The association between gender difference with metabolic syndrome, metabolic syndrome score and serum vitamin D levels in Korean adults

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Abstract
This study assessed the association between gender difference with metabolic syndrome (MetS), metabolic syndrome score (MSS) and serum vitamin D levels in Korean adults. Analyses were restricted to 5147 adults (2162 men; 2985 women) aged 20 and older, using the 2012 Korean National Health and Nutrition Examination Survey (KNHANES) data. In the non-adjusted model, serum 25-hydroxyvitamin D [25(OH)D] levels were inversely associated with MetS ($p = .001$) and MSS ($p = .009$) in men, but positively associated with MetS ($p = .002$) and MSS ($p < .001$) in women. However, when adjusted for related variables (including age), serum 25(OH)D levels were inversely associated with MetS ($p < .001$) and MSS ($p < .001$) in men, but were not associated with MetS ($p = .200$) and MSS ($p = .541$) in women. In conclusion, increases in MetS and its components were inversely associated with the serum vitamin D concentration in men.

Introduction
Metabolic syndrome (MetS) is characterized by insulin resistance and defined as exhibiting more than three out of the five MetS components [elevated blood pressure (BP), elevated fasting blood glucose (FBG), elevated triglycerides (TGs), reduced high-density lipoprotein cholesterol (HDL-C), and abdominal obesity] (Reaven 1988). MetS can strongly predict diseases such as type 2 diabetes mellitus and cardiovascular disease because each of its components is a risk factor for cardiovascular disease (McNeill et al. 2005; Yoon et al. 2015). The prevalence of MetS in South Korea was 25.3% in 1998 (Korea Centers for Disease Control and Prevention 2008), but since then its prevalence has increased due to the increase in adoption of the westernized diet (Choi et al. 2009; Lee et al. 2009).

Vitamin D is synthesized in the skin through solar UV-B irradiation of 7-dehydrocholesterol and has a major role in the regulation of calcium homeostasis and bone metabolism by exerting its actions on target tissues, such as the kidney, intestine and bone. There are also suggestions that vitamin D alters muscle metabolism (Holick 2004). Vitamin D is a hormone precursor, vitamin D$_2$ is present in certain plants and animals such as mushrooms and mackerel, and vitamin D$_3$ is synthesized from 7-dehydrocholesterol in the skin by ultraviolet light (Prentice et al. 2008). 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 (Hollis & Horst 2007). Vitamin D deficiency is associated with several diseases, such as osteoporosis, insulin resistance and cardiovascular disease (Grundy et al. 2005; Kwon et al. 2008).

The association between vitamin D and MetS has been studied in populations worldwide. However, the association is still debatable with inconsistent results reported, depending on the ethnic group and country studied. Furthermore, these inconsistencies can be caused by gender differences. Most studies have used an adjustment variable rather than a method to separate gender (Chacko et al. 2011; Moy & Bulgiba 2011; Cheng et al. 2013; Chon et al. 2014), or studied one gender only (Khader et al. 2011; Mohammadi et al. 2015). In addition, the research on gender differences...
in these associations is rare. Therefore, the present study aimed to investigate the association between gender difference with MetS and vitamin D in adults aged 20 and older using the fifth Korean National Health and Nutrition Examination Survey (KNHANES) data obtained in 2012, which is representative of Korea.

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. KNHANES comprises a health interview survey, a health behavior survey, a health examination survey and a nutrition survey. Households as sampling units were stratified and collected through a multistage, probability-based sampling design based on sex, age and geographic area, using household registries. At the time each survey was done, participants provided written informed consent for use of their data in further analyses and were given the right to refuse to participate, in accordance with the National Health Enhancement Act. The KNHANES V-3 (2012) was performed from January 2012 to December 2012. In the KNHANES V-3 (2012), 8058 individuals over age one were sampled for the survey. Among them, of the 6221 subjects who participated in the KNHANES V-3, we limited the analyses to adults aged 21 years. We excluded 1074 subjects who were missing for important analytic variables, such as the serum 25(OH)D levels (738 subjects) and, various blood chemistry tests (336 subjects). Finally, 5147 subjects (men, 2162; women, 2985) were included in the statistical analysis. The KNHANES V–3 (2012) study has been conducted according to the principles expressed in the Declaration of Helsinki. (Institutional Review Board No, 2012-01EXP-01-2C). All participants in the survey signed an informed written consent form. Further information can be found in “The KNHANES V–3 (2012) Sample”, which is available on the KNHANES website. The data from KNHANES is available on request by email if the applicant logs onto the “Korea National Health and Nutrition Examination Survey” website.

