

The factors associated with Vitamin D deficiency in community dwelling elderly in Korea

Sun Hea Kim¹, Jung Eun Oh^{1,5}, Dong Won Song¹, Choo Yon Cho², Sung Ho Hong², Yong Jin Cho¹, Byung Wook Yoo², Kyung Suk Shin³, Hyun Joe², Hwang Sik Shin¹ and Doo Yong Son³

¹Department of Family Medicine, Soonchunhyang University College of Medicine, Soonchunhyang University Cheonan Hospital, 31, Soonchunhyang 6-gil, Donagnam-gu, Cheonan-si, Chungnam 31151, Korea

²Department of Family Medicine, Soonchunhyang University College of Medicine, Soonchunhyang University Seoul Hospital, Seoul 04401, Korea

³Department of Family Medicine, Soonchunhyang University College of Medicine, Soonchunhyang University Gumi Hospital, Gyeongbuk 39371, Korea

BACKGROUND/OBJECTIVE: Recent studies showed vitamin D deficiency is linked to chronic diseases in addition to skeletal metabolism which could threaten the elderly. We analyzed health conditions and socio-demographic factors associated with vitamin D deficiency in community dwelling people aged 65 years and older.

SUBJECTS/METHOD: Data from the Korea National Health and Nutrition Examination Survey (KNHANES) 2010 to 2012 were obtained. A total of 2,687 subjects aged 65 years and older were participated. The cutoff value of the Vitamin D deficiency was considered as serum 25-hydroxyvitamin D [25(OH)D] \leq 20 ng/mL (50 nmol/L).

RESULTS: The overall prevalence rate of vitamin D deficiency in the elderly was 62.1%. The factors such as female, obesity, metabolic syndrome, current smoker, and skipping breakfast were positively associated with vitamin D deficiency, but high intensity of physical activity and more than 9 hours of sleep duration were negatively associated with vitamin D deficiency (all $P < 0.05$).

CONCLUSIONS: It is important that health professions know that the factors proved in this study are connected to vitamin D deficiency thus provide information and intervention strategies of vitamin D deficiency to old aged people.

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INTRODUCTION

According to Korean Statistical information Service, people over 65 years old is 13.8 percent of total population in 2017 and will be 41.6 percent of total population in 2040 in Korea [1]. With growth of the elderly, it would be a challenge to public health care to figure nutrition problem in old age because they hardly meet the nutritional support. Many older adults do not get enough of calcium, vitamin D, and vitamin B12 [2]. Especially, vitamin D is mainly synthesized by the skin during exposure to sunlight, and small groups of food contain vitamin D. However, aging reduces outdoor activity and interrupts vitamin D synthesis [3] and old people would have dietary problem, making the elderly are greater risk at vitamin D deficiency.

Vitamin D has a critical role in calcium homeostasis and bone metabolism. The consequences of vitamin D deficiency in old aged people are osteoporosis and osteomalacia, causing falls and fractures [4]. One-third of people over 65 will fall at least once a year [5] and fall-related fractures are associated with excess morbidity and mortality [6].

Moreover, new researches have reported that vitamin D deficiency associated with chronic diseases such as autoimmune diseases [7], cardiovascular disease [8,9], infection [10-12], diabetes [13] and certain cancers such as brain, prostate, breast, and colon [14-16]. Given that vitamin D deficiency and chronic diseases are connected in the facing of aging society, it is important to know vitamin D deficiency is linked to one of factors of leading causes of death in older people [17].

Vitamin D deficiency, defined as a 25(OH)D level of 20 ng/mL or less [17,18], is a highly prevalent condition, present in approximately 30% to 50% of the general population [19]. In the Korea National Health and Nutrition Examination Survey (KNHANES) 2008, Vitamin D insufficiency was found in 47.3% of males and 64.5% of females [20]. However, most of the studies on vitamin D deficiency were targeted general or younger population, and there is lack of information on vitamin D deficiency in the elderly, community dwelling and relatively healthy in Korea.

Therefore, with poor vitamin D status and its associated health condition in aging society, it is necessary that searching

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⁵ Corresponding Author: Jung-Eun Oh, Tel. 82-41-570-2238, Fax. 82-41-592-3810, Email. jeoh2238@naver.com

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for what risk factors are connected to vitamin D deficiency to prevent it, thus promote health and function in old aged people in Korea.

The objective of this study is to exam health conditions and socio-demographic variables association with vitamin D deficiency of relatively healthy and community dwelling people aged 65 years and older, analyzing the data from 2010 to 2012 Korea National Health and Nutrition Examination Survey (KNHANES).

SUBJECTS AND METHODS

Study population

According to 'Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES)' KNHANES is an ongoing surveillance system conducted by the Korea Centers for Disease Control and Prevention (KCDC). KNHANES is a nationwide cross-sectional survey conducted every year, and its target population comprises nationally representative non-institutionalized civilians aged 1 year and over in Korea [21].

Data from 2010 to 2012 KNHANES were obtained for this study. We had a total of 13,958 participants. People diagnosed with cancers (1,386 individuals), liver cirrhosis (53 individuals), cerebral vascular disease (340 individuals), acute coronary syndrome (532 individuals), thyroid disease (708 individuals), and/or renal failure (78 individuals) were excluded. The analysis in our study included subjects who provide vitamin D measurement (serum [25(OH)D] levels) and 65years or older. Therefore, we had 2,687 subjects in our study.

Data collection

This study protocol was reviewed and approved by the Institutional Review Board of Soonchunhyang University Cheonan Hospital, and all procedures were performed after receiving informed consent from patients (IRB No. SCHCA 2017-09-019).

KNHANES collects a number of variables regarding participants' demographic, social, health and nutritional status from three component surveys: the health interview, health examination and nutrition survey [21]. In the health interview, participants were asked to provide information about medical conditions, socioeconomic status, activity limitation, quality of life, cigarette smoking, alcohol use, physical activity, oral health. During the health examination, body measurement and laboratory test (blood) were conducted by trained medical personnel, and all equipment was calibrated periodically. The nutrition survey collected information on dietary behaviors, food frequency and food intake.

