower ($p = 0.015$) in the reduced HDL-C group (16.74 ± 5.65 ng/ml) than the normal HDL-C group (17.11 ± 5.61 ng/ml) and lower ($p < 0.001$) in the elevated FBS group (16.69 ± 5.51 ng/ml) than the normal FBS group (17.63 ± 5.84 ng/ml). However, they were higher in the elevated blood pressure group (17.45 ± 5.70 ng/ml) than the normal blood pressure group (16.89 ± 5.61 ng/ml) ($p = 0.004$). Elevated TG and abdominal obesity showed no significant difference in mean differences of serum 25(OH)D levels.

Comparisons of serum 25(OH)D levels for metabolic syndrome and MSS. Comparisons of serum 25(OH)D levels for metabolic syndrome and MSS are shown in Table 3. In terms of serum 25(OH)D levels by MSS values, serum 25(OH)D levels were 16.49 ± 5.48 ng/ml for MSS 0, 17.15 ± 5.78 ng/ml for MSS 1, 17.44 ± 5.79 ng/ml for MSS 2, 17.13 ± 5.39 ng/ml for MSS 3, 17.00 ± 5.65 ng/ml for MSS 4, and 15.84 ± 5.34 ng/ml for MSS 5. Serum 25(OH)D levels increased as MSS increased between MSS 0 and 2 but decreased as MSS increased beyond MSS 2 ($p < 0.001$). However, in terms of serum 25(OH)D levels by MSS values after

Table 1. General characteristics of research subjects (*n* = 5,483)

Variable	Category	<i>n</i> (%)	Mean ± SD
Age (year)	20–29	565 (10.3)	51.90 ± 16.73
	30–39	959 (17.5)	
	40–49	971 (17.7)	
	50–59	1,075 (19.6)	
	60–69	987 (18.0)	
	70–79	789 (14.4)	
	≥80	137 (2.5)	
Gender	Male	2,330 (42.5)	
	Female	3,153 (57.5)	
Metabolic syndrome score (MSS)	MSS 0	1,476 (26.9)	1.58 ± 1.36
	1	1,426 (26.0)	
	2	1,184 (21.6)	
	3	830 (15.1)	
	4	443 (8.1)	
	5	124 (2.3)	
Metabolic syndrome	MSS <3	4,086 (74.5)	
	MSS ≥3	1,397 (25.5)	
25(OH)D (ng/ml)	<15	2,182 (39.8)	16.99 ± 5.63
	≥15	3,301 (60.2)	
Height (cm)			161.74 ± 9.41
Weight (kg)			62.34 ± 11.75
BMI (kg/m ²)			23.75 ± 3.43
WM (cm)			81.25 ± 9.81
TC (mg/dl)			189.81 ± 36.05
TG (mg/dl)			130.12 ± 89.50
HDL-C (mg/dl)			51.64 ± 12.61
FBS (mg/dl)			98.86 ± 21.75
SBP (mmHg)			119.91 ± 17.24
DBP (mmHg)			75.66 ± 10.50

25(OH)D, 25-hydroxyvitamin D; BMI, body mass index; WM, waist measurement; TC, total cholesterol; TG, triglyceride; HDL-C, HDL-cholesterol; FBS, fasting blood sugar; SBP, systolic blood pressure; DBP, diastolic blood pressure.

adjusting for age, gender, BMI, TC, HDL-C, FBS, SBP, and DBP, etc., serum 25(OH)D levels were 17.50 ± 0.21 ng/ml for MSS 0, 17.22 ± 0.15 ng/ml for MSS 1, 16.97 ± 0.16 ng/ml for MSS 2, 16.43 ± 0.23 ng/ml for MSS 3, 16.21 ± 0.33 ng/ml for MSS 4, and 15.01 ± 0.56 ng/ml for MSS 5, showing that serum 25(OH)D levels decreased as MSS increased (*p* = 0.004). In terms of serum 25(OH)D levels by metabolic syndrome status, the difference in serum 25(OH)D level between the metabolic and non-metabolic syndrome groups was not significant (*p* = 0.887) with 16.97 ± 5.48 ng/ml and 16.99 ± 5.69 ng/ml, respectively. However, after adjusting for age, gender, BMI, TC, HDL-C, FBS, SBP, and DBP, etc., serum 25(OH)D levels were significantly lower (*p* = 0.004) in the metabolic syndrome group (16.49 ± 0.19 ng/ml) than the non-metabolic syndrome group (17.16 ± 0.09 ng/ml).

