Sex-specific relationships between alcohol consumption and vitamin D levels: The Korea National Health and Nutrition Examination Survey 2009

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Abstract

This study assessed the association between vitamin D sufficiency (serum 25(OH)D ≥ 30 ng/mL) and alcohol consumption using data from the Korea National Health and Nutrition Examination Survey conducted in 2009. The following characteristics were obtained in 7,010 Korean participants $\geq$ 19-years-of-age: serum 25(OH)D level, alcohol consumption (drinking frequency, drinking number of alcoholic beverages on a typical occasion, average daily-alcohol intake), and potential confounders (age, residence, housing status, occupation, total fat and lean mass, smoking, physical activity, history of liver diseases, liver function, and daily intake of energy, protein, and calcium). After adjusting for confounders, vitamin D sufficiency in men was significantly associated with drinking frequency, number of alcoholic drinks consumed, and average daily alcohol intake; odds ratio of 1.21-1.72, 2.17-3.04, and 2.27-3.09, respectively. Increase in the three alcohol drinking-related behaviors was also linearly associated with increase in serum 25(OH)D level in men. By comparison, there was no significant association between alcohol intake and serum 25(OH)D level in women. The positive association between vitamin D sufficiency and alcohol consumption was evident only in Korean men.

Key Words: Vitamin D sufficiency, alcohol consumption, sex

Introduction

It has long been known that excessive alcohol consumption has a negative impact on vitamin D status. Chronic alcoholism results in disturbed vitamin D metabolism and chronic alcoholics usually have low levels of serum 25-hydroxyvitamin D [25(OH)D] [1,2]. However, experimental studies in rats has determined that chronic ethanol treatment increases the serum levels of 25(OH)D [3,4]. Although these observations from a laboratory animal model suggest a possible beneficial effect of long-term alcohol consumption on vitamin D status in humans, the evidence from population-based studies has been inconsistent [5-7]. In addition, little is known regarding specific alcohol consumption-related behaviors in Asian populations. As correlates vary somewhat depending on ethnicity and sex [6,7], further studies have been necessary to demonstrate the sex-specific association between alcohol consumption and vitamin D status in Asian populations.

As only 13.2% of the male and 6.7% of the female segment of the Korean population had sufficient vitamin D [serum 25(OH)D $\geq$ 30 ng/mL] in the Fourth Korea National Health and Nutrition Examination Surveys (KNHANES IV) conducted in 2008 [8], exploration of characteristics associated with vitamin D sufficiency is important. Thus, the present study aimed to examine the sex-specific relationships between vitamin D sufficiency and alcohol consumption, using data from KNHANES IV conducted in 2009.

Subjects and Methods

The KNHANES IV was a community-based cross-sectional survey conducted from 2007 to 2009 by the Division of Chronic Disease Surveillance, Korea Centers for Disease Control and Prevention to assess the health and nutritional status of the non-institutionalized Koreans. The sampling and data collection procedures have been described in detail previously [8]. The present study included 7,010 individuals (3,068 males and 3,942 females) aged 19 years and older who participated in the survey between February and December of 2009. All the participants in this survey signed an informed consent form. Serum 25(OH)D and liver function (alkaline phosphatase, alanine aminotransferase, and aspartate amoinotransferase) were measured using a radioimmunoassay (Biosource, Nivelles, Belgium) and enzyme methods (ADVIA 1650; Siemens, Holliston, MA, USA), respectively. Serum vitamin D levels were classified as vitamin D insufficiency (serum 25(OH)D levels < 30 ng/mL) and vitamin D sufficiency (serum 25(OH)D levels $\geq$ 30 ng/mL) [9]. Self-reported question-naires were used to assess participant's alcohol consumption during the previous year, which included average drinking

frequency and number of alcoholic drinks ingested on a typical occasion. A drink was defined as 30 mL of liquor and 200 mL of beer, which were equivalent to 10 g of pure alcohol. The average daily alcohol intake (g alcohol/day) was calculated using the two variables and then categorized into four groups in women and six groups in men: non-users, < 15.0, 15.0-29.9, and ≥ 30.0 in women; non-users, < 15.0, 15.0-29.9, 30.0-49.9, 50.0-69.9, and ≥ 70.0 in men [10]. Self-reported questionnaires were also used to assess smoking status and physical activity (regular walking, high-intensity physical activity, and moderate-intensity physical activity). Face-to-face interviews were used to obtain data about participants' demographic factors including place of residence, housing status, occupation, and medical history of chronic liver diseases (hepatitis B and C and liver cirrhosis). Daily energy, protein, and calcium intake were assessed using a 24-h recall method. Total body fat mass and lean mass were measured using whole body dual energy X-ray absorptiometry (DXA) (DISCO-VERY-W fan-beam densitometer, Hologic, Bedford, MA, USA).