Variables

Smoking status was classified into two groups: never or past and current. We defined moderate alcohol consumption up to 4 drinks in male and 2 drinks in female. For alcohol drinking status, we classified into two groups, none or moderate alcohol intake and heavy drinkers who drink more than moderate amount. Physical activity was divided into 3 categories: low, moderate, and high intensity according to The Global Physical Activity Questionnaire, developed by WHO for physical activity surveillance in countries. Metabolic Equivalents (METs) are commonly used to express the intensity of physical activities.

MET is the ratio of a person's working metabolic rate relative to the resting metabolic rate. One MET is defined as the energy cost of sitting quietly, and is equivalent to a caloric consumption of 1 kcal/kg/hour. Subjects were asked and their weekly intensity of physical activities was calculated. The high intensity was set as $\geq 3,000$ METs per week, the moderate intensity was defined as between 3,000 METs and 600 METs, and the low intensity activity was set as < 600 METs. Inadequate sleep defines sleeping less than 7 hours per night since sleeping 7 to 8 hours per night is recommended to promote optimal health for adults [22]. Thus, we classified into three groups: subjects sleeping 6 or less hours per night, sleeping 7 to 8 hours per night and sleeping 9 hours and more. Chewing difficulty was checked during the health interview. Chewing efficacy is important to dietary intakes and nutritional status. All the subjects were asked to indicate whether they complain difficulty in chewing on the health questionnaire, and sorted to two groups: people having chewing difficulty or none. Waist circumference (WC) was measured at the narrowest point between the lowest rib and the iliac crest. Obesity defined as a body mass index (BMI) ≥ 25 kg/m² according to the classification and criteria of obesity in Korea [23]. People were divided to two groups: BMI ≥ 25 kg/m² and BMI < 25 kg/m². Adequate daily calorie intake defined as at least 2,000 kcal/day for male and 1,800 kcal/day for female in aged 65 over from Dietary Reference Intakes for Korean (KDRI). Thus, we sorted subjects to two groups: people who consumed more than 2,000 kcal/day for men and 1800 kcal/day for female, and who did not meet the requirement. Adequate daily calcium intake defined as 700 mg/day for male and 800 mg/day for female in aged 65 over from KDRI. Thus, we classified into two groups: subjects who had more than 700 mg/day for male and 800 mg/day for female, and who did not meet the requirement. Skipping meals were inquired using the health questionnaires that subjects recall whether they had breakfast, lunch and dinner one day ago. Three groups were classified: skipping breakfast, lunch and dinner. The definition of Metabolic Syndrome (MS) was provided by the modified Third National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (NCEP-ATP III) and the Korean Society for the Study of Obesity was used to determine MS for specific value of waist circumference [24]. MS was diagnosed if three or more of the following criteria were met: (i) abdominal obesity (men ≥ 90 cm and women ≥ 85 cm); (ii) elevated blood pressure (BP): systolic BP ≥ 130 mmHg and/or diastolic BP ≥ 85 mmHg or currently undergoing treatment for hypertension; (iii) elevated triglycerides (TGs): TGs ≥ 150 mg/dL; (iv) reduced high density lipoprotein-cholesterol (HDL-C): men < 40 mg/dL and women < 50 mg/dL; and (v) elevated fasting blood glucose (FBG): FBG ≥ 100 mg/dL or current treatment with a hypoglycemic agent or insulin.

Vitamin D measures

7-dehydrocholesterol in skin cells absorbs ultraviolet rays and is converted to pre-vitamin D₃ and spontaneously isomerizes to vitamin D₃, known as cholecalciferol. The vitamin D obtained from diet also converted to cholecalciferol. Cholecalciferol in the body is biologically inactive and needed to be converted

enzymatically in the liver to 25-hydroxyvitamin D [25(OH)D], known as calcifediol, the major circulating form, and then in the kidney to 1,25-dihydroxyvitamin D [1,25(OH)₂D], known as calcitriol, the active form [17].

The level of 25(OH)D in the blood is measured, since 1,25(OH)₂D is often normal or elevated in people who have vitamin D deficiency. The blood samples were collected for measurement of 25(OH)D during the survey and analyzed within 24 hours. According to a review article published by Hossein-nezhad A, Holickin 2013 [4] the definition of Vitamin D deficiency was considered as 25(OH)D \leq 20 ng/mL (50 nmol/L) and it is used as the cutoff value in this study.

Statistical analysis

Data analysis was performed using Statistical Package for the Social Science (SPSS) 14.0 (IBM Co., Armonk, NY, USA). The chi-square test and ANOVA were used to assess the association between vitamin D deficiency and variables, which are age, sex, drinking status (none or moderate alcohol intake and heavy drinkers), smoking status (never or past and current), obesity (BMI \geq 25 kg/m² and BMI < 25 kg/m²), physical activity (low, moderate, and high intensity), individual income, daily sleep

duration (\leq 6 hours, 7-8 hours, and \geq 9 hours), skipping meals (skipping breakfast, lunch and dinner), having chewing difficulty, daily calorie intake (more than 2,000 kcal/day for men and 1,800 kcal/day for female, and who did not meet the requirement), daily calcium intake (more than 700 mg/day for male and 800 mg/day for female, and who did not meet the requirement), and having metabolic syndrome. In order to examine the relationship between vitamin D deficiency and variables, multiple logistic regression analyses were used to find out the relationship between them and adjusted odds ratios and 95% CI were calculated. Also, gender-stratified analysis was performed to examine male and female differences in relationship between vitamin D deficiency and variables. Results with a *P*-value < 0.05 were considered statistically significant.

