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The association between visceral fat, subcutaneous fat and serum 25-hydroxyvitamin D3 levels

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ABSTRACT

Aims: Obesity has been reportedly related with vitamin D deficiency. This study aims to elucidate a relationship between subcutaneous fat, visceral fat, and serum vitamin D levels.

Methods: We used the check-up data from a university hospital located in Daegu, Republic of Korea, from January 2017 to December 2017. A total of 467 adults who had both abdominal computed tomography (CT) scan and serum 25-hydroxyvitamin D (25(OH)D) test were included. Subcutaneous fat area (SFA) and visceral fat area (VFA) were calculated from single slice CT scan. Study participants were classified according to VFA using cutoff value of 100 cm^2 and 200 cm^2; normal, mild and severe visceral obesity. Vitamin D deficiency was defined as serum 25(OH)D levels lower than 20 ng/mL.

Results: Both SFA and VFA were inversely associated with serum 25(OH)D levels in multivariate linear regression, which is confined to men. An increased chance of vitamin D deficiency was observed in men with severe visceral obesity (OR = 2.49, 95% confidence interval [CI], 1.08–5.73). No significant associations were observed in women.

Conclusions: SFA and VFA were both associated with lower serum 25(OH)D levels. Severe visceral obesity was shown to increase the risk of vitamin D deficiency.

1. Introduction

Vitamin D is obtained from exposure to sunlight, diet, and dietary supplements for humans. Solar ultraviolet B radiation (wavelength, 290–315 nm) penetrates the skin and converts 7-dehydrocholesterol to previtamin D3, and it is rapidly converted to vitamin D3(Bouillon, 2001; DeLuca, 2004; Holick, 2006). Vitamin D obtained from exposure to sunlight and diet is metabolized in the liver to 25-hydroxyvitamin D (25(OH)D), which is used to assess a patient's serum vitamin D status. Vitamin D has been associated with bone health via calcium homeostasis, and its deficiency can lead to rickets, osteomalacia, or fractures (Lips, 2006; Taylor et al., 2017; Wintermeyer et al., 2016). In addition to bones, brain, prostate, breast, and colon tissues and immune cells have a vitamin D receptor, and they respond to 1,25-dihydroxyvitamin D, the active form of vitamin D. In these tissues and cells, vitamin D acts in various ways(Bouillon, 2001; DeLuca, 2004; Dusso et al., 2005; Holick, 2006). Furthermore, the associations between vitamin D as well as obesity and several clinical outcomes correlated to obesity, such as cardiovascular diseases, type 2 diabetes mellitus, and metabolic syndrome, have been reported(Poole et al., 2006; Taylor et al., 2017; Wimalawansa, 2018). Though the results have been contradictory and inconclusive (Taylor et al., 2017), several studies have shown a significant inverse association between vitamin D deficiency and obesity.

Adipose tissue is the primary storage site for vitamin D3 and its metabolites. Moreover, key enzymes involved in the activation and degradation of vitamin D 3 have been observed in the adipose tissue (Abbas, 2017; Ding et al., 2012). Regarding enzyme activation, the expression of vitamin D activating enzymes are reduced in obese individuals, which can lead to reduced activation of vitamin D(Wamberg et al., 2013). In addition, since vitamin D3 binds tightly to adipose tissues, its bioavailability can be decreased in obese individuals (Wortsman et al., 2000).

Although the inverse association between obesity and serum vitamin D level has been assessed, whether its association differs according to fat distribution has been assessed in only few studies, and the results were conflicting. Thus, we aimed to investigate the relationship between obesity and serum vitamin D levels using abdominal obesity that is analyzed in detail as visceral and subcutaneous fats.

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2. Subjects, material and methods

2.1. Data collection and study participants

This study was based on the data acquired during the health screening conducted at a university hospital located in Daegu, Republic of Korea, from January 2017 to December 2017. We included participants who underwent both abdominal computed tomography (CT) scan and serum 25(OH)D test. Participants with prescribed osteoporosis medications were excluded. Finally, 467 adults aged 25–79 years were included in the analyses.

