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Association between alcohol consumption and bone strength in Korean adults: the Korean Genomic Rural Cohort Study

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Abstract

Previous studies have reported an inconsistent relationship between alcohol consumption and bone health. A growing body of research has shown that chronic alcoholism leads to osteopenia and increased incidence of skeletal fractures, but some studies have concluded that alcohol consumption may be associated with higher bone mineral density in elderly populations. However, most studies showing a significant relationship between alcohol consumption and bone status have been in Western countries; and subjects have usually been postmenopausal women. The purpose of the present study was to investigate the association of alcohol consumption with bone strength in Korean adults. Data were from the Korean Genomic Rural Cohort Study, which is an ongoing population-based study of adults aged 40 to 70 years from 5 regions. A total of 7713 participants (3368 men, 4345 women) were surveyed about their annual consumption of alcohol such as soju, beer, makkolli, wine, and whisky. Bone strength was measured by stiffness index using the calcaneal quantitative ultrasound method. Overall, the annual age-specific decrease rate in the stiffness index of women was 2.7 times higher than that of men (0.463% for women, 0.169% for men).After adjustment for eligible covariates, the association between alcohol consumption and risk of reduced bone strength showed a J-shaped curve for both men and women. Compared with nondrinkers, the relative risk of reduced bone strength was 0.52 (95% confidence interval, 0.33-0.83) in men who drank 4 to 5 cups of soju for an amount of 29.626 to 49.375 g of alcohol per day and 0.61 (95% confidence interval, 0.38-0.86) in men who drank 6 to 7 cups of soju for an amount of 49.376 to 69.125 g of alcohol per day. We found no significant relationship between alcohol consumption and bone strength in any other group of men. For women, results suggested that the risk of reduced bone strength was lower in the moderate-consumption group; but no significant relationship was found between alcohol consumption at any level and bone strength. Among Korean adults, alcohol consumption has a J-shaped relationship with risk of reduced bone strength.

1. Introduction

Osteoporosis is a progressive systemic disease characterized by low bone mass and deterioration of bone tissue leading to bone fragility and fracture. According to the epidemiologic projections, this worldwide annual number will rise to 6.26 million; and regions such as Asia, Latin America, the Middle East, and Africa will account for more than 70% of all fractures in the world by the year 2050. The incidence rates of hip fractures vary considerably from population to population and race to race [1]. In 2007, the proportion of the Korean population aged 65 years or older was 8.7%; and it is expected to reach 15.1% in 2020 [2]. This trend indicates that osteoporosis-related fractures may become a major health problem in Korea. The age- and sex-adjusted incidence rates of hip fracture among men and women older than 40 years, estimated from the Health Insurance Review Agency Database, were 106.0/100 000/y and 156.9/100 000/y, respectively [3].

Previous studies have shown that chronic alcoholism leads to osteopenia and increased incidence of fractures [4-6] and that "binge" alcohol consumption leading to intoxication may affect the risk of falling, but other reports have suggested that alcohol consumption may be associated

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with higher bone mineral density (BMD) in elderly populations [7,8]. However, most of these studies have been limited to postmenopausal women and to Western countries. Whether there is a dose-response relationship or a threshold limit for alcohol consumption remains unclear. Numerous studies indicate that there are considerable differences in BMD and fracture risk among different racial or ethnic groups. Asians have been suggested to have lower BMD than white people because of smaller body size and low calcium intake [9]. Therefore, the effects of alcohol consumption on bone in Asian countries may be different from those in Western countries.

The objectives of the current study were to investigate the relationship between alcohol consumption and bone strength using calcaneal quantitative ultrasound (QUS) in Korean men and women, respectively.

2. Materials and methods

2.1. Subjects

This study was conducted as a part of the Korean Genomic Rural Cohort Study, a prospective population-based cohort study among men and women aged 40 to 70 years old focused on the prevalence, incidence, and related risk factors for chronic degenerative disorders such as hypertension, diabetes, osteoporosis, respiratory disease, and metabolic syndrome, and to obtain comprehensive information on public health and functional status among Koreans. The baseline examination of the Korean Genomic Rural Cohort Study was carried out in rural areas of Wonju, Pyeongchang, Gangreung, Geumsan, and Naju from October 2005; and subjects were asked to participate in this study using the media, conferences, telephone calls, etc. All components and procedures of this study were approved by the Institutional Review Board of Yonsei University Wonju College of Medicine. A total of 8511 persons were surveyed, and informed consent was obtained from all participants. Those being treated for osteoporosis were excluded because of the possibility of medication confounding the results. Finally, 7713 participants (3368 men, 4345 women) were analyzed.