RESULTS

Socio-demographic and lifestyle characteristics according to serum 25-hydroxyvitamin D concentration

A total of 2,687 individuals aged 65 years or older were included in this study. Among this population males were 1,135 and females were 1,552. Table 1 shows the prevalence rate of

Table 1. Comparisons between socio-demographic and lifestyle variables and serum 25-hydroxyvitamin D concentration

	Serum 25-hydroxyvitamin D		<i>P</i> -value
	\leq 20 ng/mL (n = 1,669)	> 20 ng/mL (n = 1,018)	
Male, n (%)	631 (37.8)	504 (49.5)	< 0.001*
Female, n (%)	1,038 (62.2)	514 (50.5)	< 0.001
Heavy drinking, n (%)	201 (12.0)	128 (12.6)	0.684
Smoking status, n (%)			0.494
Never/Past	1,432 (85.8)	883 (86.7)	
Current	237 (14.2)	135 (13.3)	
Physical activity, n (%)			< 0.001
Low intensity	872 (52.2)	477 (46.9)	
Moderate intensity	580 (34.8)	346 (37.4)	
High intensity	217 (13.0)	195 (19.2)	
Income (quartile/person), n (%)			0.804
Q1 _{Lowest}	428 (25.6)	266 (26.1)	
Q2 _{Middle-Lowest}	432 (25.9)	250 (24.6)	
Q3 _{Middle-Highest}	419 (25.1)	251 (24.7)	
Q4 _{Highest}	390 (23.4)	251 (24.7)	
Daily sleep duration, n (%)			< 0.001
\leq 6 hours	890 (53.3)	469 (46.1)	
7 to 8 hours	649 (38.9)	422 (41.5)	
\geq 9 hours	130 (7.9)	127 (12.5)	
Skipping breakfast, n (%)	80 (4.8)	20 (2.0)	< 0.001
Skipping lunch, n (%)	100 (6.0)	64 (6.3)	0.756
Skipping dinner, n (%)	80 (4.8)	43 (4.2)	0.493
Chewing difficulty, n (%)	718 (43.0)	424 (41.7)	0.486
Daily calorie intake, n (%)			
< KDRI ¹⁾	1,022 (61.2)	576 (56.6)	0.017
Daily calcium intake, n (%)			
< KDRI ²⁾	1,481 (88.7)	868 (85.3)	0.008

¹⁾ KDRI: F; 1,600 Kcal/day, M; 2,000 Kcal/day for aged 65 over from Korea dietary reference intakes (KDRI)

²⁾ KDRI: Male; 700 mg/day, Female; 800 mg/day for aged 65 over from Korea dietary reference intakes (KDRI)

Data were presented as numbers (%). *P*-values are calculated from chi-square test.

Table 2. Comparisons between health-related variables and serum 25-hydroxyvitamin D concentration

	Serum 25-hydroxyvitamin D		P-value
	≤ 20 ng/mL (n = 1,669)	> 20 ng/mL (n = 1,018)	
Age (yrs)	72.3 ± 5.0	72.2 ± 5.1	0.529
Serum 25-hydroxyvitamin D (ng/mL)	15.0 ± 3.5	26.0 ± 5.0	< 0.001
BMI (kg/m ²)	24.1 ± 3.3	23.4 ± 3.1	< 0.001
Obesity, BMI ≥ 25 kg/m ² , n (%)	617 (37.0)	304 (29.9)	< 0.001
WC (cm)	84.2 ± 9.1	83.0 ± 9.1	0.001
SBP (mmHg)	130.8 ± 17.2	130.4 ± 17.5	0.631
DBP (mmHg)	74.7 ± 9.9	75.1 ± 10.0	0.334
FBS (mg/dL)	103.5 ± 24.8	102.0 ± 21.4	0.101
TG (mg/dL)	144.1 ± 109.6	131.2 ± 76.9	< 0.001
HDL-C (mg/dL)	46.7 ± 11.1	47.7 ± 11.2	0.036
Metabolic syndrome, n (%)	805 (48.2)	397 (39.0)	< 0.001

WC, waist circumference; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglyceride; HDL-C, high density lipoprotein-cholesterol

Data were presented as mean ± standard deviation (SD) or numbers (%). P-values are calculated from analysis of variance (ANOVA) or chi-square test.

Table 3. Independent factors of vitamin D deficiency

	Odds ratio (95% CI)	P-value
Sex		
Male (n = 1,135)	1	
Female (n = 1,552)	1.53 (1.18-1.98)	< 0.001
Obesity (BMI ≥ 25 kg/m ²)		
No (n = 1,766)	1	
Yes (n = 921)	1.23 (1.03-1.48)	0.026
Metabolic syndrome		
No (n = 1,485)	1	
Yes (n = 1,202)	1.27 (1.07-1.51)	0.006
Alcohol drinking		
None or moderate (n = 2,358)	1	
Heavy drinking (n = 329)	1.06 (0.82-1.36)	0.672
Smoking status		
Never/Past (n = 2,315)	1	
Current (n = 372)	1.45 (1.13-1.86)	0.003
Chewing difficulty		
No (n = 1,545)	1	
Yes (n = 1,142)	1.01 (0.86-1.19)	0.923
Skipping breakfast		
No (n = 2,587)	1	
Yes (n = 100)	2.14 (1.29-3.55)	0.003
Skipping lunch		
No (n = 2,523)	1	
Yes (n = 164)	0.82 (0.59-1.15)	0.255
Skipping dinner		
No (n = 2,564)	1	
Yes (n = 123)	0.93 (0.63-1.38)	0.715
Adequate daily calorie intake ¹⁾		
Yes (n = 1,089)	1	
No (n = 1,598)	1.14 (0.96-1.35)	0.139
Adequate daily calcium intake ²⁾		
Yes (n = 338)	1	
No (n = 2,349)	1.15 (0.99-1.47)	0.276

Table 3. continued

	Odds ratio (95% CI)	P-value
Physical activity		
Low physical intensity (n = 1,349)	1	
Moderate intensity (n = 926)	0.97 (0.81-1.16)	0.756
High intensity (n = 412)	0.68 (0.54-0.86)	0.001
Daily sleep duration		
7 to 8 hours (n = 1,071)	1	
≤ 6 hours (n = 1,359)	1.19 (1.00-1.41)	0.050
≥ 9 hours (n = 257)	0.65 (0.49-0.86)	0.002
Income (quartile/person)		
Q1 _{Lowest} (n = 694)	1	
Q2 _{Middle-Lowest} (n = 682)	1.12 (0.90-1.40)	0.325
Q3 _{Middle-Highest} (n = 670)	1.08 (0.86-1.35)	0.499
Q4 _{Highest} (n = 641)	1.02 (0.81-1.28)	0.885