General characteristics and blood chemistry

Research subjects were classified by gender and by age into 20–29 years, 30–39 years, 40–49 years, 50–59 years and 60 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), triglycerides (TGs), fasting blood glucose (FBG), 25(OH)D.

Serum 25(OH)D assessments

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] (Kim 2007).

Metabolic syndrome and metabolic syndrome score

Metabolic Syndrome (MetS) 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 TGs, HDL-C, blood pressure (BP), FBG, and WM. TGs over 150 mg/dl was set as the criteria for elevated TGs. The criteria for reduced HDL-C were HDL-C of less than 40 mg/dL and 50 mg/dL for men and women, respectively. FBG over 100 mg/dl was set as the criteria for elevated FBG. SBP over 130 mmHg or DBP over 85 mmHg were set as the criteria for elevated BP. The criteria for abdominal obesity were abdominal measurements of over 90 cm and 80 cm for men and women, respectively. FBG over 100 mg/dl was set as the criteria for elevated FBG. SBP over 130 mmHg or DBP over 85 mmHg were set as the criteria for elevated BP. The criteria for abdominal obesity were abdominal measurements of over 90 cm and 80 cm for men and women, respectively, according to the Asia-Pacific criteria (WHO 2000). The presence of defined abnormalities in any three of these five measures constitutes a diagnosis of MetS. The metabolic syndrome score (MSS) indicates the presence of abdominal obesity, elevated blood pressure, elevated FBG, elevated TGs, or reduced HDL-C. Subjects without any of the five risk factors received an MSS 0, and those with one, two, three and four or more of the risk factors received an MSS score of 1, 2, 3 and ≥4, respectively (Moon et al. 2008).
**Statistical analysis**

The collected data were statistically analyzed using SPSS WIN version 18.0 (SPSS Inc., Chicago, IL). The distributions of the participant characteristics were converted into percentages and the successive data were presented as means with standard deviations. The means difference in serum 25(OH)D for control subjects and the clinical elements of MetS were calculated using an analysis of variance and independent t-tests. The means difference in serum 25(OH)D for MetS and MSS was calculated using an analysis of covariance. Logistic regression analyses were performed to test the association between vitamin D deficiency, MetS and MSS. Several models were used to test the potential role of confounding factors, including (1) no adjustment; (2) adjusted for BMI and TC; (3) further adjusted for smoking, alcohol drinking, and regular exercise; (4) further adjusted for age. The significance level for all of the statistical data was set as \( p < .05 \).

**Results**

**General characteristics of research subjects**

The general characteristics of the research subjects are shown in Table 1. In men, according to the classification of coronary artery disease risk factors and the metabolic syndrome score (MSS) guidelines, 550 (25.4%), 565 (26.1%), 529 (24.5%), 332 (15.4%), and 186 (8.6%) subjects were classified as MSS 0, MSS 1, MSS 2, MSS 3, and MSS \( \geq 4 \), respectively, while the prevalence rate of MetS was 518 of the 1,626 patients (31.7%). The equivalent percentages in women were 864 (28.9%), 733 (24.6%), 590 (19.8%), 434 (14.5%), and 364 (12.2%) subjects classified as MSS 0, MSS 1, MSS 2, MSS 3, and MSS \( \geq 4 \), respectively, while the prevalence rate of MetS was 798 of the 2,985 patients (26.7%). The prevalence rate of vitamin D deficiency in men and women was 686 (31.7%) and 1382 (46.3%), respectively.

