BMJ Open

Association between alcohol consumption and Korean young women's bone health: a cross sectional study from the 2008 to 2011 Korea National Health and Nutrition Examination Survey

Seonwha Seo,[1,2] Sungsoo Chun,[2,3] Maxine Andrea Newell,[2,4] Mieun Yun[2]

To cite: Seo S, Chun S, Newell MA, *et al*. Association between alcohol consumption and Korean young women's bone health: a cross sectional study from the 2008 to 2011 Korea National Health and Nutrition Examination Survey. *BMJ Open* 2015;**5**:e007914. doi:10.1136/bmjopen-2015-007914

▸ Prepublication history for this paper is available online. To view these files please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2015-007914).

Received 11 February 2015
Revised 16 July 2015
Accepted 17 September 2015

For numbered affiliations see end of article.

Correspondence to
Dr Sungsoo Chun;
chss97@syu.ac.kr

ABSTRACT

Objectives: To assess the association between alcohol consumption and healthy Korean young women bone by Alcohol Use Disorders Identification Test (AUDIT) scores and drinking consumption; frequency and amount.

Design: Cross-sectional study composed of three parts: health interview, health examination, nutrition survey.

Setting: 2008–2011 Korea National Health and Nutrition Examination Survey.

Participants: Of the 21 303 participants whose bone mineral density (BMD) was assessed, 1176 healthy women aged 19–30 years were selected.

Primary and secondary outcome measures: Mean BMD T-scores of the total femur (TF), femur neck (FN) and lumbar spine (LB) by drinking consumption and AUDIT scores, and the odds of having a low BMD (T-score <−1) at the sites by AUDIT scores.

Results: After adjustment, lower BMD was found at three sites in those who drank more and had higher AUDIT scores. These associations were significant by AUDIT scores at TF (p=0.002) and FN (p=0.004) and by drinking frequency and amount at FN (p=0.029 and 0.039, respectively). The adjusted OR of having low BMD increased significantly, particularly at FN, in those who had higher AUDIT scores such as 16–17 harmful drinking (OR 4.31; 95% CI 1.16 to 16.06) and 20–40 alcohol dependence (OR 5.99; 95% CI 1.69 to 21.21), compared with young women who scored 0–7 low-risk drinking or abstinence. No beneficial effect of moderate drinking was observed at any of the sites and the association between alcohol consumption and bone health was most evident at FN.

Conclusions: It is crucial to promote the awareness of alcohol harm on Korean young women's bone health. At the same time, since alcohol's effect on the bone is complex with cumulative effects of various factors over the years and there is an absence of studies with young women in their twenties, more studies, in particular for FN, are needed with more precise and appropriate design to confirm our findings.

Strengths and limitations of this study

- The first study to investigate the association between alcohol consumption and young female bone health at the total femur, femur neck and lumbar spine, using a nationwide sample data representative of Korean young women in their twenties.
- Only healthy Korean young women, free of diseases known to influence bone metabolism, were considered in the study.
- The study is limited by its cross-sectional nature.
- Drinking variables based on the past year's experience were limited in their ability to fully reflect the effect of alcohol on bones by the extent and duration of alcohol exposure.
- The small number of outcome cases decreased the precision of the association between alcohol consumption and Korean young women's bone health.

INTRODUCTION

Osteoporosis is a skeletal disorder characterised by the reduction of bone density and quality, leading to weakness of the skeleton and increased risk of fractures, especially of the wrist, spine and hip.[1 2] Osteoporotic fractures are an important cause of mortality and morbidity and a considerable financial burden on economies.[1] With the trend towards ageing populations, osteoporosis is a major public health concern in many countries, including Korea.

In Korea, the proportion of people over 65 years of age was 7.2% in 2000 and is expected to reach 32.3% by 2040.[3] According to the recent 5-year (2007–2011) Korean patients with osteoporosis statistics released in 2013 by the Health Insurance Review Agency (HIRA), Korea, 93.7% of the patients were 50 years or older and the growing rate of the number of total patients was 44.3% with an annual growth rate of 9.7%. There was a particularly substantial increase in elderly patients aged over 70 years with a 75.2% increase during the same period with associated medical care costs of about 72 billion won (approximately 7.1million dollars) in 2011, an increase of 35% from 2007 with a 7.9% annual growth.[4]