¹⁾ Adequate daily calorie intake: F; 1,600 Kcal/day, M; 2,000 Kcal/day for aged 65 over from Korea dietary reference intakes (KDRI)

²⁾ Adequate daily calcium intake: Male; 700 mg/day, Female; 800 mg/day for aged 65 over from Korea dietary reference intakes (KDRI)

vitamin D deficiency according to socio-demographic variables. The prevalence rate of vitamin D deficiency is significant in females, physical activity, having less than 7 hours of daily sleep duration, skipping breakfast and inadequate daily calorie and calcium intake (all $P < 0.05$).

Comparisons between health-related variables and serum 25-hydroxyvitamin D concentration

When examining health related factors (Table 2) vitamin D deficiency is significant in subjects who are obese (BMI ≥ 25 kg/m²) and have metabolic syndrome (all $P < 0.05$). Subjects with vitamin D deficiency significantly have larger waist circumference (WC), higher Body Mass Index (BMI), higher triglyceride (TG) and lower high density lipoprotein-cholesterol (HDL-C). The mean ± standard deviation (SD) of vitamin D level is 15.0 ± 3.5 ng/mL in vitamin D deficiency population and the prevalence rate of vitamin D deficiency is 62.1%.

Table 4. Independent factors of vitamin D deficiency by gender

	Male (n = 1,135)		Female (n = 1,552)	
	Odds ratio (95% CI)	P-value	Odds ratio (95% CI)	P-value
Obesity (BMI \geq 25 kg/m ²)				
No	1		1	
Yes	1.02 (0.76-1.36)	0.905	1.40 (1.10-1.79)	0.006
Metabolic syndrome				
No	1		1	
Yes	1.33 (1.01-1.74)	0.040	1.26(1.00-1.59)	0.047
Alcohol drinking				
None or moderate	1		1	
Heavy drinking	1.33 (0.97-1.80)	0.073	0.70 (0.46-1.08)	0.110
Smoking status				
Never/Past	1		1	
Current	1.36 (1.03-1.80)	0.030	2.00 (1.07-3.74)	0.030
Chewing difficulty				
No	1		1	
Yes	1.02 (0.80-1.32)	0.842	1.00 (0.81-1.25)	0.969
Skipping breakfast				
No	1		1	
Yes	2.10 (0.88-5.01)	0.096	2.16 (1.15-4.04)	0.016
Skipping lunch				
No	1		1	
Yes	1.64 (0.86-3.12)	0.133	0.64 (0.43-0.95)	0.028
Skipping dinner				
No	1		1	
Yes	1.03 (0.63-1.38)	0.929	0.94 (0.57-1.53)	0.794
Adequate daily calorie intake ¹⁾				
Yes	1		1	
No	1.63 (1.26-2.10)	< 0.00	0.87 (0.69-1.09)	0.225
Adequate daily calcium intake ²⁾				
Yes	1		1	
No	1.05 (0.76-1.45)	0.760	1.30 (0.87-1.94)	0.197
Physical activity				
Low physical intensity	1		1	
Moderate intensity	0.87 (0.67-1.15)	0.327	1.08 (0.85-1.38)	0.541
High intensity	0.70 (0.50-0.97)	0.031	0.61 (0.44-0.85)	0.004
Daily sleep duration				
7 to 8 hours	1		1	
\leq 6 hours	1.17 (0.91-1.51)	0.228	1.23 (0.97-1.55)	0.085
\geq 9 hours	0.63 (0.42-0.95)	0.027	0.64 (0.44-0.96)	0.028
Income (quartile/person)				
Q1 _{Lowest}	1		1	
Q2 _{Middle-Lowest}	1.23 (0.88-1.74)	0.220	1.07 (0.79-1.44)	0.687
Q3 _{Middle-Highest}	1.17 (0.83-1.65)	0.366	1.05 (0.77-1.42)	0.773
Q4 _{Highest}	1.37 (0.97-1.95)	0.075	0.79 (0.59-1.08)	0.135

¹⁾ Adequate daily calorie intake: F; 1,600 Kcal/day, M; 2,000 Kcal/day for aged 65 over from Korea dietary reference intakes (KDRI)

²⁾ Adequate daily calcium intake: Male; 700 mg/day, Female; 800 mg/day for aged 65 over from Korea dietary reference intakes (KDRI)

Relationship between independent factors and vitamin D deficiency

Table 3 shows the results from multivariate analyses. The multiple regression analyses revealed that factors female, obesity, metabolic syndrome, current smoker, and skipping breakfast are all significant independent factors of vitamin D deficiency.

However, high intensity of physical activity and more than 9 hours of sleep duration are negatively associated with vitamin D deficiency. Among the factors female is the strongest risk indicator for vitamin D deficiency.

Comparison of independent factors of vitamin D deficiency between male and female

The stratified analysis by gender was conducted and its results were shown in Table 4. Variables positively associated with vitamin D deficiency are metabolic syndrome and current smoker in both genders. In contrast, high intensity of physical activity and more than 9 hours of sleep duration are negatively associated with vitamin D deficiency in both male and female.

Skipping breakfast has significant positive association with vitamin D deficiency but skipping lunch has significant negative association with vitamin D deficiency in female. Also, obesity is significant factor of vitamin D deficiency in female but not in male.

Compared to female, male with vitamin D deficiency is significantly more likely to have inadequate daily calorie defined as lower calorie intake of KDRI.

DISCUSSION

This study shows factors are associated with vitamin D status in community dwelling people aged 65 years and more in Korea. In the elderly, significant independent factors of vitamin D deficiency are female, obesity, metabolic syndrome, current smoking, and skipping breakfast. In contrast high intensity of physical activity and more than 9 hours of sleep duration are negatively associated with vitamin D deficiency.