**Comparisons of the 25-hydroxyvitamin D levels based on the MetS components in men and women**

Comparisons of the 25-hydroxyvitamin D [25(OH)D] serum levels according to the MetS components in men and women are shown in Table 2. In men, serum 25(OH)D levels were lower (\( p < .001 \)) in the elevated TGs group (17.13 ± 5.26 ng/mL) than the normal TGs group (18.38 ± 5.75 ng/mL) and lower (\( p < .001 \)) in the reduced HDL-C group (17.02 ± 5.43 ng/mL) than the normal HDL-C group (18.21 ± 5.64 ng/mL). The MetS components, abdominal obesity, elevated FBG, and elevated BP in men showed statistically similar mean

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### Table 1. General characteristics.

| Variables | Category | Total \( (n = 5147) \) | Men \( (n = 2162) \) | Women \( (n = 2985) \) | \( p \) |
|-----------|----------|------------------------|----------------------|----------------------|--------|
| Age (years) | 20–29 | 554 (10.8) | 220 (10.2) | 334 (11.2) | .747 |
| | 30–39 | 927 (18.0) | 383 (17.7) | 544 (18.2) | |
| | 40–49 | 926 (18.0) | 395 (18.3) | 531 (17.8) | |
| | 50–59 | 995 (19.3) | 418 (19.3) | 577 (19.3) | |
| | ≥60 | 1745 (33.9) | 746 (34.5) | 999 (33.5) | |
| Smoking status | Non-smoker | 3239 (62.9) | 536 (24.8) | 2703 (90.6) | |
| | Ex-smoker | 949 (18.4) | 822 (38.0) | 127 (4.3) | |
| | Current smoker | 959 (18.6) | 804 (37.2) | 155 (5.1) | |
| Alcohol drinking | No | 2647 (51.4) | 716 (33.1) | 1931 (64.7) | <.001 |
| | Yes | 2500 (48.6) | 1446 (66.9) | 1054 (35.3) | |
| Physical activity | No | 4840 (94.0) | 2004 (92.7) | 2836 (95.0) | .001 |
| | Yes | 307 (6.0) | 158 (7.3) | 149 (5.0) | |
| cMSS | 0 | 1119 (21.7) | 529 (24.5) | 590 (19.8) | |
| | 1 | 1298 (25.2) | 565 (26.1) | 733 (24.6) | |
| | 2 | 1119 (21.7) | 529 (24.5) | 590 (19.8) | |
| | 3 | 766 (14.9) | 332 (15.4) | 434 (14.5) | |
| | ≥4 | 550 (10.7) | 186 (8.6) | 364 (12.2) | |
| MS | MSS < 3 | 3831 (74.4) | 1644 (76.0) | 2187 (73.3) | .024 |
| | MSS ≥ 3 | 1316 (25.6) | 518 (24.0) | 798 (26.7) | |
| 25(OH)D (ng/mL) | ≥15 | 3079 (59.8) | 1476 (68.3) | 1603 (53.7) | <.001 |
| | <15 | 2068 (40.2) | 686 (31.7) | 1382 (46.3) | |
| *BMI (kg/m²) | 23.7 ± 3.40 | 24.07 ± 3.14 | 23.51 ± 3.56 | <.001 |
| *WM (cm) | 81.09 ± 9.77 | 84.39 ± 8.72 | 78.71 ± 9.79 | <.001 |
| *SBP (mmHg) | 119.66 ± 17.09 | 121.93 ± 15.71 | 118.01 ± 17.84 | <.001 |
| *DBP (mmHg) | 75.89 ± 17.09 | 78.55 ± 10.81 | 73.97 ± 9.76 | <.001 |
| *TC (mg/dL) | 189.88 ± 36.17 | 187.61 ± 35.83 | 191.33 ± 36.33 | <.001 |
| *TG (mg/dL) | 130.33 ± 90.17 | 148.82 ± 110.16 | 116.93 ± 86.05 | <.001 |
| *HDL-C (mg/dL) | 51.74 ± 12.61 | 48.34 ± 11.55 | 54.21 ± 12.77 | <.001 |
| *FBG (mg/dL) | 98.68 ± 22.01 | 101.16 ± 23.10 | 96.89 ± 21.00 | <.001 |