2.2. Interview

Each study participant received a comprehensive physical examination and completed an interviewer-administered questionnaire. Detailed data on sociodemographic factors and personal characteristics were collected including age, income, occupation, marital status, and education. Information on individual and familial medical history including stroke, myocardial infarction, hypertension, diabetes, cancer, and fractures was collected, as was information relating to other lifestyle factors including smoking status, alcohol intake, and physical activity. In addition, dietary data were obtained using a semiquantitative food-frequency questionnaire that listed 103 food items generally consumed by Koreans. These data were collected through face-to-face interviews. Three sections of interview skill training were conducted for all interviewers before the interview, including general interview skill and the detailed objectives of the survey. Each session takes approximately 2 to 3 hours.

2.3. Alcohol consumption

The *alcohol drinker* was defined as one who drinks alcoholic beverages at least once a month. Current drinkers were asked how often, on average, over the past year they consumed each beverage. We calculated total alcohol intake by multiplying the average consumption of each beverage by the alcohol content of the specified portion size (13.27 g for makkolli, 9.875 g for soju, 6.952 g for beer, 8.532 g for wine, and 9.480 g for whisky) and summing across beverages. These figures were based on the average concentrations of alcohol in various types of beverages set by the Government Alcohol Agency in Korea. Because the most popular liquor in Korea is soju, level of total alcohol consumption was grouped into 5 categories for men: less than or equal to 1 cup of soju, 2 to 3 cups of soju, 4 to 5 cups of soju, 6 to 7 cups of soju, and greater than or equal to 8 cups of soju; for women, grouping was based on the fact that their consumption was half that of men: less than or equal to 1/2 cup of soju, 1 to 3/2 cups of soju, and greater than or equal to 2 cups of soju.

2.4. Bone measurements

Bone strength was assessed by stiffness index using the Achilles ultrasonometer (Lunar Model A-1000 Plus; GE Lunar, Madison, WI) at the right calcaneus. The ultrasound system consists of 2 sound transducers (emitting and receiving) that were faced with elastomer pads. Contact between the heel and the emitting and receiving transducer of the ultrasound was achieved with ultrasonic coupling gel. The ultrasound signal is emitted from one transducer and transmitted to the second transducer. After the signal is digitized and stored, the data are sent to a computer for automated analysis. The stiffness index was expressed as a percentage of young normal values and obtained by a mathematical combination of broadband ultrasound attenuation (in decibels per megahertz) and speed of sound (in milliseconds) using the following formula: stiffness index = 0.67 × broadband ultrasound attenuation + 0.28 × speed of sound − 420 [10]. Calcaneal bone stiffness correlates highly (r <0.85) with the BMD of the purely cancellous bone, and accuracy is high [11]. Quality control checking was performed daily before testing the subjects by scanning phantoms provided by the manufacturer.

2.5. Anthropometric measurements

The anthropometric measurements of each participant were taken after an overnight fast and while wearing light clothing and no shoes. Height was determined using a fixed wall-scale measuring device and was measured to the

Table 1
Sociodemographic characteristics of the study subjects

		Men n (%)	Women n (%)
Total		3368 (100)	4345 (100)
Age‡ (y)	40-49	650 (19.3)	1232 (28.4)
	50-59	1199 (35.6)	1536 (35.4)
	60-70	1519 (45.1)	1577 (36.2)
Occupation‡	None/housewife	269 (8.0)	1145 (26.4)
	Worker	626 (18.6)	730 (16.8)
	Farmer	2473 (73.4)	2470 (56.8)
Income‡ (10 000 won/mo)	≤99 (low)	1758 (51.1)	2869 (57.5)
	100-299 (medium)	1197 (34.8)	1185 (23.7)
	≥300 (high)	486 (14.1)	939 (18.8)
Education‡	Elementary school or less	1808 (52.4)	3795 (75.3)
	Middle school	755 (21.9)	678 (13.5)
	High school/college	877 (25.7)	565 (11.2)
Marital status‡	Single	224 (6.7)	791 (18.2)
	Married	3144 (93.3)	3554 (81.8)