2.2. Demographic characteristics and lifestyles habits of participants

The participants were interviewed about their demographic characteristics and lifestyle habits using a self-administered questionnaire. Physical activity was categorized as none, low-intensity exercise, and moderate-vigorous intensity exercise according to the average intensity and frequency of exercise within the last year. Those who responded none to the questions, such as “How many days a week did you do strenuous exercise for more than 20 min a day?”, “How many days a week did you do moderate intensity exercise which needs more effort than usual activity for more than 30 min a day?”, and “How many days a week did you walk for more than 30 min a day?” were classified in the none group. Meanwhile, those who reported 3 or more days of strenuous exercise or more than 5 days of moderate intensity exercise were categorized in the moderate-vigorous intensity exercise group, and the other participants not included in either the none and moderate-vigorous intensity exercise group classified in the low-intensity exercise group. Regarding smoking, the participants were categorized as non-smoker, previous smoker, and current smoker. Non-smokers were defined as those who have never smoked or smoked less than 100 cigarettes in their lifetime. The participants who reportedly smoked in the past but quit smoking were classified as previous smokers. Those who were still smoking were categorized as current smokers. Alcohol consumption was assessed according to the frequency and amount of alcohol intake. High-risk alcohol consumption was defined as drinking alcohol more than twice a week, with an average amount per drink of 7 or more glasses in men, and or 5 or more glasses in women. Comorbidities such as hypertension, diabetes, dyslipidemia, and cancers, were also assessed. In women, menopausal status was assessed based on the answers to the question, “Do you have regular menstrual periods?”. Those who responded no were considered to be menopausal.

2.3. Determination of SFA and VFA on CT scan

Subcutaneous fat area (SFA) and visceral fat area (VFA) were quantified based on abdominal CT scan images. Transverse views at the level of the lowest to the highest part of the umbilicus, which is near the L4–L5 vertebral interspace, were selected for the calculation of SFA and VFA using the Aquarius iNtuition software program (TeraRecon, Foster City, CA). Visceral obesity was defined as a VFA greater than 100 cm^2 and classified into two groups (mild visceral obesity and severe visceral obesity) using the cutoff values of 100 and 200 cm^2. Abdominal obesity was defined as a waist circumference greater than 90 cm for men and greater than 85 cm for women(Alberti et al., 2005).

2.4. Assessment of vitamin D status and measurement of covariates

Vitamin D status was evaluated using serum 25(OH)D levels. Serum 25(OH)D was measured by chemiluminescent immunoassay with DiaSorin Inc. solution using LIAISON® analyzer. According to the American endocrine society guideline (Holick et al., 2011), vitamin D deficiency was defined as a 25(OH)D level lower than 20 ng/mL. Since sun exposure is an important factor for subcutaneous vitamin D synthesis, we assessed the season when the study participants underwent the health screening. Regarding anthropometric measurement, height and weight were measured using a standard method to the nearest 0.1 cm for height and 0.1 kg for weight. Waist circumference was measured at the midpoint between the lowest level of the ribs and iliac crest. Body mass index (BMI) was estimated by dividing weight in kilograms by height in meters squared. Body fat percentage was also obtained using a body composition analyzer.

Blood pressure was measured using an automatic sphygmomanometer in the right arm in sitting position after 5 min of resting. The average systolic blood pressure and diastolic blood pressure were obtained after repeated measurement. Blood samples were obtained in the morning after an overnight fast. Fasting glucose level, hemoglobin A1C level, and lipid profiles were assessed.