*MS: metabolic syndrome score; **MS: metabolic syndrome; *BMI: body mass index; *WM: waist measurement; *SBP: systolic blood pressure; *DBP: diastolic blood pressure; *TC: total cholesterol; *TG: triglyceride; *HDL-C: HDL-cholesterol; *FBG: fasting blood glucose, M ± SD.
serum 25(OH)D levels. In women, serum 25(OH)D levels were higher \((p = .001)\) in the abdominal obesity group \((16.59 \pm 5.53 \text{ ng/mL})\) than the non-abdominal obesity group \((16.59 \pm 5.48 \text{ ng/mL})\), higher \((p < .001)\) in the elevated FBG group \((17.09 \pm 6.02 \text{ ng/mL})\) than the normal FBG group \((15.88 \pm 55.30 \text{ ng/mL})\), and higher \((p = .032)\) in the elevated BP group \((16.55 \pm 5.70 \text{ ng/mL})\) than the normal BP group \((16.06 \pm 5.44 \text{ ng/mL})\). The elevated TG and reduced HDL-C showed no significant difference in mean serum 25(OH)D levels.

**Comparison of serum 25(OH)D levels for MetS and MSS in men and women**

The comparison of serum 25(OH)D levels for MetS and MSS is shown in Figures 1 and 2. In men, the non-adjusted model, MetS \((p = .001)\) and MSS \((p = .009)\) were inversely associated with serum 25(OH)D levels. Similarly, in the adjusted model, MetS \((p < .001)\) and MSS \((p < .001)\) were inversely associated with serum 25(OH)D levels. In women, in the non-adjusted model, MetS \((p = .002)\) and MSS \((p < .001)\) were positively associated with serum 25(OH)D levels. However, in the adjusted model, MetS \((p = .200)\) and MSS \((p = .541)\) were not associated with serum 25(OH)D levels.

**Odds ratio comparisons of vitamin D deficiency for MetS and MSS in men**

The odds ratios (ORs) were determined to investigate whether vitamin D deficiency is an independent risk factor for MetS development and MSS \(\geq 1\). The odds ratio (OR) comparisons of vitamin D deficiency for MetS and MSS in men are shown in Table 3. In models 1, 2 and 3, the ORs of vitamin D deficiency for MSS, with MSS 0 as a reference group, showed no significance for MSS 1, 2 and 3, whilst the OR for MSS \(\geq 4\) was significant. However, when further adjusted for age, the ORs of vitamin D deficiency, with MSS 0 as a reference group, were not significant for MSS 1 \([1.20 (95\% \text{ confidence interval [CI], 0.91–1.57}]\), but they were significant for MSS 2 \([1.35 (95\% \text{ CI, 1.01–1.81}])\], MSS 3 \([1.66 (95\% \text{ CI, 1.18–2.33}])\], and MSS \(\geq 4\) \([2.53 (95\% \text{ CI, 1.68–3.80})]\). In addition, the OR of vitamin D deficiency for MetS compared to non-MetS was significant \([1.56 (95\% \text{ CI, 1.23–1.98})]\).

**Odds ratio comparisons of vitamin D deficiency for MetS and MSS in women**

The odds ratio (OR) comparisons of vitamin D deficiency for MetS and MSS in women are shown in Table 4. In model 1, the ORs of vitamin D deficiency, with MSS 0 as a reference group, were not significant for MSS 1 \([0.81 (95\% \text{ CI, 0.37–0.99}])\), MSS 2 \([0.59 (95\% \text{ CI, 0.48–0.73})]\), MSS 3 \([0.62 (95\% \text{ CI, 0.49–0.79})]\), and MSS \(\geq 4\) \([0.63 (95\% \text{ CI, 0.49–0.80})]\). In addition, the OR of vitamin D deficiency for MetS compared to non-MetS was significant \([0.77 (95\% \text{ CI, 0.65–0.91})]\). However, when adjusted for BMI, TC, smoking, alcohol consumption, regular exercise, and age, the ORs of vitamin D deficiency, with MSS 0 as a reference group, were not significant for MSS 1 \([1.01 (95\% \text{ CI, 0.82–1.25})]\), MSS 2 \([0.89 (95\% \text{ CI, 0.69–1.14})]\), MSS 3 \([1.01 (95\% \text{ CI, 0.76–1.34})]\), and MSS \(\geq 4\) \([1.06 (95\% \text{ CI, 0.78–1.45})]\).
addition, the OR of vitamin D deficiency for MetS compared to non-MetS was not significant [1.08 (95% CI, 0.89–1.31)].