As there was a significant interaction between sex and alcohol consumption in the relationships with serum 25(OH)D level categories, sex-specific analysis was conducted. In these relationships, the potential confounders were age, demographic factors, total body fat and lean mass, liver function, physical activity, smoking, medical history of chronic liver diseases, and dietary intake. Multiple logistic regression analyses or a general linear model were applied to find associations between alcohol consumption and serum 25(OH)D level as discrete or continuous variables, respectively, after adjusting for potential confounders. These analyses were performed using PASW, Statistics18, Release 18.0.0 (SPSS, Chicago, IL, USA).

Results

Of the 7,010 participants, 8.7% of the men and 4.1% of the women were vitamin D sufficient. Drinking frequency and daily alcohol intake were significantly higher in the men with sufficient vitamin D level compared to the men with insufficient vitamin D level. However, the number of alcoholic beverages consumed was significantly lower in the women with sufficient vitamin D level compared to their counterparts (Table 1). On the other hand, total bone mineral density was positively associated with consumed alcohol amount in both men (P for trend 0.006) and women (P for trend < 0.001). When potential confounders were adjusted, the significant association between vitamin D sufficiency and alcohol consumption remained in the men but not in the women. Compared to the men who did not or rarely consumed alcohol, the adjusted odds of vitamin D sufficiency

Table 1. Factors associated with serum vitamin D status (25(OH)D[1]) in men and women separately.

	25(OH)D in men (n = 3,068)		25(OH)D in women (n = 3,942)	
	< 30 ng/mL	≥ 30 ng/mL	< 30 ng/mL	≥ 30 ng/mL
N (%)	2,801 (91.3)	267 (8.7)	3,781 (95.9)	161 (4.1)
Alcohol consumption-related behavior				
Drinking frequency per month	7.0 ± 8.1	10.2 ± 9.7*	2.1 ± 4.4	2.2 ± 5.3
Drinks of alcoholic beverages on a typical occasion	4.9 ± 3.6	5.1 ± 3.5	2.0 ± 2.4	1.7 ± 2.3*
Alcohol consumption (g alcohol/day)	15.5 ± 20.8	21.5 ± 24.8*	3.2 ± 9.3	2.8 ± 10.1
Potential confounders				
Total fat mass (kg)	15.1 ± 5.3	13.8 ± 4.8*	18.7 ± 5.4	18.4 ± 5.3
Toal lean mass (kg)	53.4 ± 7.1	52.1 ± 7.2*	38.0 ± 4.8	37.3 ± 5.1
Age (yrs)	47.9 ± 16.5	55.7 ± 14.3*	48.6 ± 16.3	57.2 ± 15.4*
Aspartate aminotransferase (U/L)	25.2 ± 17.3	26.4 ± 15.8	20.5 ± 8.9	22.0 ± 8.4*
Alanine aminotransferase (U/L)	27.4 ± 26.0	25.0 ± 17.9	17.7 ± 13.2	18.6 ± 11.5
Alkaline phosphatase (U/L)	235.6 ± 70.5	231.4 ± 58.7	216.7 ± 74.1	221.9 ± 68.8
Energy intake (kcal/day)	2,217 ± 897	2,295 ± 907	1,586 ± 618	1,576 ± 971
Protein intake (g/day)	79 ± 40	79 ± 41	55 ± 28	54 ± 31
Calcium intake (mg/day)	552 ± 351	540 ± 361	423 ± 319	384 ± 222
Current smoker, N (%)	1,217 (43.7)	103 (38.7)*	230 (6.1)	8 (5.0)
Physical activity, N (%)				
High intensity	535 (19.2)	51 (19.2)	551 (14.6)	20 (12.5)
Moderate intensity	402 (14.4)	43 (16.2)	523 (13.9)	30 (18.8)
Walking	1,322 (47.5)	141 (53.0)*	1,630 (43.3)	79 (49.4)
Live in rural areas, N (%)	674 (24.1)	130 (48.7)*	931 (24.6)	61 (37.9)*
Dwell in apartment, N (%)	1,179 (42.1)	61 (22.8)*	1,601 (42.3)	35 (21.7)*
Manual workers, N (%)	986 (35.6)	155 (59.8)*	701 (18.6)	49 (31.0)*
History of chronic liver diseases, N (%)	53 (1.9)	6 (2.2)	45 (1.2)	1 (0.6)