‡ $P < .001$.

nearest 0.1 cm. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

2.6. Statistical analysis

Frequencies and mean of potential confounding variables by level of alcohol consumption and tertile of stiffness index were examined using χ^2 test and 1-way analysis of variance. The Pearson correlation coefficient was used to examine the relationship between potential osteoporotic risk factors and stiffness index, and alcohol consumption. The association between alcohol consumption and stiffness index was calculated by odds ratio (OR) using logistic regression adjusting for age and associated variables. In the logistic regression models, stiffness index was dichotomized as the first tertile vs the second and the third tertiles. Statistical analysis was performed on SPSS for Windows version 12.0 (SPSS, Chicago, IL). $P < .05$ was considered statistically significant.

3. Results

Descriptive sociodemographic characteristics of the 3368 men and 4345 women are shown in Table 1. The majority of subjects were aged 50 to 70 years and were farmers, and more than half had a low level of education and low income (<1 000 000 won/mo).

We performed Pearson correlation coefficient tests to examine the relationship of the stiffness index to potential osteoporotic risk factors and alcohol consumption by sex (Table 2). In men, the stiffness index showed negative correlations with age ($r = -0.169$, $P = .000$), history of fractures (no vs yes; $r = -0.053$, $P = .002$), and lifetime tobacco smoking ($r = -0.036$, $P = .041$) and positive correlation with BMI ($r = 0.082$, $P = .000$) and dietary calcium intake ($r = 0.042$, $P = .014$). Meanwhile, in women, BMI ($r = 0.060$, $P = .000$), any chronic disease (no vs yes; $r = -0.045$, $P = .003$), history of fractures (no vs yes; $r = -0.125$, $P = .000$), time spent exercising ($r = 0.051$, $P = .001$), and dietary calcium intake ($r = 0.113$, $P = .000$) were positively correlated with stiffness index; but age ($r = -0.463$, $P = .000$), menopause status (premenopause vs postmenopause; $r = -0.378$, $P = .000$), age at menarche ($r = -0.160$, $P = .000$), and number of pregnancies ($r = -0.267$, $P = .000$) were inversely correlated with stiffness index. Moreover, the alcohol consumption also showed significant correlations with age and smoking in both men and women.

Table 3 shows the characteristics of the study subjects according to alcohol consumption. The proportion of drinkers was 63.2% for men and 27.2% for women. We found that 307 men (9.12%) reported an average alcohol consumption of more than 8 cups of soju, the highest level in our 6-category classification system. Among women, 240

Table 2
Correlation coefficients of potential osteoporotic risk factors with alcohol consumption and stiffness index

	Men				Women			
	Alcohol consumption (g/d)		Stiffness index (%)		Alcohol consumption (g/d)		Stiffness index (%)	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Age (y)	−0.047	.006	−0.169	.000	−0.057	.000	−0.463	.000
Income (10 000 won/mo)	0.12	.522	0.111	.000	0.054	.001	0.215	.000
Any chronic disease[a]	−0.017	.320	−0.026	.139	−0.021	.168	−0.045	.003
History of fractures[a]	0.046	.009	−0.053	.002	−0.004	.816	−0.125	.000
BMI (kg/m^2)	0.006	.749	0.082	.000	0.001	.950	0.060	.000
Smoking (pack-year)	0.069	.000	−0.036	.041	0.054	.000	−0.015	.337
Exercise (h/wk)	−0.017	.341	0.026	.141	−0.013	.390	0.051	.001
Calcium (mg/d)	0.040	.020	0.042	.014	0.021	.160	0.113	.000
Postmenopause[a]					−0.063	.000	−0.378	.000
Age at menarche (y)					−0.015	.336	−0.160	.000
Pregnancy (times)					−0.018	.240	−0.267	.000

[a] Nominal variable of 0 (no) or 1 (yes).