2.5. Statistical analyses

All analyses were conducted using IBM SPSS version 19.0 (IBMCo., Armonk, NY, USA). Chi-square test and one-way analysis of variance were used to compare the baseline characteristics of the participants according to vitamin D status and gender. A simple linear regression was performed to examine the correlation between serum 25(OH)D level and clinical variables. A multiple linear regression was utilized to examine the association between serum 25(OH)D level and obesity. Since the serum 25(OH)D values were not normally distributed in the study participants, they were log transformed to obtain a normal distribution for the analyses. We adjusted for age, season, smoking, alcohol consumption, and physical activity to examine the independent association between serum 25(OH)D level and obesity. In women, menopausal status was additionally adjusted. To examine the association between vitamin D deficiency and visceral obesity, a multivariate logistic regression analysis was performed. A P-value less than 0.05 was considered statistically significant.

3. Results

3.1. Characteristics of the study population

Table 1 shows the baseline characteristics of the study population according to gender and vitamin D status. A total of 326 men and 130 women were included in this study. Among them, 62.6% of men and 73.1% of women were vitamin D deficient. No differences were observed in terms of height, weight, waist circumference, and BMI in both men and women according to vitamin D status. However, in men with vitamin D deficiency, body fat percentage was 26.1 ± 5.2%, and VFA was 147.0 ± 62.2 cm^2 which was significantly higher than those with normal vitamin D status. (body fat percentage: 24.8 ± 5.0%, VFA: 130.0 ± 56.0 cm^2) Moreover, abdominal obesity was more prevalent in the group with vitamin D deficiency (34.8%) than in the group with normal vitamin D status (22.1%). However, no significant differences were observed in such factors in women according to vitamin D status. Regarding SFA and visceral obesity, no significant differences were observed in both men and women according to vitamin D status.

Similarly, no differences were noted in the blood pressure, fasting glucose level, hemoglobin A1C, and HDL cholesterol level of both men and women according to vitamin D status. However, in both men and women, triglyceride level was significantly higher in the group with vitamin D deficiency than in the group with normal vitamin D status. (men: 150.0 ± 101.1 mg/dL vs 112.2 ± 65.8, women: 94.5 ± 58.3 mg/dL vs 72.8 ± 30.5 mg/dL) Moreover, in men, LDL cholesterol level was higher in participants with vitamin D deficiency than in those with normal vitamin D status. (130.0 ± 36.3 mg/dL vs 117.8 ± 33.0 mg/dL) However, this difference was not observed in women.

No significant differences were noted in terms of season when the study participants underwent the health screening according to vitamin D status in both men and women. However, in men, the number of

Table 1
Baseline characteristics of study population (N = 456) according to gender and vitamin D status.