Using the definition of serum 25(OH)D concentration ≤ 20 ng/mL, we found that 62.1% of people aged 65 over would be categorized as vitamin D deficiency. In this group female showed higher rate of vitamin D deficiency than males (62.2% and 37.8% respectively) and female had 1.53 times increased risk for vitamin D deficiency. Compare with males, females were more prone to develop vitamin D deficiency, which supported the results from other researches [3,25-27]. However reasons of such gender difference are unclear. It is suggested that skin synthesis of vitamin D [28] and sun exposure between genders [29] are different in some studies. In our study we do not have record of subjects' sun exposure time but possible explanation is women tend to have more activities indoors and use sunscreen outside. Further study is required for the difference between male and female.

Several studies proved that cardiovascular disease risk factors, including obesity were found to be associated with vitamin D deficiency [30,31]. Our finding confirmed being obese has the risk of vitamin D deficiency 1.23 times more than non-obese. Similar results that obesity is related to vitamin D deficiency were reported. Research on 453 participants aged 65 years and older in The Netherlands found that higher body mass index, waist circumference, and sum of skin folds were statistically significantly associated with lower 25(OH)D [32]. A study in Spain with 73 consecutive morbidly obese patients (BMI ≥ 40 kg/m²) reported that Vitamin D deficiency was diagnosed in 63% of morbidly obese patients [33]. However, there is limited evidence to support the link between obesity and vitamin D deficiency, for example, it is not clear that obesity cause low vitamin D status or the other way around. There is possible hypothesis that adipose tissue accumulation could absorb and sequester of vitamin D, which is fat-soluble, hence circulating

25(OH)D level decreased [34]. Another supports that obesity could be the consequence of a low vitamin D status. Lower serum 25(OH)D concentration promote lower calcium absorption, and lower serum calcium level lead increase in parathyroid hormone secretion which causing calcium influx into the adipocytes. In these cells intracellular calcium enhances lipogenesis, the process your body uses to convert carbohydrates into fatty acids, which are the building blocks of fats [32].

Also, from gender-stratified analysis, obesity is significantly associated with vitamin D deficiency in female but not in male. This fact may be cause of differences in adiposity between men and women with the same BMI [35]. One study shows that less vitamin D is stored in fat tissue in men [36] due to the fact that men have 10-15% less fat content than women with the same BMI [35].

Prevalence of metabolic syndrome increases with aging years. According to Korean Statistical information Service, prevalence rate of metabolic syndrome in Korean population of over aged 65 years old is 43.6% (male: 37.8%, female: 48.8%) which is highly prevalent [37]. Metabolic syndrome is serious health condition for old aged people because it is one of important risk factors of marked increased cardiovascular disease and diabetes [38]. It is revealed that vitamin D is associated with metabolic syndrome in previous research findings [39,40]. In this study subjects with metabolic syndrome have 1.27 times higher risk of vitamin D deficiency than those who were not diagnosed metabolic syndrome in our study. One study concordance with our study shows higher 25(OH)D concentrations in the elderly are associated with lower prevalence of metabolic syndrome [41]. Some mechanisms support that relationship between vitamin D and metabolic syndrome: 1) vitamin D influence formation of apolipoprotein A-1, main component of HDL cholesterol [33], 2) vitamin D helps stimulation of insulin secretion and effects on insulin sensitivity [42].

There is no gender difference in vitamin D deficiency with metabolic syndrome from stratified analysis, but on our best of knowledge there were not any studies to compare our finding. Further study is required to support gender difference in association between metabolic syndrome and vitamin D status.

Current smoking status is one of the factors that associated with vitamin D deficiency. Our analyses demonstrate that current smoker has higher risk of vitamin D deficiency than those who never smoked. Other studies showed that current smokers were at increased risk of developing vitamin D insufficiency [43] and the percentage of current smoker was significantly higher in the vitamin D deficiency group [31]. Recent studies have in fact shown that metabolic derivatives of naphthalene, a metabolite in cigarette smoke, such as tetralones can inhibit CYP27A1 [44], which converts vitamin D into 25(OH)D, known as calcifediol, the major circulating form [45]. Thus, substances from smoking interrupt vitamin D metabolism and so make vitamin D concentration lower.

In our study, subjects who skipped breakfast has twice higher incidence of vitamin D deficiency. To the best of knowledge, there has been no data to association between meal skipping and vitamin D deficiency in the elderly. In previous Korean study shows young adults, aged 18-29 years in Seoul who ate breakfast daily had significantly higher serum 25(OH)D levels

than who ate breakfast less than 4 day/week [46]. Also, another study revealed that participants aged over 20 years skipped breakfast had higher risk of vitamin D deficiency than those who consumed breakfast [47]. Thus, eating breakfast regularly had an effect on serum 25(OH)D level. A study from Peter *et al.* [48] in Brazil shows a group of teenagers eating breakfast has higher vitamin D level than a group who did not have breakfast. It is assumed that dietary intake affect vitamin D level thus people having breakfast tend to have higher vitamin D level. However, KNHNE 2010-2012 data has insufficient information on intake of vitamin D through food and supplement. In future study, it is required to reveal; 1) vitamin D from food source for breakfast affects serum 25(OH)D level. 2) Skipping breakfast cause shortage of energy required for a day thus is associated with vitamin D deficiency. 3) Vitamin D deficiency is associated eating breakfast influencing following meals such as lunch, dinner and snacks between meals, nutritional supplement, outdoor activity and obesity.

From gender-stratified analysis women skipping breakfast has higher vitamin D deficiency but skipping breakfast is not a factor for male with vitamin D deficiency. Also skipping lunch tends to have lower risk of vitamin D deficiency in women. Skipping meals especially are related to poverty, isolation, changing in sight and hearing, physical and mental illness, immobility, loss of appetite and inability to cook in the elderly [49]. There are not any previous studies on skipping meals and vitamin D deficiency in gender difference or in difference among skipping of breakfast, lunch and dinner for the elderly, thus it is hard to make comparison of our finding with others. Therefore, the association between vitamin D deficiency and skipping meals in the elderly is required to be considered in future study.