Even though osteoporosis is considered an age-related disease, it is also affected by many other factors such as weight, dietary factors, family history of osteoporosis, menopausal status, exercise, smoking and drinking. Heavy drinking in particular is known to have detrimental effects on bone density, while the effect of light or moderate drinking on bones remains mixed: it can be beneficial for postmenopausal women but no benefit was found for premenopausal women.[5–7] Many human and animal studies indicate that alcohol consumption interrupts bone growth and replacement of bone tissue, causing increased bone fragility and susceptibility to fractures.[8–13] Influencing directly or indirectly on bone metabolism, alcohol consumption during adolescence and young adulthood, before the mid-30s, prevents the attainment of optimal peak bone mass (PBM), which is a major contributor to the development of strong and healthy bones in later years.[14 15]

The annual Korea National Health and Nutrition Examination Survey (KNHANES), however, suggests that alcohol consumption among Korean young women in their twenties was outstanding in every drinking indicator: high-risk drinking (on average more than 5 glasses per occasion more than two times per week) and weekly binge drinking (on average more than 5 glasses at a sitting more than once per week) rates in this group are 10.6% and 17.4%, higher than the 8% and 14.8% of all women aged over 19 years, respectively. The rates of their yearly and monthly drinking were also higher at 86.5% and 57.7%, respectively, than any other female age groups.[16] Besides, alcohol consumption in this life stage, particularly the formation of unhealthy drinking habits, may have deleterious effects on health in later years.

Most research on the effects of alcohol consumption on bone health has focused on middle-aged women over the age of 40 or postmenopausal women, when excessive bone loss is the key concern rather than adequate PBM attainment. There are few studies on the association of alcohol use with the bone health of Korean women younger than 35 years of age, even though optimal bone growth and development typically occur in this life stage. The aim of this study, therefore, is to assess the association between alcohol consumption and Korean young female adults' bone health by drinking patterns, using national-based data from the KNHANES.

METHODS

KNHANES is a cross-sectional survey conducted by the Korea Centers for Disease Control and Prevention and the Korean Ministry of Health and Welfare since 1998. The survey was made up of three parts: a health interview survey, a health examination survey and a nutrition survey. KNHANES represents a nationwide study of non-institutionalised civilians and used a stratified and multistage probability sampling design with a rolling survey-sampling model. Using a structured questionnaire, trained interviewers conducted face-to-face interviews.

Participants

We used KNHANES data collected between 2008 and 2011. A total of 37 753 people (80.7% of the total target population of 46 777), all of whom provided written consent, participated in the survey and 21 303 of them had their bone mineral density (BMD) measured. Among them, only female respondents aged from 19 to 30 years, and who completed the interview survey related to female health (n=1315), were included in the present analysis. Those diagnosed with hypertension (n=5), hyperlipidaemia (n=7), cardiac infarction/angina (n=1), arthritis (n=22), osteoarthritis (n=14), rheumarthritis (n=10), osteoporosis (n=5), tuberculosis (n=21), asthma (n=35), renal failure (n=2), diabetes (n=7), thyrosis (n=29), stomach cancer (n=2), liver cancer (n=2), breast cancer (n=2), cervical cancer (n=2), other cancers (n=3), hepatitis B (n=6), hepatitis C (n=2) and thyroid gland cancer (n=4) were excluded. Pregnant women (n=2) were also excluded. Finally, a total of 1176 participants were selected for analysis in the present study.

Variables

Bone status variables

T-scores of bone mineral density of the total femur (TF), femur neck (FN) and lumbar spine (LB) were used as a continuous variable or as a binary variables (T-score ≥−1 or <−1, respectively), to determine bone health status and characteristics of the participants by bone status. According to the WHO's standard, T-scores of ≥−1 are considered normal; −2.5< T-score <−1, osteopenia; and T-score ≤−2.5, osteoporosis; however, in this study, we categorised them into two groups: the normal (T-score ≥−1) and low-BMD groups (T-score <−1, osteopenia or osteoporosis). In order to measure BMD at these three sites, whole body dual-energy X-ray absorptiometry (DXA) was performed with a QDR Discovery (formerly known as the QDR 4500A) fan beam densitometer (Hologic, Inc, Bedford, Massachusetts, USA) following procedures recommended by the manufacturer. The results of DXA were analysed using the

standard techniques of the Korean Society of Osteoporosis and Hologic Discovery software (V.13.1).