Discussion
The present study investigated the association between gender difference with MetS, increase in MetS components and vitamin D serum concentration using data from the fifth KNHANES conducted in 2012. This study provided several key findings. After the data were further adjusted for age, MetS and an increase in MetS components were associated with a decrease in serum 25(OH)D levels and an OR increase of vitamin D deficiency in men, but there was no equivalent association in women (Tables 3 and 4 and Figures 1 and 2).
In previous studies, the prevalence of MetS was 17.3% and 19.3% in Canada (Setayeshgar et al. 2012), 36.8% and 31.0% in Germany (Henneman et al. 2008), and 35.1% and 32.6% in the US, for men and women, respectively (Ervin 2009). We found MetS prevalence of 24.0% and 26.7% in men and women, respectively, which is similar to that found in Canada. Previously, the prevalence of vitamin D deficiency (25(OH)D < 15.0 ng/mL), was found to be 20% in Canada (Greene-Finestone et al. 2011), 58% in Germany (Hintzpeter et al. 2008), and 35% in the US (Ganji et al. 2012). We found 40% prevalence of vitamin D deficiency, which is similar to that found in the US. Vitamin D deficiency is known to increase the incidence of diseases, such as type 2 diabetes, hypertension, atherosclerosis, and cardiovascular disease (Kim 2007; Shin & Kwun 2012). Each component of MetS is a risk factor for coronary artery disease, and MetS is a useful indicator to identify groups at a high risk for cardiovascular disease and type 2 diabetes mellitus. (Meigs 2000; Grundy 2007).

Previous studies found inconsistent results in the association between MetS and vitamin D (Table 5). Some studies reported that vitamin D was inversely associated with MetS (Chacko et al. 2011; Moy & Bulgiba 2011; Cheng et al. 2013), while others reported that vitamin D was not associated with MetS (Khader et al. 2011; Chon et al. 2014; Mohammadi et al. 2015). These inconsistencies may be caused by differences in population ethnicity, age and country studied. However, research on the association between gender differences with MetS and vitamin D is rare. Chung and Hong (2013) found MetS and MSS were significantly associated with vitamin D deficiency in men and women (although no p-values were shown). Bea et al. (2015) found MetS was associated with vitamin D deficiency in men (p < .001) and women (p < .05) (Bea et al. 2015). In contrast, Majumdar and colleagues in Asian Indian, found MetS was not associated with vitamin D status in men (p = .785) or women (p = .640) (Majumdar et al. 2011).

In the present study, in the non-adjusted model, MetS and MSS were inversely associated with the 25(OH)D levels in men but positively associated with the 25(OH)D level in women. These results suggest that the vitamin D level exacerbated MetS in women. However, after multivariable adjustment, no significance was found. We considered that these associations may be caused by the serum 25(OH)D levels, according to the components of MetS in men and women. Previous research on the association between vitamin D and the individual components of MetS reported inconsistent results across studies due to differences in the country and the ethnicity of the population investigated. Moy and Bulgiba (2011) reported that abdominal obesity and elevated TG were

### Table 3. Odds ratio of vitamin D deficiency for MetS and MSS in men.

| Variables | Model 1 | p | Model 2 | p | Model 3 | p | Model 4 | p |
|-----------|---------|---|---------|---|---------|---|---------|---|
| MSS 0     | 1.00    |   | 1.00    |   | 1.00    |   | 1.00    |   |
| 1         | 0.92 (0.72–1.19) | .546 | 0.92 (0.71–1.19) | .531 | 0.93 (0.72–1.20) | .573 | 1.20 (0.91–1.57) | .200 |
| 2         | 0.92 (0.71–1.21) | .568 | 0.94 (0.72–1.24) | .678 | 1.35 (1.01–1.81) | .042 |
| 3         | 1.07 (0.80–1.43) | .656 | 1.07 (0.78–1.46) | .691 | 1.08 (0.79–1.49) | .631 | 1.66 (1.18–2.33) | .004 |
| ≥4        | 1.61 (1.15–2.27) | .006 | 1.57 (1.07–2.29) | .021 | 1.59 (1.08–2.33) | .019 | 2.53 (1.68–3.80) | <.001 |
| Non-MetS  | 1.00    |   | 1.00    |   | 1.00    |   | 1.00    |   |
| MetS      | 1.31 (1.07–1.62) | .010 | 1.29 (1.03–1.62) | .029 | 1.29 (1.03–1.63) | .029 | 1.56 (1.23–1.98) | <.001 |