Table 3
Mean levels of potential osteoporotic risk factors by alcohol consumption in men and women

	Age (y)	Stiffness index	BMI (kg/m^2)	Smoking (pack-year)	Exercise (h/wk)	Calcium (mg/d)	Age at menarche (y)	Pregnancy (times)
Men								
No (n = 804)	58.6 ± 7.70	89.8 ± 16.8	23.9 ± 3.66	21.5 ± 30.1	1.49 ± 7.60	384.7 ± 291.0		
Ex (n = 437)	58.9 ± 7.57	91.0 ± 15.9	24.3 ± 4.76	27.1 ± 34.2	1.77 ± 7.16	383.0 ± 253.8		
≤1 Cup of soju (n = 614)	57.0 ± 7.73	92.5 ± 16.5	24.2 ± 4.36	25.7 ± 56.1	1.38 ± 5.96	443.7 ± 288.0		
2-3 Cups of soju (n = 628)	56.7 ± 8.08	91.3 ± 16.3	24.0 ± 4.14	22.8 ± 32.2	0.76 ± 2.55	409.4 ± 276.4		
4-5 Cups of soju (n = 306)	56.1 ± 7.54	91.9 ± 17.0	24.3 ± 3.02	28.7 ± 45.8	0.91 ± 2.55	422.1 ± 340.9		
6-7 Cups of soju (n = 272)	57.7 ± 8.04	90.1 ± 16.0	23.8 ± 3.03	25.7 ± 25.7	1.03 ± 2.75	423.8 ± 295.5		
≥8 Cups of soju (n = 307)	56.4 ± 8.44	90.5 ± 16.4	24.3 ± 5.60	33.0 ± 45.6	1.08 ± 4.19	446.5 ± 293.3		
P value	.000	.076	.229	.000	.062	.000		
Women								
No (n = 2961)	56.2 ± 7.96	82.7 ± 15.6	24.9 ± 3.63	0.20 ± 2.40	1.15 ± 4.74	422.5 ± 326.1	16.7 ± 1.88	3.52 ± 1.58
Ex (n = 204)	56.1 ± 8.28	82.8 ± 14.6	25.4 ± 4.41	0.29 ± 1.88	1.47 ± 4.87	378.4 ± 249.7	16.9 ± 1.93	3.33 ± 1.60
≤1/2 Cup of soju (n = 759)	54.0 ± 8.31	85.5 ± 14.7	25.0 ± 5.25	0.27 ± 2.53	1.10 ± 3.77	435.3 ± 368.7	16.7 ± 2.04	3.46 ± 1.49
1-3/2 Cups of soju (n = 181)	51.8 ± 8.18	86.6 ± 17.3	25.1 ± 3.39	3.46 ± 39.7	0.74 ± 1.76	440.3 ± 379.0	16.3 ± 1.71	3.16 ± 1.59
≥2 Cups of soju (n = 240)	53.0 ± 8.59	83.3 ± 15.5	24.8 ± 3.19	1.41 ± 6.54	1.01 ± 2.26	461.9 ± 348.5	16.7 ± 2.14	3.26 ± 1.66
P value	.000	.000	.465	.000	.612	.075	.044	.007

(5.52%) reported the highest level of average alcohol consumption for women, more than 2 cups of soju. In addition, we found that, in men, alcohol consumption was associated with age, lifetime tobacco smoking, and calcium intake; in women, it was associated with age, stiffness index, lifetime tobacco smoking, age at menarche, and number of pregnancies.

The distribution of the potential osteoporotic risk factors according to the tertile of stiffness index in men is shown in Table 4. Male subjects in the lower tertile group were older and had lower BMI than those in either the medium or upper tertile group. Mean dietary calcium intake was lowest in the lower tertile group, whereas the proportions of previous history of fracture and lifetime tobacco smoking were highest in the lower tertile group. The amount of alcohol consumption did not differ according to the tertile of stiffness index (23.9 ± 39.9 for lower tertile groups, 25.3 ± 47.4 for medium tertile groups, and 24.4 ± 45.4 for upper tertile groups, respectively).

Table 5 shows the potential osteoporotic risk factors according to the tertile of stiffness index in women. The amount of alcohol consumption also did not differ according to the tertile of stiffness index (2.04 ± 9.72 for lower tertile groups, 2.08 ± 7.64 for medium tertile groups, and 1.99 ± 9.03 for upper tertile groups, respectively). Subjects in the lower tertile group were older and had a higher proportion of previous history of fractures than other tertile groups. Mean time spent exercising and calcium intake were significantly lower in the lower tertile group than in the upper tertile group, whereas the age at menarche and number of pregnancies were significantly higher in the lower tertile group than in either the medium or upper tertile group.