Drinking variables

Drinking variables were assessed through items which inquired about whether they had ever drunk at least a glass of alcohol in their lifetime or not, frequency of alcohol consumption and amounts of alcohol consumed per occasion in the last year. In this study, abstainers were defined as those who never drank in their lifetime or who drank less than one per month with 1–2 glasses per occasion in the last year. Those who had not drunk at all only in the last year were excluded as missing values since the reason they stopped drinking could have been due to health problems, which could have had a confounding effect on our analysis if included in the study. The drinking frequency was divided into three groups: less than once per month, monthly (more than once per month), weekly and daily (more than two times per week). For drinking amount, the number of glasses people drank per occasion was categorised into less than 4 glasses, 5–6 glasses and more than 7 glasses. In this study, 1 glass is equivalent to roughly 8 g of pure alcohol, which can be found in 220 mL of regular beer with about 4.5% alcohol and 50 ml of distilled spirits (soju) with about 19% alcohol. The amount of alcohol was computed as (amount of drink (mL)×volume of alcohol (%)×density of ethanol at room temperature (0.8))/100. With 8 g of pure alcohol per glass, less than four glasses were considered equal to less than 32 g of pure alcohol. In the analysis, those who drank either less than once per month or less than four glasses were regarded as moderate drinkers. Alcohol Use Disorders Identification Test (AUDIT) scores were also considered. The participants were grouped according to their AUDIT scores: abstinence or low-risk drinking (0–7 points), more than low-risk drinking (8–15 points), harmful and hazardous drinking (16–19 points) and alcohol dependence (20–40 points).

Other variables

We considered age, height, weight, body mass index (BMI), age of initiation of smoking, physical activity, nutritional intake, age of menarche, family history of osteoporosis, oral contraceptive and female hormone use as potential confounding factors. The KNHANES health examination measured height and body weight, and BMI was calculated from the measured weight and height measurements as weight/height^2 (kg/m^2). Information for age, age of initiation of smoking and drinking, physical activity, age of menarche, family history of osteoporosis, oral contraceptive and female hormone use was examined through the health interview survey. Lifetime smoking also was examined by asking 'How many cigarettes have you smoked in your lifetime' (under or more than 100 or never). All data for nutritional intake were collected by using a 24 h dietary recall. Part of the health examination survey included the collection of blood samples which were used for biochemical measurements.

STATISTICAL ANALYSIS

Complex sample analysis was used in this study to correct the distributions of the cluster sample regarding the primary sampling unit, covariance and significance to correspond with those of the general Korean population. In order to compare means between the normal group (T-score ≥−1) and the low-BMD group (T-score <−1, osteopenia or osteoporosis) at each of the three sites, TF, FN and LB, the Student t test was used and to compare proportions, the χ^2 test was used. Analysis of covariance (ANCOVA) was used to compare the BMD levels (T-score) of participants at the three sites by drinking patterns after adjusting for covariates. The covariates included age, height, BMI, age of initiation of smoking, blood creatinine and alkaline phosphatase. Logistic regression analysis was conducted to calculate OR and 95% CIs for the association between AUDIT scores and the binary variable of BMD (T-score ≥−1: normal, T-score <−1: low BMD) at TF and FN. All statistical tests were two-tailed, and statistical significance was defined as $p<0.05$. The statistical calculation was performed with SPSS Statistics V.18 (SPSS, Chicago, Illinois, USA).