Comparisons of odds ratios of vitamin D deficiency by metabolic syndrome and MSS. Comparisons of ORs of vitamin D deficiency by metabolic syndrome and MSS are shown in Table 4. ORs of vitamin D deficiency by MSS with MSS 0 as a reference group showed significant for MSS 1 [95% confidence interval (CI), 0.70–0.94], MSS 2 [0.69 (95% CI, 0.59–0.80)], MSS 3 [0.75 (95% CI, 0.63–0.89)], and MSS 4 [0.79 (95% CI, 0.64–0.98)]. However, the OR for MSS 5 was not significant [1.29 (95% CI, 0.90–1.87)]. After adjusting for age, gender, BMI, TC, HDL-C, FBS, SBP, and DBP, etc., the ORs of vitamin D deficiency with MSS 0 as a reference group were not significant for MSS 1 [1.10 (95% CI, 0.92–1.31)] and MSS 2 [1.13 (95% CI, 0.91–1.42)]. However, they were significant for MSS 3 [1.36 (95% CI, 1.03–1.79)], MSS 4 [1.49 (95% CI, 1.04–2.12)], and

MSS 5 [2.51 (95% CI, 1.53–4.12)]. In addition, the OR of vitamin D deficiency of the metabolic syndrome group compared to the non-metabolic syndrome group was not significant [0.96 (95% CI, 0.85–1.09)], but after adjusted for age, gender, BMI, TC, HDL-C, FBS, SBP, and DBP, etc., the OR of the metabolic syndrome group was significantly higher [1.24 (95% CI, 1.08–1.48)].

Discussion

The present study investigated the association between metabolic syndrome, MSS, and vitamin D using data from the fifth KNHANES conducted in 2012. There were several key findings of this study after adjustment for variables relevant to serum 25(OH)D. Metabolic syndrome and increased MSS scores were associated with a decrease in serum 25(OH)D levels and an increase in the ORs of vitamin D deficiency (Table 3 and 4).

Vitamin D deficiency is found in various populations worldwide in high proportions, and it is becoming a serious concern due to the health problems it causes.⁽³¹⁾ In particular, Korea has been reported to be one of the countries with severe vitamin D deficiency.^(32,33) Vitamin D is known to prevent cardiovascular disease, hypertension, diabetes, and osteoporosis,⁽³⁴⁾ and its deficiency is reported to lead to secondary parathyroid hyperparathyroidism due to the increase in parathyroid hormone levels in the blood, causing diabetes, elevated blood pressure, acceleration of atherosclerosis, cardiovascular calcification, etc.⁽¹⁷⁾ Each component of metabolic syndrome is a risk factor for coronary artery disease, and metabolic syndrome in which the components

Table 2. Serum 25(OH)D levels by subject characteristics (n = 5,483)

Variable	Category	25(OH)D (ng/ml) (Mean ± SD)	p value
Age (year)	20–29	14.66 ± 4.62	<0.001
	30–39	15.77 ± 4.94	
	40–49	16.13 ± 5.02	
	50–59	17.52 ± 5.50	
	60–69	18.52 ± 6.10	
	70–79	18.23 ± 6.19	
	≥80	18.33 ± 6.07	
Gender	Male	17.94 ± 5.59	<0.001
	Female	16.27 ± 5.55	
Body mass index (kg/m ²)	<25	16.51 ± 5.17	0.015
	≥25	17.02 ± 5.83	
Total cholesterol (mg/dl)	<200	16.84 ± 5.76	0.021
	≥200	17.21 ± 5.37	
Waist measurement (cm)	Normal ^a	16.96 ± 5.69	0.628
	Abdominal obesity ^b	17.03 ± 5.51	
Triglyceride (mg/dl)	Normal ^r	17.02 ± 5.73	0.352
	Elevated triglyceride ^s	16.87 ± 5.36	
HDL-cholesterol (mg/dl)	Normal ^e	17.11 ± 5.61	0.017
	Reduced HDL-C ^c	16.74 ± 5.65	
Fasting blood sugar (mg/dl)	Normal ⁿ	17.63 ± 5.84	<0.001
	Elevated FBS ^o	16.69 ± 5.51	
Blood pressure (mm/Hg)	Normal ^k	16.89 ± 5.61	0.004
	Elevated blood pressure ^l	17.45 ± 5.70	

^aWM <90 cm in male or <80 cm in female, ^bWM ≥90 cm in male or ≥80 cm in female, ^rTG <150 mg/dl, ^sTG ≥150 mg/dl, ^eHDL-C ≥40 mg/dl in male or ≥50 mg/dl in female, ^cHDL-C <40 mg/dl in male or <50 mg/dl in female, ⁿFBS <100 mg/dl, ^oFBS ≥100 mg/dl, ^kSBP <130 mmHg or DBP <85 mmHg, ^lSBP ≥130 mmHg or DBP ≥85 mmHg.