To check the effect of alcohol consumption on bone strength, we undertook logistic regression analysis to determine the ORs of reduced bone strength. We defined subjects in the combined medium and upper tertiles as a reference, and ORs were calculated for level of alcohol consumption in the lower tertile of stiffness index compared with reference. Among men, the relative risk of reduced bone strength according to amount of alcohol consumed showed a J-shaped curve; and there was a significantly lower risk of reduced bone strength with subjects who drank 1 to 5 cups of soju per day compared with nondrinkers in univariate analysis (Fig. 1A). Furthermore, after adjustment for age,

Table 4
The potential osteoporotic risk factors to the tertile of stiffness index in the male subjects

Tertile[a]	Stiffness index (%)		
	Lower	Medium	Upper
n	1103	1133	1132
Age (y)	59.3 ± 7.55	56.7 ± 7.90*	56.4 ± 7.92*
Income (10 000 won/mo)	104.1 ± 105.6	127.3 ± 112.1*	129.4 ± 115.8*
Education‖			
Elementary school or less	641 (59.7)	535 (47.4)	570 (50.4)
Middle school	205 (19.1)	278 (24.6)	252 (22.3)
High school/college	228 (21.2)	315 (27.9)	308 (27.3)
Any chronic disease			
No	423 (39.0)	438 (38.7)	433 (38.3)
Yes	662 (61.0)	695 (61.3)	698 (61.7)
History of fractures§			
No	803 (74.4)	884 (78.2)	910 (80.7)
Yes	276 (25.6)	246 (21.8)	218 (19.3)
BMI (kg/m^2)	23.6 ± 4.92	24.3 ± 4.40*	24.4 ± 2.85*
Smoking (pack-year)	28.0 ± 44.1	23.6 ± 32.9*	24.6 ± 42.2
Alcohol consumption (g/d)	23.9 ± 39.9	25.3 ± 47.4	24.4 ± 45.4
Exercise (h/wk)	1.16 ± 5.97	1.27 ± 4.73	1.37 ± 6.21
Calcium (mg/d)	394.0 ± 288.1	429.8 ± 292.9*	414.5 ± 285.7

[a] Lower (18 ≤ stiffness index ≤ 83), medium (84 ≤ stiffness index ≤ 99), and upper (100 ≤ stiffness index ≤ 162).

* $P < .05$ vs first bone stiffness tertile.

§ $P < .01$.

‖ $P < .001$.

Table 5
The potential osteoporotic risk factors to the tertile of stiffness index in the female subjects

Tertile[a]	Stiffness index (%)		
	Lower	Medium	Upper
n	1482	1357	1506
Age (y)	60.0 ± 7.01	54.5 ± 7.66*	51.9 ± 7.64*,†
Income (10 000 won/mo)	76.7 ± 92.0	110.4 ± 114.4*	126.2 ± 116.9*,†
Education‖			
Elementary school or less	1220 (82.6)	947 (71.0)	979 (65.4)
Middle school	157 (10.6)	210 (15.7)	260 (17.4)
High school/college	100 (6.8)	177 (13.3)	259 (17.3)
Any chronic disease			
No	468 (31.6)	458 (34.3)	525 (34.9)
Yes	1014 (68.4)	879 (65.7)	981 (65.1)
History of fracture‖			
No	1169 (79.3)	1141 (85.7)	1332 (88.6)
Yes	306 (20.7)	191 (14.3)	172 (11.4)
BMI (kg/m^2)	24.8 ± 4.59	25.1 ± 3.24	25.1 ± 3.90
Smoking (pack-year)	0.39 ± 3.36	0.64 ± 13.7	0.19 ± 2.16
Alcohol consumption (g/d)	2.04 ± 9.72	2.08 ± 7.64	1.99 ± 9.03
Exercise (h/wk)	0.85 ± 3.68	1.25 ± 3.83	1.31 ± 5.41*
Calcium (mg/d)	381.2 ± 258.1	433.2 ± 311.6*	459.7 ± 404.9*
Postmenopause‖			
No	92 (7.3)	254 (24.0)	458 (40.0)
Yes	1173 (92.7)	804 (76.0)	688 (60.0)
Age at menarche (y)	17.1 ± 1.99	16.7 ± 1.87*	16.4 ± 1.85*
Pregnancy (times)	4.0 ± 1.68	3.3 ± 1.46*	3.1 ± 1.42*