	Men			Women		
	Normal	Vitamin D deficiency	P-value	Normal	Vitamin D deficiency	P-value
N (%)	122 (37.4)	204 (62.6)		35 (26.9)	95 (73.1)	
Age (yr)	55.6 ± 8.8	52.4 ± 9.4	0.002	57.9 ± 8.1	54.5 ± 9.4	0.058
Height (cm)	169.3 ± 5.7	170.0 ± 5.7	0.318	156.7 ± 4.6	157.1 ± 6.4	0.757
Weight (kg)	71.5 ± 9.2	73.1 ± 11.0	0.158	56.1 ± 8.9	57.7 ± 8.3	0.340
Waist circumference (cm)	85.3 ± 6.2	86.4 ± 7.6	0.151	76.0 ± 8.1	76.4 ± 8.1	0.828
Body mass index (kg/m^2)	24.9 ± 2.5	25.3 ± 3.2	0.271	22.9 ± 3.5	23.4 ± 3.2	0.390
Body fat percentage (%)	24.8 ± 5.0	26.1 ± 5.2	0.026	33.1 ± 6.3	34.4 ± 6.1	0.278
Visceral fat area (cm^2)	130.0 ± 56.0	147.0 ± 62.2	0.014	77.5 ± 42.0	83.3 ± 44.6	0.509
Subcutaneous fat area (cm^2)	120.5 ± 50.6	130.6 ± 54.9	0.100	137.1 ± 64.3	146.6 ± 58.0	0.423
Abdominal obesity, n (%)	27 (22.1)	71 (34.8)	0.016	4 (11.4)	16 (16.8)	0.448
Visceral obesity, n (%)			0.054			1.000
Mild visceral obesity	71 (58.2)	117 (57.4)		11 (31.4)	29 (30.5)	
Severe visceral obesity	13 (10.7)	37 (18.1)		0 (0)	1 (1.1)	
Systolic blood pressure (mmHg)	121.9 ± 11.9	121.9 ± 11.3	0.962	118.1 ± 16.3	121.5 ± 11.4	0.189
Diastolic blood pressure (mmHg)	78.5 ± 8.7	77.8 ± 8.2	0.475	75.3 ± 9.8	76.9 ± 7.2	0.324
Fasting glucose (mg/dL)	102.4 ± 20.1	104.5 ± 28.5	0.469	93.5 ± 14.8	96.6 ± 18.7	0.375
Hemoglobin A1C (%)	5.7 ± 0.6	5.8 ± 1.0	0.145	5.6 ± 0.4	5.6 ± 0.5	0.899
Triglycerides (mg/dL)	112.2 ± 65.8	150.0 ± 101.1	< .001	72.8 ± 30.5	94.5 ± 58.3	0.038
HDL cholesterol (mg/dL)	51.8 ± 14.0	49.0 ± 11.7	0.055	62.5 ± 16.9	60.1 ± 14.6	0.431
LDL cholesterol (mg/dL)	117.8 ± 33.0	130.0 ± 36.3	0.002	115.8 ± 31.9	128.5 ± 33.7	0.056
Season, n (%)			0.120			0.068
Spring	16 (13.1)	39 (19.1)		6 (17.1)	13 (13.7)	
Summer	42 (34.4)	43 (21.1)		10 (28.6)	23 (24.2)	
Fall	46 (37.7)	57 (27.9)		15 (42.9)	23 (24.2)	
Winter	18 (14.8)	65 (31.9)		4 (11.4)	36 (37.9)	
Physical activity, n (%)			0.936			0.523
None	13 (10.7)	20 (9.8)		4 (11.4)	13 (13.7)	
Low-intensity exercise	72 (59.0)	125 (61.3)		17 (48.6)	54 (56.8)	
Moderate to vigorous exercise	37 (30.3)	59 (28.9)		14 (40.0)	28 (29.5)	
Smoking, n (%)		24 (12.1)	0.019			0.625
Never smoker	18 (15.0)	81 (40.7)		32 (94.1)	83 (94.3)	
Ex-smoker	64 (53.3)	94 (47.2)		0 (0)	3 (3.4)	
Current smoker	38 (31.7)	77 (37.7)		2 (5.9)	2 (2.3)	
High-risk alcohol consumption, n (%)	44 (36.1)	NA	0.761	1 (2.9)	3 (3.2)	1.000
Menopausal state, n (%)	NA			31 (88.6)	63 (66.3)	0.012
Comorbidities, n (%)		51 (25.0)				
Hypertension	37 (30.3)	27 (13.2)	0.294	6 (17.1)	16 (16.8)	0.968
Diabetes	16 (13.1)	47 (23.0)	0.975	4 (11.4)	8 (8.4)	0.733
Dyslipidemia	23 (18.9)	10 (4.9)	0.373	10 (28.6)	14 (14.7)	0.071
Any cancers	5 (4.1)		0.738	3 (8.6)	5 (5.3)	0.443

Data are shown as mean ± SD or number (percentage).

current smokers was higher in the group with vitamin D deficiency than in the group with normal vitamin D status. This difference was not observed in women. Regarding menopausal status, the number of menopausal women in the group with vitamin D deficiency was relatively low.