Our study shows that high intensity of physical activity is linked to lower risk of vitamin D deficiency. Also, in our finding high intensity physical activity has significantly lower risk of vitamin D deficiency in both genders from gender-stratified analysis. We have reviewed some researches and one study shows the intensity of physical activity was associated with vitamin D. In this study, subjects engaged in daily vigorous activity have higher vitamin D level compared to with inactive people. Also, with regard to leisure-time physical activity, the adjusted mean serum 25(OH)D concentrations were lowest in participants who had no leisure-time physical activity during the previous month, compared with those who were physically active, and increased in a stepwise fashion with increasing frequency of activity [50]. In addition, study conducted in Korea showed that compared to the active group, moderate and high intensity of physical activity performed in 150 minutes per week, the inactive group is 4 times higher risk of vitamin D deficiency in aged 65 and older adults [51].

Sleep duration affects vitamin D level in old age our study. We found that subjects slept more than 9 hours have lower risk of vitamin D deficiency. One Korean research supported our results that sleep duration was positively associated with serum vitamin D level in the elderly and suggested inadequate sleep duration may be associated with lower serum vitamin D levels in older adults, aged 60 to 80 [52]. Another study reported sleep improvement after vitamin D supplementation with

approximately 45 minutes longer sleep duration [53]. Our finding and both studies above support that vitamin D and sleep duration are associated, but last one conducted in all the ages, not age specific. Thus further study is necessary to exam difference in the ages for the association vitamin D and sleep duration.

It is meaningful that all subjects were 65 years and older in our study, on the contrary, other researches about vitamin D were based on teenagers or young adults. Strength of our study is that serum vitamin D concentration, 25(OH)D was directly measured, which indicates vitamin D status in the body best.

Several limitations are found in this study. First it is based on a cross sectional study, which does not permit distinction between cause and effect. Therefore, further prospective research is necessary to evaluate correlation between vitamin D deficiency and risk factors. Second, vitamin D seasonal variation was disregarded since the data we used were from the KNHANES and each subject was not inquired for the amount of sunshine. Third, we did not have information about vitamin D intake from vitamin D containing supplement or food, which affect individual's vitamin D level from KNHANES.

In conclusion we found that vitamin D deficiency in old age is the issue to concern today because it is connected to chronic diseases and all-cause mortality [19]. Thus, the factors associated with vitamin D are necessarily to be found. In our study, risk factors such as female, obesity, metabolic syndrome, current smoking status, skipping breakfast are linked to vitamin D deficiency, and high intensity of physical activity and more than 9 hours of sleep duration are negatively associated with vitamin D deficiency in community dwelling people aged 65 years and older in Korea. These factors, except sex, could be corrected by life style modification to prevent vitamin D deficiency. Future prospective study is needed to be aware of risk factors associated with vitamin D deficiency and to promote public health strategies to preventing and controlling chronic diseases in the elderly.

CONFLICT OF INTEREST

The authors declare no potential conflicts of interests.

ORCID

Sun Hea Kim: <https://orcid.org/0000-0002-7080-9687>
 Jung Eun Oh: <https://orcid.org/0000-0001-9117-0571>
 Dong Won Song: <https://orcid.org/0000-0002-6676-9694>
 Choo Yon Cho: <https://orcid.org/0000-0003-0981-9787>
 Sung Ho Hong: <https://orcid.org/0000-0002-6037-6830>
 Yong Jin Cho: <https://orcid.org/0000-0002-5932-1138>
 Byung Wook Yoo: <https://orcid.org/0000-0002-8753-9660>
 Kyung Suk Shin: <https://orcid.org/0000-0002-2456-1406>
 Hyun Joe: <https://orcid.org/0000-0002-5134-2866>
 Hwang Sik Shin: <https://orcid.org/0000-0003-0166-8523>
 Doo Yong Son: <https://orcid.org/0000-0002-2895-6165>

REFERENCES

1. KOREAN Statistical Information Service. Statistical database for aging population 2017 [Internet]. Daejeon: KOREAN Statistical Information