[a] Lower (2.6 ≤ stiffness index ≤ 76), medium (77 ≤ stiffness index ≤ 91), and upper (92 ≤ stiffness index ≤ 141).
* $P < .05$ vs first bone stiffness tertile.
† $P < .05$ vs second bone stiffness tertile.
‖ $P < .001$.

income, current medication for clinical disease, history of fracture, exercise, smoking, BMI, and calcium intake, there was a statistically significant lower risk of reduced bone strength with subjects who drank 4 to 5 cups of soju per day (OR, 0.52; 95% confidence interval [CI], 0.33-0.83) and 6 to 7 cups of soju per day (OR, 0.61; 95 % CI, 0.38-0.86) compared with nondrinkers. However, the subjects who drank more than 8 cups of soju per day had higher risk of reduced bone strength; and this difference was not significant (Fig. 1B).

To examine the relationship between alcohol consumption and the risk of reduced bone strength among women, we grouped alcohol consumption into 5 categories, which also showed a J-shaped curve. In univariate logistic regression analysis, there was a lower risk of reduced bone strength in subjects who drank less than or equal to 1/2 cup of soju per day (OR, 0.61; 95% CI, 0.48-0.78) and 1 to 3/2 cups of soju per day (OR, 0.52; 95% CI, 0.31-0.86) compared with nondrinkers (Fig. 2A). However, we found no significant association between any level of alcohol consumption and risk of reduced bone strength in women after adjustment for age, income, current medication, history of fracture, exercise, smoking, BMI, calcium intake, menopausal status, age at menarche, number of pregnancies, and estrogen therapy (Fig. 2B).

4. Discussion

Bone is a living tissue. It is constantly resorbed and formed in the process known as *remodeling*. Thus, bone formation takes place not only during growth but throughout life. Osteoblasts are the cells responsible for bone formation and resorption. During growth, bone formation exceeds bone resorption. From age 30 to 50 years, the amount of bone formed approximately equals the amount resorbed. From menopause in women and from about the sixth decade in men, bone resorption starts to exceed bone formation. The mass of bony tissue present at any time during adult life is the difference between the amount accumulated at maturity and that lost with aging [12]. In this present study, the annual age-specific decrease rate in the stiffness index of women was 2.7 times higher than that of men (0.463% for women, 0.169% for men). These results are not consistent with previous studies [13-16]. For example, the total age-related decreasing rate for bone stiffness in women was lower than that of Italian women but higher than that of Chinese women. The decreasing rate for bone stiffness in men was higher than that of Italian and Chinese men. This difference could be accounted for by multiple factors such as body size, lifestyle, nutritional, and racial differences.

At present, several methods are used to determine bone status, of which the most common are dual-energy x-ray absorptiometry (DXA) and QUS. The central DXA, the most common method, predicts fracture risk by BMD and has become recognized as the criterion standard for predicting osteoporosis. However, QUS technology of bone measurement has been recently used because it is cost effective, lacks the deleterious effects of radiation, and is portable compared with DXA [17,18]. In addition, earlier studies have shown that it could predict fracture as effectively as the BMD does in both men and women [19-21]. The QUS measurements have been proposed because they provide not only the BMD but also the structural properties of bone as predictors of bone strength [22-24]. The stiffness index, one of the QUS parameters, has been a recent focus for evaluation and prediction of osteoporosis and fracture risks worldwide [25-29]; and many studies have suggested that bone stiffness identifies patients with osteoporotic fractures better than other parameters [18,30-32]. Moreover, Hans et al [20] pointed out that bone stiffness could be used as a single index to predict the fracture risk. Therefore, we used the stiffness value as an index of bone strength to predict the fracture risk.

We found that old age, lower BMI, and lower calcium intake were related to low stiffness in men and women. In addition, age at menarche and number of pregnancies in women showed a strong correlation with stiffness index. These findings are identical to those in Western countries, including studies on BMD [33-37]. After adjustment for