RESULTS

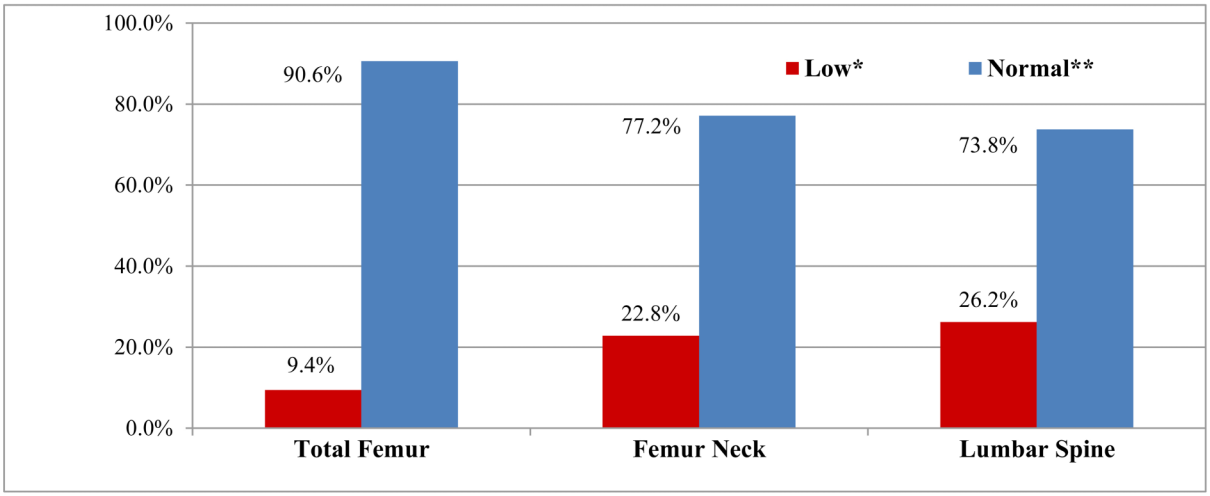
In this sample of 1176 Korean young women, the mean age was 24.68 (±0.12), height 161.38 (±0.21) and BMI 21.50 (±0.13). Among them, 95.07% are lifetime drinkers and 22.04% lifetime smokers. Age of initiation of both drinking and smoking was around 18 years. The average BMD T-scores (±SE) were 0.223 (±0.032), −0.273 (±0.036) and −0.399 (±0.034) at TF, FN and LB, respectively. In total, 9.4% of them have low BMD (either osteopenia or osteoporosis) at TF, 22.8% at FN and 26.2% at LB (figure 1).

General characteristics of the participants according to bone status (low: T-score <−1 vs normal: T-score ≥−1)

In table 1, the anthropometric and behavioural characteristics of Korean young women aged 19 to 30 years are presented according to bone health status. Low BMD was more frequent in younger women at TF and LB but in older women at FN. Those who were shorter had significantly low BMD at FN and LB. Lower weights and BMI were found in those women who had low BMD at all three sites.

The blood tests revealed significantly higher levels of alkaline phosphatase among those with low BMD, but no association was found between the levels of vitamin D and BMD at all three sites. Lower levels of blood creatinine were found in the participants with low BMD at all the sites, but the difference in LB was not statistically significant.

The behavioural variables demonstrated that low BMD at TF was significantly more common in the women who



	Total Femur			Femur Neck			Lumbar Spine		
	N	%	S.E	N	%	S.E	N	%	S.E
Low*	106	9.4%	1.0%	241	22.8%	1.4%	299	26.2%	1.5%
Normal**	1,049	90.6%	1.0%	815	77.2%	1.4%	845	73.8%	1.5%
Total	**1,155**	**100.0%**	**0.0%**	**1,056**	**100.0%**	**0.0%**	**1,144**	**100.0%**	**0.0%**

* Low T-score<-1 indicating osteopenia or osteoporosis

**Normal T-score≥-1

Figure 1 Distribution of low bone mineral density of total femur, femur neck and lumbar spine among the participants.

took in less vitamin A and carotene and started smoking at an earlier age. The portion of participants who practised intermediate physical activity was also lower among those with low BMD at TF. Unlike BMD at TF and FN, BMD at LB was associated with age of menarche, indicating that those who started their first period at a later age tended to have low BMD at LB. No association was found between BMD at all sites and calcium, phosphorus, sodium and potassium dietary intakes, family history of osteoporosis or fractures, intense physical activity practice and use of oral contraceptives and female hormones.

Mean BMD T-score comparisons at the TF, FN and LB according to drinking consumption and AUDIT scores.

Table 2 presents the average BMD T-scores at TF, FN and LB according to drinking consumption and AUDIT scores of the participants after adjustments.

Lower T-scores were found at all sites in those who drank more frequently and more number of glasses. However, the trend was statistically significant by both drinking frequency (p=0.029) and amount (p=0.039) for FN alone. Although the decreasing trend by drinking frequency was not significant at TF, BMD T-scores of abstainers (0.519±0.152) were higher than those of weekly drinkers (0.141±0.117) in its intergroup comparison.