**Vitamin D deficiency**: 25(OH)D < 15 ng/mL; **MSS**: Metabolic syndrome score; **Non-MetS**: Non-metabolic syndrome (MSS < 3); **MetS**: Metabolic syndrome (MSS ≥ 3); n = 2162.

Model 1, Non-adjusted; Model 2, adjusted for BMI and TC; Model 3, adjusted for BMI, TC, smoking, alcohol drinking, and regular exercise; Model 4, adjusted for BMI, TC, smoking, alcohol drinking, and regular exercise and age.

### Table 4. Odds ratio of vitamin D deficiency for MetS and MSS in women.

| Variables | Model 1 | p | Model 2 | p | Model 3 | p | Model 4 | p |
|-----------|---------|---|---------|---|---------|---|---------|---|
| MSS 0     | 1.00    |   | 1.00    |   | 1.00    |   | 1.00    |   |
| 1         | 0.59 (0.48–0.73) | <.001 | 0.61 (0.48–0.77) | <.001 | 0.61 (0.49–0.78) | <.001 | 0.89 (0.69–1.14) | .357 |
| 3         | 0.62 (0.49–0.79) | <.001 | 0.64 (0.50–0.83) | <.001 | 0.65 (0.50–0.84) | <.001 | 1.01 (0.76–1.34) | .969 |
| ≥4        | 0.63 (0.49–0.80) | <.001 | 0.65 (0.49–0.86) | <.001 | 0.65 (0.49–0.86) | <.001 | 1.03 (0.78–1.45) | .703 |
| Non-MetS  | 1.00    |   | 1.00    |   | 1.00    |   | 1.00    |   |
| MetS      | 0.77 (0.65–0.91) | .002 | 0.85 (0.71–1.01) | .068 | 0.85 (0.71–1.02) | .075 | 1.08 (0.89–1.31) | .420 |

**Vitamin D deficiency**: 25(OH)D < 15 ng/mL; **MSS**: Metabolic syndrome score; **Non-MetS**: Non-metabolic syndrome (MSS < 3); **MetS**: Metabolic syndrome (MSS ≥ 3); n = 2985.

Model 1, Non-adjusted; Model 2, adjusted for BMI and TC; Model 3, adjusted for BMI, TC, smoking, alcohol drinking, and regular exercise; Model 4, adjusted for BMI, TC, smoking, alcohol drinking, and regular exercise and age.
associated with serum 25(OH)D levels. Majumdar et al. (2011) reported that MetS and all MetS components were associated with serum 25(OH)D levels in both men and women. However, Jang and colleagues, found that although not all the components of MetS were significantly associated with serum 25(OH)D levels, MetS was significantly inversely associated with serum 25(OH)D (Jang et al. 2013). In the present study, in men, the serum 25(OH)D level was significantly lower in the abnormal group (elevated TGs and reduced HDL-C) than the normal group. However, in women, serum 25(OH)D level was significantly higher in the abnormal group (abdominal obesity, elevated FBG, and elevated BP) than the normal group. Therefore, MetS and MSS, which consists of the sum of the components of MetS, were inversely associated with serum 25(OH)D levels in men and were positively associated with serum 25(OH)D levels in women (Figure 1 and Table S1 and S2). However, in the adjusted model, MetS and MSS were inversely associated with the ORs of vitamin D deficiency and 25(OH)D levels in women. The mechanisms underlying the association between gender difference with MetS and vitamin D have not yet been defined. We considered that these associations may be caused by the age of the subjects. Aging causes many bodily changes. As men age, testosterone production is gradually decreased (Ferrini & Barrett-Connor 1988). In women, menopause causes a severe decrease in estrogen levels (Khosla et al. 1997). Many previous studies have suggested that vitamin D levels are positively associated with an increase in sexual hormones, such as testosterone in men and estrogen in women (Nashold et al. 2009; Parikh et al. 2010). Increases in testosterone and estrogen are inversely associated with MetS incidence (Guarner-Lans et al. 2011). However, although vitamin D levels increased in older women, a severe decrease in estrogen increases the incidence of MetS (Lobo 2008). In the present study, in the adjusted model (except age), MetS and MSS were positively associated with the ORs of vitamin D deficiency and 25(OH)D levels in women. However, when further adjusted for age, MetS and MSS were not associated with the ORs of vitamin D deficiency and 25(OH)D levels in women. Gender differences exist in lifestyle (drinking, smoking, and physical activity) and cardiovascular disease (Bernabe-Ortiz et al. 2012; Regitz-Zagrosek 2012). For these reasons, some researchers suggest that medical hypotheses need to be considered to more accurately compare men and women in such studies (Kanter & Caballero 2012; Morrow 2015).