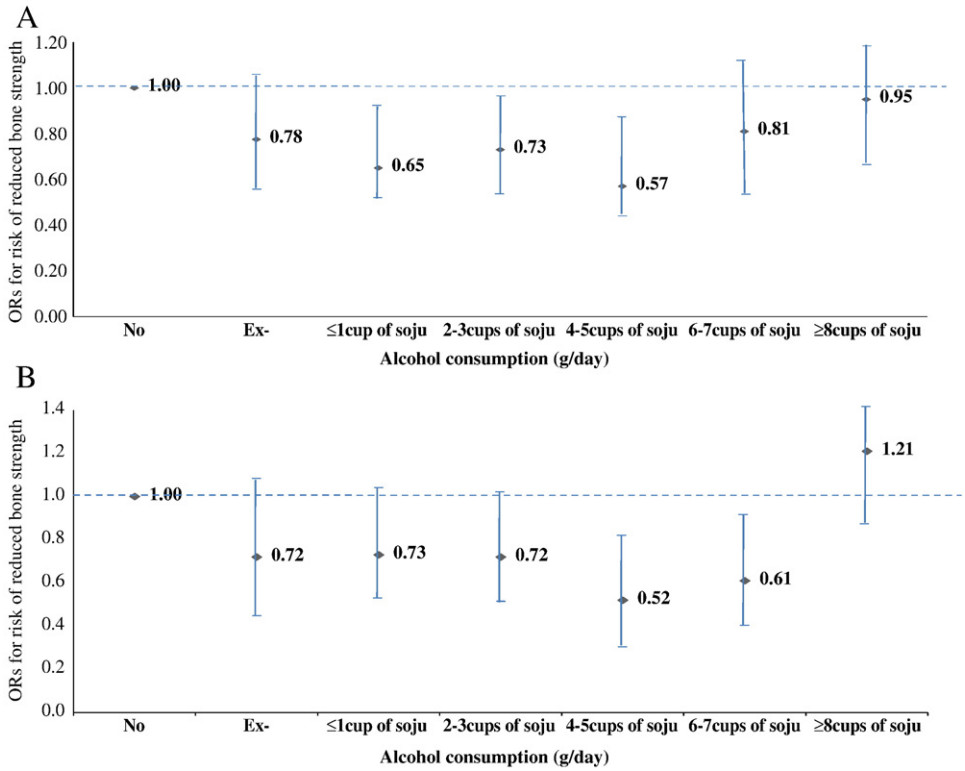

Fig. 1. A, Unadjusted odds ratios and 95% CIs of daily alcohol consumption on bone stiffness as a dichotomized variable (lower tertile vs medium and upper tertiles) in men. B, Adjusted odds ratios and 95% CIs of daily alcohol consumption on bone stiffness as a dichotomized variable (lower tertile vs medium and upper tertiles) in men.

eligible covariates, the association between alcohol consumption and risk of reduced bone strength showed a J-shaped curve in Korean adults. In particular, we found the lowest risk of reduced bone strength among men who drank 4 to 5 cups of soju (29.626-49.375 g of alcohol) per day compared with nondrinkers.

This threshold is much higher than that previously reported in Western countries. Laitinen et al [5] first reported a positive correlation between alcohol intake and BMD, with a 12%, 15%, and 9% increase in the lumbar spine, Ward triangle, and femoral neck, respectively; changes in values for the spine and Ward triangle were significant. In a prospective study, Holbrook and Barrett-Connor [38] observed that alcohol consumption was associated with an increase in BMD. They reported a significant increase in BMD of the femoral neck in men as alcohol intake increased. Furthermore, Hansen et al [39] observed a decreased rate of bone loss in 121 postmenopausal women with moderate alcohol consumption followed prospectively over a 12-year period. In the Framingham Study, Felson et al [40] observed that women who drank at least 23.1 g of alcohol per day had higher bone density at most sites than did women with the lowest alcohol intake and that men who were heavy drinkers (46 g/d) also had higher bone density than light drinkers but the difference was not significant. Cawthon et al [41] reported that moderate-to-heavy alcohol consumers (≥25.6 g/d) had a multivariate-adjusted mean BMD of 0.981 g/cm^2 of the hip, whereas nondrinkers had an adjusted mean BMD of 0.948 g/cm^2. In the Cardiovascular Health Study [42], alcohol intake was shown to have a significant U-shaped relationship with risk of hip fracture, with an approximately 20% lower risk for consumers of up to 23.4 g/d than for nondrinkers, even after multivariable adjustment. However, there was a graded positive relationship between alcohol intake and BMD of the hip. The pathogenesis of increasing bone density with alcohol consumption has not been established, but it may be estimated that alcohol promotes the production of adrenal androstenedione and increases its conversion to estrogen. In contrast with our findings, several studies have reported an increased risk of osteoporosis and osteoporotic fractures with increasing alcohol intake [43-45]. Kim et al [46] found that the BMDs in the femur and trochanter were lower in alcoholics who drank more than 40 g of alcohol per day than in those who drank less than 20 g/d. However, we found no significant association between any level of alcohol consumption and risk of reduced bone strength in women. Few female subjects(9.7%) were current alcohol drinkers who consumed more than 1 cup of soju per day, so alcohol consumption did not appear to have a major influence on stiffness index in this study. Moreover, Lau et al [47] also reported that the proportion of Asian women with alcohol consumption was low and that the prevention of