Table 3. Comparisons of serum 25(OH)D levels for metabolic syndrome and MSS (n = 5,483)

	25(OH)D (ng/ml)		25(OH)D (ng/ml)	
	Non-adjusted (Mean ± SD)	p value	Adjusted*(Mean ± SE)	p value
Metabolic syndrome score 0	16.49 ± 5.48	<0.001	17.50 ± 0.21	0.004
1	17.15 ± 5.78		17.22 ± 0.15	
2	17.44 ± 5.79		16.97 ± 0.16	
3	17.13 ± 5.39		16.43 ± 0.23	
4	17.00 ± 5.65		16.21 ± 0.33	
5	15.84 ± 5.34		15.01 ± 0.56	
Non-Metabolic syndrome	16.99 ± 5.69	0.887	17.16 ± 0.09	0.004
Metabolic syndrome	16.97 ± 5.48		16.49 ± 0.19	

*Adjusted for age, gender, BMI, TC, HDL-C, FBS, SBP, and DBP.

Table 4. Comparisons of odds ratios of vitamin D deficiency by metabolic syndrome and MSS (n = 5,483)

	Vitamin D deficiency		Vitamin D deficiency	
	[25(OH)D <15 ng/ml]		[25(OH)D <15 ng/ml]	
	Non-adjusted OR	p value	Adjusted* OR	p value
Metabolic syndrome score 0	1	0.005	1	0.309
1	0.81 (0.70–0.94)		1.10 (0.92–1.31)	
2	0.69 (0.59–0.80)		1.13 (0.91–1.42)	
3	0.75 (0.63–0.89)		1.36 (1.03–1.79)	
4	0.79 (0.64–0.98)		1.49 (1.04–2.12)	
5	1.29 (0.90–1.87)		2.51 (1.53–4.12)	
Non-metabolic syndrome	1	0.5	1	0.015
Metabolic syndrome	0.96 (0.85–1.09)		1.24 (1.08–1.48)	

*Adjusted for age, gender, BMI, TC, HDL-C, FBS, SBP, and DBP.

occur in a cluster with resistance to insulin is a useful indicator to identify groups at a high risk for cardiovascular disease and type 2 diabetes.^(35,36)

Among previous studies on vitamin D and metabolic syndrome, Lu *et al.*⁽²³⁾ reported that reduced serum 25(OH)D levels were associated with metabolic syndrome and its components, and in particular, obesity was highly associated with insulin resistance and serum 25(OH)D when compared to normal weight. In addition, among Korean studies, Kim *et al.*⁽²⁴⁾ reported that metabolic syndrome and hypertension were associated with serum 25(OH)D levels in a study of middle-aged Koreans. Moreover, Nam *et al.*⁽³⁷⁾ reported that serum 25(OH)D levels were significantly lower among those with obesity, abdominal obesity, and metabolic syndrome, in a study on the association between vitamin D and obesity in 713 adolescents aged 12–19. On the other hand, in a study with Jordanian adults aged 18 or older, Khader *et al.*⁽²⁶⁾ reported no correlation between serum 25(OH)D levels and metabolic syndrome and its components. Moreover, in a study on an obese population, Hjelmessaeth *et al.*⁽²⁷⁾ reported that serum 25(OH)D was not associated with metabolic syndrome. In addition, in a Korean study with 4,364 postmenopausal women, Chon *et al.*⁽²⁵⁾ reported that while elevated blood pressure, elevated TG, and reduced HDL-C showed significant associations with serum 25(OH)D levels, metabolic syndrome was not significantly related to serum 25(OH)D levels. It is believed that the inconsistencies in previous domestic and foreign studies on vitamin D and metabolic syndrome and its components are due to the fact that serum 25(OH)D levels vary across countries and races, and previous studies targeted specific age groups and populations, such as adolescents, the aged, postmenopausal women, the obese, and diabetics.