Table 5. Studies reporting an association between vitamin D status and MetS.

| Study (country of origin) | Gender (M/F) | Adjustments | Main results |
|--------------------------|-------------|-------------|--------------|
| Cheng et al. 2013 (Taiwan) | M (n = 655) | Age, BMI, smoking, alcohol drinking, and betel quid chewing | 25(OH)D was inversely associated with MetS (p = 0.045) in men. |
| Chacko et al. 2011 (US) | F (n = 292) | Age, race-ethnicity, month of blood draw, and geographic region | 25(OH)D was inversely associated with MetS (p = 0.01). |
| Chon et al. 2014 (Korea) | F (n = 4364) | Age, seasonality, occupation, education, alcohol, smoking, physical activity, and hypertension | 25(OH)D was not associated with MetS (p = 0.057). |
| Moy & Bulgiba 2011 (Malaysia) | M/F (n = 380) | Age, sex, abdominal obesity, diastolic blood pressure, and low HDL-cholesterol | 25(OH)D was inversely associated with MetS (p = 0.044). |
| Khader et al. 2011 (Jordanian) | M/F (n = 3234) | Age, gender, marital status, smoking habits, BMI, physical activity, and hypertension | 25(OH)D was not associated with MetS (p = 0.057). |
| Mohammadi & Hong 2015 (Iran) | M/F (n = 2357) | Age, sex, smoking status, physical activity, macronutrients intake, total fiber intake, calcium, and dairy products | 25(OH)D was not associated with MetS (p = 0.340). |
| Chung & Hong 2013 (Korea) | M/F (n = 18,305) | Age, smoking status, alcohol consumption, regular exercise, and physical activity | OR (95% CI) of prevalence of MetS for the vitamin D deficiency group vs. normal group were 1.46 (1.05–2.02) in men and 1.60 (1.21–2.11) in women. |
| Bea et al. 2015 (US) | M/F (n = 2096) | Age, race/ethnicity, supplemental calcium, and WHR | 25(OH)D was inversely associated with MetS in men (p < 0.001) and women (p < 0.05). |
Conclusion

The present study investigated the association between gender difference with MetS, MSS and serum vitamin D levels in Korean adults aged 20 and older, using the 2012 KNHANES data. MetS and increases in its components were inversely associated with the serum vitamin D concentration in Korean men, but there was no equivalent association in Korean women.

The present study has a few limitations. The serum 25(OH)D varies across seasons, yet but the 2012 KNHANES data did not specify serum 25(OH)D levels for each season. Also, the 2012 KNHANES data did not measure the parathyroid hormone (PTH) of the participants. The serum 25(OH)D levels for each season and PTH levels should be included as variables of vitamin D status in future studies. Other factors associated with vitamin D status, such as diet, physical activity, and lifestyle should also be included in future studies. More accurate results might be obtained by performing a cohort study by including these variables. Although the present study has limitations, this is the first reported study to determine the association between MetS and the increase in its components with vitamin D deficiency in Korean adults.

Disclosure statement

The authors declare that there is no conflict of interest associated with this manuscript. All authors were involved in the concept and design of this study. HY, DKJ, and CEP collected the data and performed the analyses. HY, HJO, and SGK assessed the quality of study design and the data independently. HY performed the statistical analysis and wrote the manuscript.

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