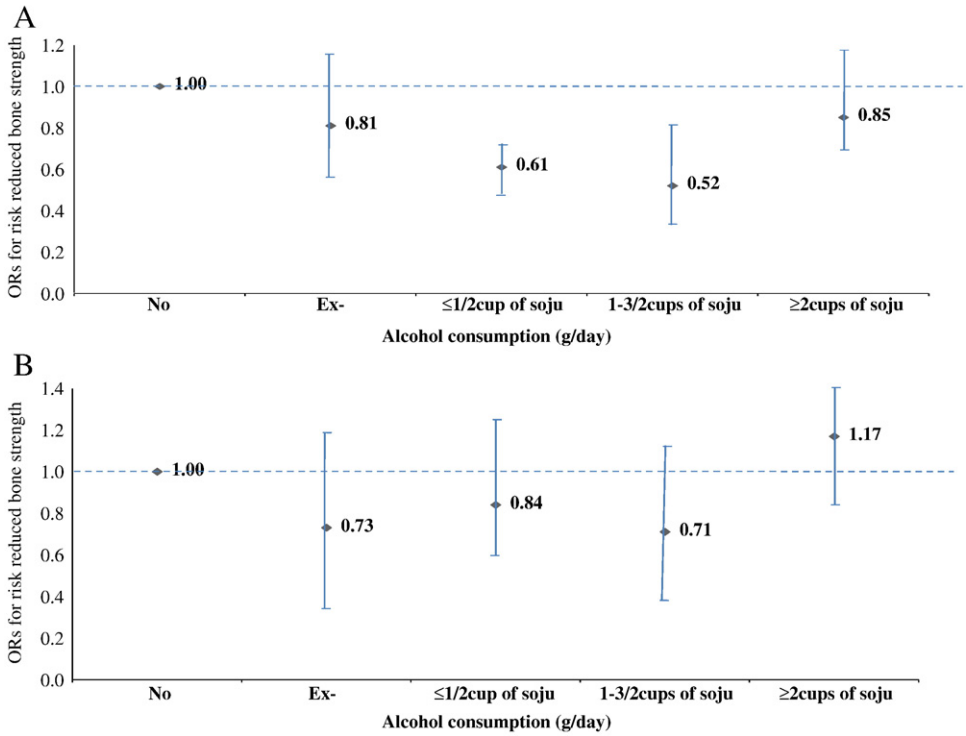

Fig. 2. A, Unadjusted odds ratios and 95% CIs of daily alcohol consumption on bone stiffness as a dichotomized variable (lower tertile vs medium and upper tertiles) in women. B, Adjusted odds ratios and 95% CIs of daily alcohol consumption on bone stiffness as a dichotomized variable (lower tertile vs medium and upper tertiles) in women.

alcohol consumption might have a relatively small effect on bone strength among Korean women.

The current study has some limitations. First, this study is cross-sectional rather than longitudinal, which might not be suitable for revealing detailed causation or reverse causation between alcohol consumption and bone health. Another limitation is that because Koreans drink irregularly in social settings, self-reported alcohol consumption may be underestimated. The reported amount and frequency of alcohol consumption by these subjects may differ from that reported. Despite these limitations, this study includes the largest sample size of the general population ever investigated in Korea. This is also the first epidemiologic study of alcohol consumption for bone status in both sexes.

In conclusion, our population-based study suggests that the decreasing rate of stiffness index with age is higher in women than in men. Secondly, the association between alcohol consumption and risk of reduced bone strength shows a J-shaped curve. Therefore, moderate alcohol consumption is beneficial for men to enhance bone strength, whereas heavy consumption may reduce bone strength in Korean adults.

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