- Service; 2017 [cited 2018 May 18]. Available from: http://kosis.kr/statHtml/statHtml.do?orgId=350&tblId=DT_35007_N136&conn_path=I2.
2. Medicine I. Providing Healthy and Safe Foods as We Age: Workshop Summary. Washington, D.C.: The National Academies Press; 2010.
 3. de Jongh RT, van Schoor NM, Lips P. Changes in vitamin D endocrinology during aging in adults. *Mol Cell Endocrinol* 2017; 453:144-50.
 4. Lips P, van Schoor NM. The effect of vitamin D on bone and osteoporosis. *Best Pract Res Clin Endocrinol Metab* 2011;25:585-91.
 5. Mulley G. Book of the month falls in older people. *J R Soc Med* 2001;94:202.
 6. Annweiler C, Montero-Odasso M, Schott AM, Berrut G, Fantino B, Beauchet O. Fall prevention and vitamin D in the elderly: an overview of the key role of the non-bone effects. *J Neuroeng Rehabil* 2010;7:50.
 7. Ritterhouse LL, Crowe SR, Niewold TB, Kamen DL, Macwana SR, Roberts VC, Dedeke AB, Harley JB, Scofield RH, Guthridge JM, James JA. Vitamin D deficiency is associated with an increased autoimmune response in healthy individuals and in patients with systemic lupus erythematosus. *Ann Rheum Dis* 2011;70:1569-74.
 8. Porto CM, Silva VL, da Luz JS, Filho BM, da Silveira VM. Association between vitamin D deficiency and heart failure risk in the elderly. *ESC Heart Fail* 2018;5:63-74.
 9. Anderson JL, May HT, Horne BD, Bair TL, Hall NL, Carlquist JF, Lappé DL, Muhlestein JB; Intermountain Heart Collaborative (IHC) Study Group. Relation of vitamin D deficiency to cardiovascular risk factors, disease status, and incident events in a general healthcare population. *Am J Cardiol* 2010;106:963-8.
 10. Maceda EB, Gonçalves CC, Andrews JR, Ko AI, Yeckel CW, Croda J. Serum vitamin D levels and risk of prevalent tuberculosis, incident tuberculosis and tuberculin skin test conversion among prisoners. *Sci Rep* 2018;8:997.
 11. Mulrennan S, Knuiman M, Walsh JP, Hui J, Hunter M, Divitini M, Zhu K, Cooke BR, Musk AWB, James A. Vitamin D and respiratory health in the Busselton Healthy Ageing Study. *Respirology* 2018;23: 576-82.
 12. Huang SJ, Wang XH, Liu ZD, Cao WL, Han Y, Ma AG, Xu SF. Vitamin D deficiency and the risk of tuberculosis: a meta-analysis. *Drug Des Devel Ther* 2016;11:91-102.
 13. de Oliveira VR, Domingueti CP. Association of vitamin D deficiency and type 1 diabetes mellitus: a systematic review and meta-analysis. *Int J Diabetes Dev Ctries* Forthcoming 2018.
 14. Jacobs ET, Kohler LN, Kunihiro AG, Jurutka PW. Vitamin D and colorectal, breast, and prostate cancers: a review of the epidemiological evidence. *J Cancer* 2016;7:232-40.
 15. Holick MF. Vitamin D deficiency. *N Engl J Med* 2007;357:266-81.
 16. Meehan M, Penckofer S. The role of vitamin D in the aging adult. *J Aging Gerontol* 2014;28:60-71.
 17. Forrest KY, Stuhldreher WL. Prevalence and correlates of vitamin D deficiency in US adults. *Nutr Res* 2011;31:48-54.
 18. Hossein-nezhad A, Holick MF. Vitamin D for health: a global perspective. *Mayo Clin Proc* 2013;88:720-55.
 19. Lee JH, O'Keefe JH, Bell D, Hensrud DD, Holick MF. Vitamin D deficiency an important, common, and easily treatable cardiovascular risk factor? *J Am Coll Cardiol* 2008;52:1949-56.
 20. Choi HS, Oh HJ, Choi H, Choi WH, Kim JG, Kim KM, Kim KJ, Rhee Y, Lim SK. Vitamin D insufficiency in Korea—a greater threat to younger generation: the Korea National Health and Nutrition Examination Survey (KNHANES) 2008. *J Clin Endocrinol Metab* 2011;96:643-51.
 21. Kweon S, Kim Y, Jang MJ, Kim Y, Kim K, Choi S, Chun C, Khang YH, Oh K. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). *Int J Epidemiol* 2014;43: 69-77.
 22. Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, Hazen N, Herman J, Katz ES, Kheirandish-Gozal L, Neubauer DN, O'Donnell AE, Ohayon M, Peever J, Rawding R, Sachdeva RC, Setters B, Vitiello MV, Ware JC, Adams Hillard PJ. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. *Sleep Health* 2015;1:40-3.
 23. Kim MK, Lee WY, Kang JH, Kim BT, Kim SM, Kim EM, Suh SH, Shin HJ, Lee KR, Lee KY, Lee SY, Lee SY, Lee SK, Lee CB, Chung S, Jeong IK, Hur KY, Kim SS, Woo JT; Committee of Clinical Practice Guidelines; Korean Society for the Study of Obesity. 2014 clinical practice guidelines for overweight and obesity in Korea. *Endocrinol Metab* 2014;29:405-9.
 24. Lee SY, Park HS, Kim DJ, Han JH, Kim SM, Cho GJ, Kim DY, Kwon HS, Kim SR, Lee CB, Oh SJ, Park CY, Yoo HJ. Appropriate waist circumference cutoff points for central obesity in Korean adults. *Diabetes Res Clin Pract* 2007;75:72-80.
 25. Cashman KD, Dowling KG, Škrabáková Z, Gonzalez-Gross M, Valtueña J, De Henauw S, Moreno L, Damsgaard CT, Michaelsen KF, Mølgaard C, Jorde R, Grimnes G, Moschonis G, Mavrogianni C, Maniatis Y, Thamm M, Mensink GB, Rabenberg M, Busch MA, Cox L, Meadows S, Goldberg G, Prentice A, Dekker JM, Nijpels G, Pilz S, Swart KM, van Schoor NM, Lips P, Eiriksdottir G, Gudnason V, Cotch MF, Koskinen S, Lamberg-Allardt C, Durazo-Arvizu RA, Sempos CT, Kiely M. Vitamin D deficiency in Europe: pandemic? *Am J Clin Nutr* 2016;103:1033-44.
 26. Verdoia M, Schaffer A, Barbieri L, Di Giovine G, Marino P, Suryapranata H, De Luca G; Novara Atherosclerosis Study Group (NAS). Impact of gender difference on vitamin D status and its relationship with the extent of coronary artery disease. *Nutr Metab Cardiovasc Dis* 2015;25:464-70.
 27. Mithal A, Wahl DA, Bonjour JP, Burckhardt P, Dawson-Hughes B, Eisman JA, El-Hajj Fuleihan G, Josse RG, Lips P, Morales-Torres J; IOF Committee of Scientific Advisors (CSA) Nutrition Working Group. Global vitamin D status and determinants of hypovitaminosis D. *Osteoporos Int* 2009;20:1807-20.
 28. Dawson-Hughes B, Harris SS, Dallal GE. Plasma calcidiol, season, and serum parathyroid hormone concentrations in healthy elderly men and women. *Am J Clin Nutr* 1997;65:67-71.
 29. Maggio D, Cherubini A, Lauretani F, Russo RC, Bartali B, Pierandrei M, Ruggiero C, Macchiarelli MC, Giordano R, Minisola S, Ferrucci L. 25(OH)D Serum levels decline with age earlier in women than in men and less efficiently prevent compensatory hyperparathyroidism in older adults. *J Gerontol A Biol Sci Med Sci* 2005;60:1414-9.
 30. Johnson LK, Hofsvø D, Aasheim ET, Tanbo T, Holven KB, Andersen LF, Røislien J, Hjeltnesæth J. Impact of gender on vitamin D deficiency in morbidly obese patients: a cross-sectional study. *Eur J Clin Nutr* 2012;66:83-90.
 31. Chung JY, Hong SH. Vitamin D status and its association with cardiometabolic risk factors in Korean adults based on a 2008-2010 Korean National Health and Nutrition Examination Survey. *Nutr Res Pract* 2013;7:495-502.
 32. Snijder MB, van Dam RM, Visser M, Deeg DJ, Dekker JM, Bouter