There was also a decreasing trend in T-scores at all sites with greater AUDIT scores. The relationship was, however, statistically significant for TF and FN but not for LB. Those in abstinence or low-risk drinking especially had significantly higher T-scores of TF and FN (TF: 0.4 14±0.096, FN:−0.050±0.099) than in harmful and hazardous drinking (−0.077±0.100, −0.568±0.133) and in alcohol dependence (−0.110±0.189, −0.626 ±0.176). No significant difference was observed in LB BMD T-scores by any drinking variables used in the study.

Association between AUDIT scores and low BMD (T-score <−1) of TF and FN

Table 3 presents adjusted OR and 95% CIs for the associations between AUDIT scores and BMD T-score category, normal and low BMD groups. No significant association was found at either site, after adjustment for age, height and BMI. When adjusted for age, height, BMI, creatinine, alkaline phosphatase and age of initiation of smoking, however, the chances of having low BMD, particularly at FN, significantly increased with higher AUDIT scores. The odds of having either osteopenia or osteoporosis at FN was OR 4.31 (95% CI 1.16 to 16.06) for those in harmful drinking (AUDIT score: 16–19) and 5.99 (95% CI 1.69 to 21.21) for those in alcohol dependence (20–40), compared with those who are in abstinence or low-risk drinking categories (0–7).

DISCUSSION

Osteoporosis is the direct consequence of the failure to attain sufficient PBM in youth, typically before the mid-30s, and/or excessive rate of bone loss in later years, suggesting that the risk of fragility fractures in the

Table 1 Anthropometric and behavioural characteristics of Korean young women aged 19–30 years according to bone status (low: T-score <−1 vs normal: T-score ≥−1)

	Total femur					Femur neck					Lumbar spine				
	Low	±SE	Normal	±SE	p Value	Low	±SE	Normal	±SE	p Value	Low	±SE	Normal	±SE	p Value
Age (years), mean (±SE)	22.96	(0.45)	24.85	(0.12)	0.000***	25.68	(0.22)	25.08	(0.13)	0.014*	24.19	(0.22)	24.89	(0.14)	0.000***
Height (cm), mean (±SE)	160.52	(0.61)	161.52	(0.22)	0.122	159.93	(0.38)	161.83	(0.25)	0.000***	160.57	(0.36)	161.62	(0.25)	0.020*
Weight (kg), mean (±SE)	49.35	(0.82)	56.67	(0.39)	0.000***	51.14	(0.48)	57.39	(0.44)	0.000***	51.02	(0.4)	57.85	(0.45)	0.000***
BMI (kg/m^2), mean (±SE)	19.17	(0.34)	21.71	(0.14)	0.000***	20.00	(0.18)	21.90	(0.16)	0.000***	19.79	(0.15)	22.13	(0.16)	0.000***
Creatinine (mg/dL), mean (±SE)	0.67	(0.01)	0.70	(0.00)	0.006**	0.68	(0.01)	0.70	(0.00)	0.026*	0.69	(0.01)	0.70	(0.00)	0.080
Vitamin D (ng/mL), mean (±SE)	14.28	(0.75)	15.11	(0.23)	0.265	15.28	(0.43)	15.01	(0.25)	0.576	15.24	(0.45)	14.99	(0.24)	0.580
Alkaline Phosphatase (IU/L), mean (±SE)	211.81	(7.2)	186.36	(1.85)	0.001***	196.79	(4.43)	184.48	(2.1)	0.009**	198.82	(3.6)	185.61	(2.17)	0.000***
Calcium (mg), mean (±SE)	426.38	(35.09)	444.60	(10.24)	0.621	472.24	(22.2)	449.39	(11.9)	0.354	456.07	(19.07)	438.03	(11.03)	0.400
Phosphorus (mg), mean (±SE)	961.01	(52.7)	999.25	(17.19)	0.492	1032.87	(34.57)	1008.21	(19.47)	0.520	1001.97	(30.16)	997.47	(19.17)	0.900
Sodium (mg), mean (±SE)	3637.97	(246.4)	4102.15	(103.81)	0.089	4216.99	(249.91)	4093.89	(111.01)	0.646	3988.63	(167)	4101.63	(118.51)	0.580
Potassium (mg), mean (±SE)	2395.65	(127.99)	2520.04	(46.17)	0.370	2600.93	(89.98)	2536.60	(49.88)	0.507	2490.08	(78.19)	2526.49	(50.93)	0.690
Vitamin A (μg), mean (±SE)	571.16	(47.16)	715.32	(28.26)	0.008**	700.38	(56.13)	712.51	(29.38)	0.841	674.45	(49.87)	711.13	(30.93)	0.520
Carotene (μg), mean (±SE)	2789.47	(266.72)	3405.82	(152.47)	0.042*	3412.39	(322.37)	3357.77	(154.18)	0.874	3389.01	(291.31)	3332.80	(164.65)	0.860
Menarche age (years), mean (±SE)	13.09	(0.17)	13.09	(0.07)	0.989	13.24	(0.12)	13.11	(0.08)	0.312	13.36	(0.14)	12.99	(0.07)	0.020*
Starting age of drinking (years), mean (±SE)	17.87	(0.23)	18.05	(0.08)	0.463	18.42	(0.16)	18.05	(0.09)	0.045*	18.02	(0.13)	18.03	(0.09)	0.915
Starting age of smoking (years), mean (±SE)	16.47	(0.78)	18.13	(0.21)	0.040*	18.02	(0.57)	18.22	(0.22)	0.738	17.84	(0.49)	18.03	(0.23)	0.730
Family history, number (%)	11	(9.4%)	65	(5.2%)	0.082	18	(5.8%)	54	(5.5%)	0.854	25	(7.9%)	52	(5.0%)	0.080
Practising intense physical activity, number (%)†	10	(10.3%)	137	(12.8%)	0.510	24	(10.6%)	110	(13.3%)	0.331	35	(13.2%)	112	(12.6%)	0.810
Practising intermediate physical activity, number (%)‡	5	(3.5%)	101	(9.2%)	0.035*	20	(7.6%)	80	(9.1%)	0.521	24	(6.8%)	80	(9.3%)	0.200
Use of oral contraceptive, number (%)	4	(4.6%)	113	(11.1%)	0.092	26	(11.4%)	89	(11.3%)	0.990	31	(9.8%)	86	(10.7%)	0.690
Use of female hormone, number (%)	0	(0%)	14	(1.3%)	0.293	2	(1.0%)	12	(1.4%)	0.730	3	(1.1%)	11	(1.2%)	0.830