3.2. Correlations between serum 25(OH)D level and clinical variables

Table 2 shows the correlations between serum 25(OH)D level and clinical indicators. In all study participants regardless of gender, age was positively associated with serum 25(OH)D level. By contrast, body fat percentage, triglyceride level, and LDL cholesterol level were inversely associated with serum 25(OH)D level. In men, VFA and SFA were inversely associated with serum 25(OH)D level, which was not observed in women or in all study participants. In addition, a positive association was observed between serum 25(OH)D and HDL cholesterol levels in men. However, no clinical indicators were significantly associated with serum 25(OH)D level in women.

3.3. Associations between serum 25(OH)D and clinical measures of obesity

Table 3 shows the associations between serum 25(OH)D level and some obesity indicators according to gender. Waist circumference, BMI, body fat percentage, VFA, and SFA were used as obesity indicators.

Table 2
Simple linear regression of serum 25(OH)D[a] and clinical variables.

	All	Men	Women
Age (yr)	0.006**	0.007**	0.005
Height (cm)	0.004	−0.002	0.003
Weight (kg)	0.001	−0.003	0.000
Waist circumference (cm)	0.001	−0.004	0.002
Body mass index (kg/m^2)	−0.002	−0.009	−0.003
Body fat percentage (%)	−0.011***	−0.011**	−0.008
Visceral fat area (cm^2)	0.000	−0.001*	−0.001
Subcutaneous fat area (cm^2)	−0.001*	−0.001**	0.000
Systolic blood pressure (mmHg)	−0.001	−0.001	−0.001
Diastolic blood pressure (mmHg)	0.002	0.001	0.003
Fasting glucose (mg/dL)	0.000	0.000	−0.001
Hemoglobin A1C (%)	−0.020	−0.027	−0.028
Triglycerides (mg/dL)	−0.001**	−0.001***	−0.001
High-density lipoprotein cholesterol (mg/dL)	0.033	0.004*	0.005
Low-density lipoprotein cholesterol (mg/dL)	−0.001*	−0.001*	−0.002

Data are shown as β.
*P < 0.05, **P < 0.01, ***P < 0.001.
[a] Log-25(OH)D was used for simple linear regression analysis.

Table 3
Multivariate adjusted[a] association between serum 25(OH)D[b] and clinical measures of obesity.

	Men		Women	
	β	P-value	β	P-value
Waist circumference (cm)	−0.006	0.058	−0.003	0.666
Body mass index (kg/m^2)	−0.011	0.148	−0.016	0.292
Body fat percentage (%)	−0.013	0.002	−0.015	0.081
Visceral fat area (cm^2)	−0.001	0.004	−0.002	0.165
Subcutaneous fat area (cm^2)	−0.001	0.016	0.000	0.615

Data are shown as β.
[a] Adjusted for age, season, smoking, alcohol consumption, and physical activity. Menopausal state was additionally adjusted for women.
[b] Log-25(OH)D was used for multivariate linear regression analysis.

Possible confounding factors, such as age, season, smoking, alcohol consumption, and physical activity were adjusted for the analysis. Menopausal status was additionally adjusted for women. In men, the coefficient β for serum 25(OH)D level was −0.013 in body fat percentage, and −0.001 in both VFA, and SFA. However, no significant associations were observed in women.

3.4. Associations between vitamin D deficiency and visceral obesity in men

Table 4 shows the adjusted odds ratios (OR) for vitamin D deficiency according to the classification of visceral obesity in men. Among the 326 male participants, 188 (57.7%) presented with mild visceral obesity, and 50 (15.3%) had severe visceral obesity. As shown in models 1 and 2, severe visceral obesity increased the risk of vitamin D deficiency compared with who did not have visceral obesity even after adjusting for age, season, smoking, alcohol consumption, and physical activity. (adjusted OR: 2.49, 95% CI: 1.08–5.73) However, no significant associations were observed in any of models assessed for mild visceral obesity.