[1] Multiply by 2.496 to convert to the International System of Units
[2] Mean ± SD
*P < 0.05 using t-test or Chi-square test

Table 2. The associations between sufficient vitamin D level (serum 25(OH)D ≥ 30 ng/mL[1]) and alcohol consumption-related behavior for men and women separately

	Overall[2]	P for trend	Men[3]	P for trend	Women[3]	P for trend
Frequency of alcohol consumed		0.021		0.010		0.56
Non-user/≤1/month	1.0		1.0		1.0	
2-4/month	1.06 (0.76,1.47)		1.21 (0.79, 1.85)		0.86 (0.50, 1.48)	
2-3/week	1.18 (0.83,1.68)		1.36 (0.89, 2.09)		0.79 (0.35, 1.77)	
≥ 4/week	1.56 (1.09, 2.22)		1.72 (1.14, 2.61)		0.94 (0.32, 2.75)	
Drinks of alcoholic beverages on a typical occasion		< 0.001		< 0.001		0.44
Non-user	1.0		1.0		1.0	
1-2	1.60 (1.17, 2.19)		2.17 (1.29, 3.67)		1.32 (0.88,1.97)	
3-4	1.29 (0.87, 1.92)		1.75 (1.01, 3.05)		0.94 (0.50, 1.77)	
5-6	1.79 (1.18, 2.73)		2.60 (1.50, 4.52)		0.92 (0.37, 2.26)	
≥ 7	2.28 (1.55, 3.37)		3.04 (1.82, 5.08)		1.84 (0.80, 4.24)	
Alcohol consumption (g alcohol/day)		< 0.001		< 0.001		0.68
Non-user	1.0		1.0		1.0	
< 15.0	1.61 (1.21, 2.15)		2.27 (1.43, 3.60)		1.28 (0.87, 1.88)	
15.0-29.9	1.04 (0.58,1.87)		1.46 (0.74, 2.90)		0.43 (0.06,3.19)	
≥ 30 (women)	-				0.82 (0.19, 3.57)	
30-49.9 (men)			3.09 (1.76, 5.45)			
50-69.9 (men)	-		2.93 (1.39, 6.18)		-	
≥ 70 (men)	-		3.09 (1.49, 6.43)		-	

[1] Multiply by 2.496 to convert to the International System of Units
[2] Multiple logistic regression model after adjusting for sex and potential confounders [age, smoking, physical activity, place of residence, housing status, occupation, and medical history of chronic liver diseases, aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, total lean mass, total fat mass, and daily energy intake (energy, protein, and calcium intake)]
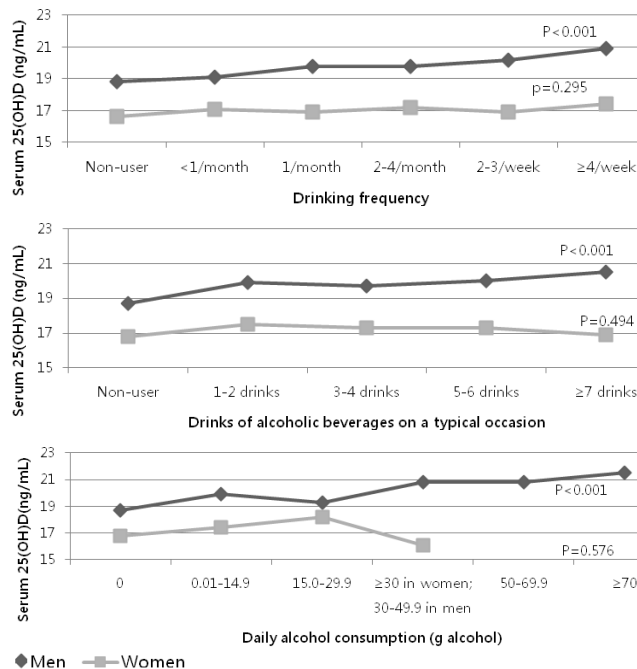[3] Potential confounders
*$P < 0.05$.