Statistical significance *p≤0.05, **p≤0.01, ***p≤0.001.
†Intense physical activity: those who practise intense physical activity for more than 20 min at a time and more than 3 days per week. Examples of intense physical activity: running, mountain hiking, fast cycling, fast swimming, soccer, basketball, squash, single tennis, carrying/moving heavy loads, etc.
‡Intermediate physical activity: those who practise intermediate physical activity for more than 30 min at a time and more than 5 days per week. Examples of intermediate physical activity: slow swimming, double tennis, volleyball, badminton, ping pong, carrying/moving light loads, etc.
BMI, body mass index.

Table 2 Mean BMD T-score comparison at the total femur, femur neck and lumbar spine according to drinking patterns and AUDIT scores after adjustment†

	Total femur				Femur neck				Lumbar spine			
	N	Average	SE	p Value	N	Average	SE	p Value	N	Average	SE	p Value
Drinking frequency				**0.245**				**0.029***				**0.935**
Abstainer‡	**247**	0.519	0.152	–	232	0.119	0.121	–	243	−0.300	0.183	–
Less than 1 per month	142	0.369	0.211	0.561	126	−0.017	0.202	0.561	139	−0.326	0.136	0.912
Monthly (more than 1 per month)	499	0.257	0.081	0.136	444	−0.305	0.099	0.008**	496	−0.312	0.092	0.954
Weekly (more than 2 per week)	129	0.141	0.117	0.047*	119	−0.269	0.116	0.014*	131	−0.388	0.091	0.670
Total N	1017				921				1009			
Drinking amount				**0.122**				**0.039***				**0.882**
Abstainer‡	247	0.517	0.151	–	232	0.104	0.124	–	243	−0.303	0.184	–
Less than 4 glasses	365	0.408	0.122	0.570	331	−0.075	0.124	0.285	362	−0.280	0.122	0.918
5–6 glasses	185	0.129	0.142	0.066	165	−0.334	0.150	0.029*	185	−0.407	0.121	0.645
More than 7 glasses	226	0.179	0.084	0.052	199	−0.324	0.107	0.009**	225	−0.324	0.087	0.920
Total N	1023				927				1015			
AUDIT score				**0.002****				**0.004****				**0.228**
0–7 low-risk drinking or abstinence	777	0.414	0.096	–	715	−0.050	0.099	–	767	−0.262	0.104	–
8–15 in excess of low-risk drinking	230	0.284	0.100	0.357	208	−0.169	0.112	0.418	231	−0.243	0.098	0.898
16–19 harmful and hazardous drinking	41	−0.077	0.100	0.001***	32	−0.568	0.133	0.002**	41	−0.522	0.144	0.148
20–40 alcohol dependence	37	−0.110	0.189	0.019*	35	−0.626	0.176	0.007**	37	−0.504	0.141	0.198
Total N	1085				990				1076			