4. Discussion

In this study, both VFA and SFA were inversely associated with serum 25(OH)D levels in men. In addition, visceral obesity, which is defined as a VFA greater than 100 cm^2, also increased the risk of vitamin D deficiency. However, statistical significance was only observed in participants with severe visceral obesity.

In this study population, the prevalence of vitamin D deficiency was 62.6% in men and 73.1% in women. This is relatively low compared with that of the general Korean population at 2014, 75.2% in men and 82.5% in women(Park et al., 2018). Considering that the study population only included those who underwent the health examination in Daegu, a southern city in Korea, the amount of sun exposure might be greater in this population compared with that of the general Korean population(Cho, 2011). In addition, those who underwent checkups are likely to take more vitamin D supplements for their health.

When the study population characteristics are compared according to vitamin D status and gender, the group with normal vitamin D status was older, compared with the group of vitamin D deficiency especially in men. This might reflect the trend that older people tend to take more dietary supplements including vitamin D. Since this can considerably affect the results, as mentioned in the methods section, we adjusted age for the analyses. In addition body fat percentage, VFA, and the prevalence of abdominal obesity were higher in those with vitamin D deficiency, although this was only observed in men. In addition, regarding the metabolic risk factors, serum triglyceride levels were significantly higher in individuals with vitamin D deficiency than in those without vitamin D deficiency in both men and women. Serum LDL cholesterol level was also elevated in the group with vitamin D deficiency, although this was only observed in men. The inverse association between serum 25(OH)D level and metabolic risk factors, including obesity, has already been reported in several studies (Aasheim et al., 2008; Abbas, 2017; Cheng et al., 2010; Shin et al., 2015), which led to the increased risk of metabolic syndrome or diabetes in individuals with vitamin D deficiency(Wimalawansa, 2018).

The relationship between vitamin D and obesity was first suggested in early 1970s in an experimental study of rats(Rosenstreich et al., 1971). When supplementing radioactive vitamin D to vitamin D-deficient weanling rats, the highest amount of radioactivity during the experimental period was observed in the adipose tissue, which led to a low serum 25(OH)D level. In another study of rats, a high calcium diet inhibits adipocyte fatty acid synthesis and stimulates lipolysis. This was further evaluated epidemiologically by the same research team, which showed a significant inverse association between calcium intake and body fat(Zemel et al., 2000). Since these results were reported, several studies have examined the underlying mechanisms associated with the relationship between vitamin D and body composition as well as the role of vitamin D in obesity(Song and Sergeev, 2012).

Some studies have shown that 1α,25(OH)$_2$-D3, which is the biologically active form of vitamin D, inhibits preadipocyte differentiation and fatty acid synthesis in 3T3-L1 adipocytes at the gene expression level(Kong and Li, 2006; Lee et al., 2005). Moreover, 1α,25(OH)$_2$-D3 is also involved in adipocyte apoptosis. However, results about the effects of 1α,25(OH)$_2$-D3 on adipogenesis have been conflicting owing to the study design and different species used in previous studies(Abbas, 2017). Recent studies have also shown that vitamin D regulates the secretion of adipokines, such as leptin and adiponectin, which are involved in energy homeostasis(Abbas, 2017). Since the chronic stimulation of immune cells may be associated with the pathogenesis of obesity (Cinti et al., 2005; Lolmede et al., 2011), the anti-inflammatory effects of vitamin D mediated by some immune cells can partially explain the association between vitamin D and obesity(Abbas, 2017; Ding et al., 2012).

Considering that excess visceral fat may be a key factor in the pathogenesis of metabolic syndrome (Hiuge-Shimizu et al., 2012; Sato et al., 2017) and low vitamin D level has also been associated with metabolic syndrome (Taylor et al., 2017), VFA rather than SFA might be more significantly associated with vitamin D deficiency. However, in contrast to the initial assumption that the association between vitamin D and obesity might be different according to body fat distribution, both SFA and VFA were inversely associated with serum 25(OH)D levels in this study. Similarly, in a large cohort study, 25(OH)D level was

Table 4
Adjusted odds ratios (OR) for vitamin D deficiency according to the classification of visceral obesity in men (N = 326).