The present study used the data of the entire adult population aged 20 and older from the KNHANES data, which is representative of Koreans. The study results showed that serum 25(OH)D level of the metabolic syndrome group was lower than that of the non-metabolic syndrome group, but the difference was not significant ($p = 0.887$), and the OR of vitamin D deficiency did not increase significantly ($p = 0.500$). These results are consistent with previous studies^(25–27) that did not find significant differences in serum 25(OH)D levels related to metabolic syndrome status. However, in the results after adjustments for relevant variables that influence serum 25(OH)D, serum 25(OH)D level was significantly lower in the metabolic syndrome group than the non-metabolic syndrome group ($p = 0.004$), and the OR of vitamin D deficiency increased significantly to 1.24 (95% CI, 1.08–1.48). These results were similar to the research of Moy and Bulgiba.⁽³⁸⁾ Their results show that prior to multivariable adjustment, metabolic syndrome was not significantly related to the OR of vitamin D deficiency [1.29 (95% CI, 0.82–2.02)], but after multivariable adjustment, the OR of vitamin D deficiency had increased significantly to 1.73 (95% CI, 1.02–2.92).

Not only metabolic syndrome defined by NCEP-ATP III standards, the present study examined serum 25(OH)D levels for increases in metabolic syndrome components. In the results after the adjustment for relevant variables, serum 25(OH)D levels significantly decreased with the increase in metabolic syndrome components ($p = 0.004$). In addition, after the adjustment for relevant variables, the ORs of vitamin D deficiency increased

significantly with MSS for MSS 3, MSS 4, and MSS 5 compared to MSS 0, although the ORs for MSS 1 and MSS 2 were not statistically significant. Among the components of metabolic syndrome, the variables such as reduced HDL-C ($p = 0.017$), elevated FBS ($p < 0.001$), and elevated blood pressure ($p = 0.004$) showed a significant difference in serum 25(OH)D levels, but abdominal obesity and elevated TG did not show a significant difference. In addition, the serum 25(OH)D levels of the reduced HDL-C group and the elevated FBS group were lower than the normal groups, but the elevated blood pressure group showed a higher result than the normal group. However, if the components occur simultaneously, they decrease the serum 25(OH)D levels and increase the OR of vitamin D deficiency. Currently, research on the association between vitamin D and the increase of metabolic syndrome components is lacking. In a cross-sectional study, although only two components (abdominal obesity and elevated TG) were associated with serum 25(OH)D levels, the serum 25(OH)D levels were inversely associated with the increase of metabolic syndrome components ($p = 0.009$).⁽³⁸⁾ In another cross-sectional study, although not all components were significantly associated with serum 25(OH)D levels, an increase of metabolic syndrome components was significantly inversely associated with serum 25(OH)D ($p = 0.02$).⁽³⁹⁾ The association between vitamin D and individual components of metabolic syndrome varies between countries and races. Although individual components may not be associated with vitamin D, increases of its components were inversely associated with the serum vitamin D concentration. It is unclear whether metabolic syndrome increased the incidence of vitamin D deficiency, or vitamin D deficiency increased the incidence of metabolic syndrome. Furthermore, the association between metabolic syndrome and vitamin D is still debated.

In the present study results, metabolic syndrome was associated with a decrease in serum 25(OH)D levels and an increase in the OR of vitamin D deficiency. As one of the reason for these results, we are thought that serum 25(OH)D levels are decreased with the components of metabolic syndrome increasing.

The present study has a few limitations. The serum 25(OH)D varies across seasons, but the data of the KNHANES V-3 did not specify serum 25(OH)D levels for each season. The data of the KNHANES V-3 was also not measure the parathyroid hormone (PTH) of these participants. The serum 25(OH)D levels for each season and PTH should be included as variables of vitamin D status in future studies. Other factors associated with vitamin D status such as dietary survey, physical activity, and lifestyle should also be included in future studies. Although the present study has limitations of these, this is the first reported study to determine the relationship between the metabolic syndrome and the increase of its components and vitamin D deficiency in Korea adults. Therefore, more accurate results might be obtained by performing a cohort study by adding these variables.

Conflict of Interest

We have not received any financial support or other benefits from commercial sources for the work reported in the manuscript. None of the authors have financial interests that could create a potential conflict of interest or appearance of a conflict of interest with regard to this work.

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