Statistical significance *p≤0.05, **p≤0.01, ***p≤0.001.
†Adjusted: age, height, BMI, creatinine, alkaline phosphatase and age of initiation of smoking.
‡Abstainer: lifetime non-drinkers or those who drank less than 1 per month with 1 or 2 glasses.
AUDIT, Alcohol Use Disorders Identification Test; BMD, bone mineral density; BMI, body mass index.

Table 3 Association between AUDIT and low BMD (T-score <−1) of total femur and femur neck

Audit score	N	Adjusted OR†	95% CI Low	95% CI Upper	p Value	Adjusted OR‡	95% CI Low	95% CI Upper	p Value
Total femur					**0.860**				**0.926**
0–7 low-risk drinking or abstinence	777	**Reference**				**Reference**			
8–15 in excess of low-risk drinking	230	0.860	0.422	1.754	0.679	0.926	0.233	3.677	0.913
16–19 harmful and hazardous drinking	41	1.483	0.518	4.248	0.463	0.922	0.162	5.237	0.927
20–40 alcohol dependence	37	1.186	0.326	4.313	0.796	1.549	0.355	6.755	0.560
Femur Neck					**0.756**				**0.024***
0–7 low-risk drinking or abstinence	715	**Reference**				**Reference**			
8–15 in excess of low-risk drinking	208	0.910	0.569	1.457	0.695	1.992	0.672	5.905	0.213
16–19 harmful and hazardous drinking	32	1.485	0.562	3.928	0.425	4.311	1.158	16.059	0.029*
20–40 alcohol dependence	35	1.334	0.508	3.504	0.558	5.990	1.692	21.208	0.006**

Statistical significance *p≤0.05, **p≤0.01.
†Adjusted: age, height and BMI.
‡Adjusted: age, height, BMI, creatinine, alkaline phosphatase and age of initiation of smoking.
AUDIT, Alcohol Use Disorders Identification Test; BMD, bone mineral density; BMI, body mass index.

elderly can start from the first two decades of life. According to a previous study, sufficient bone accrual has even more effect on the probability of frangibility fracture in old age than the rate of bone loss.[15] Although PBM attainment is mainly attributable to genetic factors,[17] it can be affected by environmental factors such as alcohol consumption. The purpose of this study was to examine bone status (of TF, FN and LB) of healthy Korean young women aged from 19 to 30 years by their alcohol use.

We found that BMD at the three sites was different by age, weight, BMI and level of alkaline phosphatase. Lower levels of creatinine were related to low BMD of TF and FN and lower height to that of LB and FN. Of the three sites, only low BMD of TF showed strong correlation with low levels of vitamin A and carotene intake; less intermediate physical activity and earlier age of initiation of smoking; and older age at menarche was associated with low BMD at LB. No significant difference in BMD at the three sites was found by the levels of vitamin D and calcium and intense physical activity, three of the well-known risk factors for osteoporosis. Overall, insufficient levels of vitamin D (15.02 ng/mL±0.23) and calcium (442.17mg±9.54) were found among the participants, according to the Vitamin D Council and the Institute of Medicine standard.[18 19] This observed low level of calcium intake can be part of the reason for the insignificant relation between physical activities and BMD with the possibility that the beneficial effect of physical activity on bone is manifest only through synergistic interaction with high calcium intake—over 1000 mg/day.[20]

After adjustment for eligible covariates, the different BMD T-scores by alcohol use were found at TF and FN in young Korean women while no difference was found at LB. The BMD of TF and FN tends to get lower with higher AUDIT scores. Those who drink more frequently are more likely to have lower BMD at FN. This difference in FN BMD became more significant between abstainers and young women who were weekly and monthly drinkers and drank more than five glasses per occasion. There was no significantly higher BMD of moderate drinkers at all three sites than that of abstainers.