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Normal (N = 88)	1.00	1.00	1.00
Mild visceral obesity (N = 188)	1.24 (0.73–2.09)	1.32 (0.77–2.28)	1.37 (0.77–2.43)
Severe visceral obesity (N = 50)	2.32 (1.07–5.03)	2.23 (1.00–4.94)	2.49 (1.08–5.73)

Model 1: Adjusted for age.
Model 2: Adjusted for age, and season.
Model 3: Adjusted for age, season, smoking, alcohol consumption, and physical activity.

inversely associated with both visceral adipose tissue (VAT) (− 2.3 ng/mL per SD increment in VAT, $p < 0.0001$) and subcutaneous adipose tissue (SAT) (− 1.1 ng/mL per SD increment in SAT, $p = 0.016$) (Cheng et al., 2010).

By contrast, in a cross-sectional study of elderly Koreans, their serum 25(OH)D levels decreased by 0.002 ng/mL per 1 cm^2 of VFA, although SFA was not significantly associated with serum 25(OH)D levels(Seo et al., 2012). Similarly, in another cross-sectional study that elucidated the relationship between vitamin D as well as obesity and the risk for cardiovascular diseases, VAT lowered the serum 25(OH)D concentrations at 0.545 ng/mL per 1 cm^3 of VAT, although this inverse association was not observed in SAT(Shin et al., 2015). Compared to these studies, the present study included a broader age group and adjusted more health behavior-related factors, such as smoking, alcohol consumption, and physical activity, although all studies have evaluated the association between vitamin D and obesity in Korean populations.

In this study, the significant inverse association between body fat area and serum 25(OH)D levels was observed only in men. As shown in Table 1, since more men were involved in this study, relatively fewer women might affect the different results by gender. Besides, since several obesity parameters, such as the prevalence of abdominal obesity and visceral obesity, the average SFA and VFA were higher in men than in women (data not shown). These might affect the different results according to gender. Similarly, in a cross-sectional study of Chinese adults, increased visceral fat area was also associated with higher vitamin D insufficiency and deficiency, which was more prevalent in men than in women(Zhang et al., 2015). The relatively higher incidence of obesity and the prevalence of visceral obesity in men are the possible reasons associated with the association between obesity and vitamin D in terms of gender. By contrast, in a study of Korean men and women aged 65 years and older who have similar visceral fat levels, the inverse associations between vitamin D and VFA were evident in men only. Based on these findings, some differences in the efficacy of visceral fat in storing vitamin D according to gender may exist (Seo et al., 2012), although, this has not been examined.

The present study had several limitations despite the identification of VFA and SFA on CT scan, which is the most reproducible method (Sjostrom et al., 1986). First, the causal relationship between body fat area and vitamin D cannot be assessed owing to the cross-sectional nature of the study. In addition, since we targeted those who voluntarily received health checkups, selection bias might have affected the study, and the results observed in this study are not generalizable to the general Korean population. Although we excluded those who took osteoporosis medications from the study population to reduce the possible effects of vitamin D supplements and assessed for the season, which can also affect the serum 25(OH)D levels, other possible conditions, such as actual sun exposure time and vitamin D supplementation, not for osteoporosis, were not fully examined. Nevertheless, this study showed the definite relationship between visceral obesity and vitamin D deficiency in men, and this result may be used as a basis for encouraging men with abdominal obesity to increase their vitamin D supplementation because such vitamin D has various important actions in the body.

In conclusion, both VFA and SFA were inversely associated with serum 25(OH)D levels in Korean men. Considering the upward trend of obesity, particularly in men, and vitamin D deficiency in Korea, further evaluation must be conducted to elucidate the causality between body fat and vitamin D.

Conflicts of interest

None.

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