- LM, Seidell JC, Lips P. Adiposity in relation to vitamin D status and parathyroid hormone levels: a population-based study in older men and women. *J Clin Endocrinol Metab* 2005;90:4119-23.
33. Botella-Carretero JI, Alvarez-Blasco F, Villafruela JJ, Balsa JA, Vázquez C, Escobar-Morreale HF. Vitamin D deficiency is associated with the metabolic syndrome in morbid obesity. *Clin Nutr* 2007;26:573-80.
34. Gilsanz V, Kremer A, Mo AO, Wren TA, Kremer R, Vitamin D. Vitamin D status and its relation to muscle mass and muscle fat in young women. *J Clin Endocrinol Metab* 2010;95:1595-601.
35. Gallagher D, Heymsfield SB, Heo M, Jebb SA, Murgatroyd PR, Sakamoto Y. Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. *Am J Clin Nutr* 2000;72:694-701.
36. Wortsman J, Matsuoka LY, Chen TC, Lu Z, Holick MF. Decreased bioavailability of vitamin D in obesity. *Am J Clin Nutr* 2000;72:690-3.
37. Korean Statistical Information Service. Statistical database for metabolic syndrome [Internet]. Daejeon: KOREAN Statistical Information Service; 2017 [cited 2018 May 18]. Available from: http://kosis.kr/statHtml/statHtml.do?orgId=350&tblId=DT_35007_N136&conn_path=12.
38. Maggi S, Noale M, Gallina P, Bianchi D, Marzari C, Limongi F, Crepaldi G; ILSA Working Group. Metabolic syndrome, diabetes, and cardiovascular disease in an elderly Caucasian cohort: the Italian Longitudinal Study on Aging. *J Gerontol A Biol Sci Med Sci* 2006;61:505-10.
39. Rho HR, Lee SW, Lee HS, Shim KW, Chun H, Byun AR, Kim JH, Lee HK. The association between serum vitamin D level and metabolic syndrome in elderly people: based on the Korean National Health and Nutrition Examination Survey 2012. *Korean J Fam Pract* 2016;6:315-21.
40. Al-Dabhani K, Tsilidis KK, Murphy N, Ward HA, Elliott P, Riboli E, Gunter M, Tzoulaki I. Prevalence of vitamin D deficiency and association with metabolic syndrome in a Qatari population. *Nutr Diabetes* 2017;7:e263.
41. Vitezova A, Zillikens MC, van Herpt TT, Sijbrands EJ, Hofman A, Uitterlinden AG, Franco OH, Kiefte-de Jong JC. Vitamin D status and metabolic syndrome in the elderly: the Rotterdam study. *Eur J Endocrinol* 2015;172:327-35.
42. Tai K, Need AG, Horowitz M, Chapman IM. Vitamin D, glucose, insulin, and insulin sensitivity. *Nutrition* 2008;24:279-85.
43. Cutillas-Marco E, Fuertes-Prosper A, Grant WB, Morales-Suárez-Varela M. Vitamin D deficiency in South Europe: effect of smoking and aging. *Photodermatol Photoimmunol Photomed* 2012;28:159-61.
44. Kassi EN, Stavropoulos S, Kokkoris P, Galanos A, Moutsatsou P, Dimas C, Papatheodorou A, Zafeiris C, Lyrakis G. Smoking is a significant determinant of low serum vitamin D in young and middle-aged healthy males. *Hormones (Athens)* 2015;14:245-50.
45. Bergada L, Pallares J, Maria Vittoria A, Cardus A, Santacana M, Valls J, Cao G, Fernández E, Dolcet X, Dusso AS, Matias-Guiu X. Role of local bioactivation of vitamin D by CYP27A1 and CYP2R1 in the control of cell growth in normal endometrium and endometrial carcinoma. *Lab Invest* 2014;94:608-22.
46. Joh HK, Lim CS, Cho B. Lifestyle and dietary factors associated with serum 25-hydroxyvitamin D levels in Korean young adults. *J Korean Med Sci* 2015;30:1110-20.
47. Yoo SY, Hong ST, Yang JH. Breakfast frequency and vitamin D status in South Korean adults: Korean National Health and Nutrition Examination Survey 2013-2014. *Korean J Fam Pract* 2017;7:830-6.
48. Peters BS, Verly E Jr, Marchioni DM, Fisberg M, Martini LA. The influence of breakfast and dairy products on dietary calcium and vitamin D intake in postpubertal adolescents and young adults. *J Hum Nutr Diet* 2012;25:69-74.
49. Yim KS, Lee TY. Sociodemographic factors associated with nutrients intake of elderly in Korea. *Korean J Nutr* 2004;37:210-22.
50. Scragg R, Camargo CA Jr. Frequency of leisure-time physical activity and serum 25-hydroxyvitamin D levels in the US population: results from the Third National Health and Nutrition Examination Survey. *Am J Epidemiol* 2008;168:577-86.
51. Lee I, Kang H. Association of physical activity and body fatness with vitamin D deficiency in older adults. *Korean J Obes* 2016;25:24-30.
52. Kim JH, Chang JH, Kim DY, Kang JW. Association between self-reported sleep duration and serum vitamin D level in elderly Korean adults. *J Am Geriatr Soc* 2014;62:2327-32.
53. Huang W, Shah S, Long Q, Crankshaw AK, Tangpricha V. Improvement of pain, sleep, and quality of life in chronic pain patients with vitamin D supplementation. *Clin J Pain* 2013;29:341-7.