Fig. 1. Sex-specific serum mean 25(OH)D levels[†] plotted against the drinking frequency, average drinks of alcoholic beverages consumed on a typical occasion, and daily alcohol consumption (from top to bottom panel) after adjusting for age, smoking, physical activity, place of residence, housing status, occupation, medical history of chronic liver diseases, aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, total lean mass, total body fat mass, daily nutrient intake (energy, protein, and calcium). *P*-value derived from test for the linear trend. [†]Multiply by 2.496 to convert to the International System of Units.

was significantly higher in the men who drank on at least one occasion per month or in the men who consumed at least one drink on a typical occasion. Furthermore, the odds in these associations increased with increase in the level of alcohol consumption (Table 2). The sex-specific relationships between serum 25(OH)D level and alcohol consumption after adjustment for potential confounders is shown in Fig. 1. Serum 25(OH)D level linearly increased with increase in drinking frequency, number of alcoholic beverage consumed, and average daily alcohol intake in the men. In contrast, these linear trends were not significant in the women.

Discussion

In this cross-sectional study, increased alcohol consumption was associated with vitamin D sufficiency in the men but not in the women. These findings remained after controlling for age, smoking status, physical activity, total fat mass, total lean mass, liver function, history of chronic liver diseases, residential characteristics, occupation, and dietary intake. The association of alcohol intake with higher vitamin D concentrations that was observed in this study has not been seen consistently in other reports. The discrepancy may be attributed to differences in ethnicity, adjustment level of confounders, and alcohol consumption-related measures. Previous research has shown that chronic alcoholism generally results in disturbed vitamin D metabolism,

although short-term exposure has no effect [11]. The biochemical processes underlying the inverse relationship between alcohol consumption and vitamin D level is complex. Although studies have suggested that a low vitamin D level in chronic alcoholics is due to malabsorption, poor dietary intake, lack of sunlight exposure, or a direct effect of alcohol on vitamin metabolism [11,12], malabsorption of vitamin D, decreased levels of vitamin-D binding protein, or a reduction in the ability to hydroxylate vitamin D in the liver have been clearly demonstrated to explain the vitamin D levels [11]. In one study of elderly Americans [5] and another study of participants aged 49-75 years [6], there were no significant association between serum 25(OH)D level and alcohol intake when the results were controlled for various confounding factors. By comparison, in the recent populations-based 'Cohort Consortium Vitamin D Pooling Project of Rarer Cancers' study, current alcohol consumption (vs. none) was associated with an increase in serum 25(OH)D level and was a protective factor for very low serum 25(OH)D level (< 25 nmol/L) [7]. However, as this study did not examine the association specifically for consumed alcohol drinks per typical occasion or alcohol use frequency, these results cannot be directly compared with the current findings.

Despite adjustment for potential confounders, residual and unmeasured confounders such as seasonal variation of vitamin D level, dietary sources or supplements of vitamin D, and lifestyle favorable to vitamin D sufficiency may explain current findings. Higher serum 25(OH)D level in heavy alcohol users may reflect disturbed vitamin D metabolism (i.e. inhibition of conversion from 25(OH)D to 1,25-dihydroxy vitamin D) and then increase in bone resorption and decreased bone mineralization, rather than vitamin D sufficiency [3] However, in the current study, as total bone mineral density was positively associated with the amount of alcohol consumed, a defect in bone mineralization in heavy alcohol users did not seem to be evident. An underlying biochemical mechanism to explain the positive association between alcohol consumption and serum 25(OH)D level needs to be demonstrated.

The underlying mechanism to explain the sex-related difference in these associations is also unclear, although inconsistent ethanol-related health effects between men and women and sex-difference in the genetic background in the metabolism of alcohol and tissue-sensitivities to ethanol may be related to current observation [13]. Probably, the small number of heavy female alcohol users may also explain the sex-related difference.

There are limitations that should be considered. Firstly, important confounders including the season of measurement, vitamin D intake, and serum calcium and phosphate concentration that could influence serum 25(OH)D level were not adjusted for because that information was not provided. Secondly, data collection on alcohol consumption based on self-report may lead to underreporting, particularly among heavy drinkers and women. Particularly, lack of female heavy drinkers may have hindered any conclusion concerning a sex-specific relationship between alcohol consumption

and vitamin D. Finally, this study design does not allow for an evaluation of temporal relationships between vitamin D and alcohol consumption. As serum 25(OH)D level is the accepted biomarker for short-term vitamin D status [14], the associations between long-term vitamin D status and alcohol consumption may not be extrapolated from the current study.

Despite these limitations, this population-based study using data from a nationally representative Korean population indicates that increased alcohol consumption is associated with vitamin D sufficiency in Korean men, independent of other lifestyle, nutritional status, sociodemographic variables, and liver disease-related measures. These association was absent in women, indicating (but not confirming) a specific role of sex in these associations. Further relevant studies in other populations should be performed to confirm these findings and explain the underlying mechanism.

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