Unlike our result, previous studies observed higher hip or spine BMD in women who drank moderately than in those who were abstainers and heavy drinkers.[6 5 21–24] However, the optimal drinking amount for beneficial effect on bone cannot be defined since the threshold varies among studies: 8 g alcohol/day,[23] 28–57 g/week,[24] 11–29 g/day,[5] more than 2 drinks/day,[6] and more than 29 drinking occasions/month.[21] Additionally, this beneficial effect was observed mostly in postmenopausal but not premenopausal women.[21 25] A previous study also revealed increased hip and forearm fracture risk in premenopausal women with 5–24 g/day drinking.[7] These conflicting results can be explained by the earlier reports that moderate alcohol intake can increase BMD levels indirectly by elevating oestrogen levels whose dramatic decrease after menopause is a major contributor to the rapid rate of bone loss in postmenopausal women.[26 27] The misclassification of abstainers can be another reason for this inconsistent result. The beneficial effect of alcohol consumption on BMD can be exaggerated by integrating lifetime abstainers with past drinkers who may have stopped drinking due to health concerns.[28] A meta-analysis suggested that this benefit was observed in most studies with insufficient adjustment for major potential confounders, reflecting confounding by unmeasured healthy behaviours.[11]

Our findings also support the idea that the skeletal responsiveness to alcohol may differ by site as well as

age.[29 30] Compared with TF and FN BMD, no significant difference in LB BMD by alcohol use was found in this study. The different result can be explained by animal studies whose results implied that the alcohol-related bone deficiencies during adolescence and young adulthood may be caused by decreasing the activity of growth plate at the end of femur, insulin-like growth factor 1 (IGF-1) levels in the blood and maturity of the bone, rather than a loss of bone itself.[9 31 32] Since the majority of previous studies have been conducted with postmenopausal women, more studies are needed with more precise and appropriate designs to confirm our findings, especially the effects of moderate drinking on bone health and the more detrimental effect of alcohol on femur than lumbar BMD of young Korean women in their twenties.

In OR analysis, the tendency to have osteopenia or osteoporosis at FN was found more commonly in the women with higher AUDIT scores, while this correlation was not observed at TF. In particular, those who were harmful drinkers (16–19) and alcohol dependent (20–40) were four and six times more likely to have low FN BMD than those who were low-risk drinkers or abstinent (0–7), respectively. This finding should be considered critical because low BMD of FN is highly related to increased risk of hip fractures,[33 34] which is the most serious of all osteoporotic fractures, leading to high premature mortality and morbidity.[1] Its medical cost is also substantial with inevitable surgery and long hospital stays, similar to the number of stays for cardiovascular disease, breast cancer and chronic obstructive pulmonary disease,[35] accounting for 63% of the total cost of all osteoporotic fractures.[36]

Among Asian countries, Japan has the highest annual expenditure of over $4.9 billion for hip fracture care alone and the total cost for hip fractures within the first year after fracture in Singapore is projected to be $145 million in 2050.[37] Globally, ageing populations continue to have an increasing incidence of hip fractures, making it one of the most serious social and economic burdens in most countries, including Korea. The worldwide number of osteoporotic hip fractures is estimated to grow threefold from 1.7 million in 1990 to 6.3 million by 2050,[38] and over 50% of the hip fractures are expected to occur in Asia by 2050.[39] Hip fractures among Koreans have also been on the rise, especially in women over 50 years of age, with a 4.7% increase from 2001 to 2004, with a remarkable sixfold increase in Honam province in the southern part of Korea for the past 13 years; 1991–2004.[40] The reason for these rising trends in hip fractures, however, cannot be explained by the ageing of the population alone, as many former studies reported that age-specific incidence is also growing.[41–43]

The detrimental association that we observed between alcohol consumption and FN BMD implies that the growing prevalence of alcohol consumption, especially high-risk drinking (about 10% from 2005 to 2010) among Korean young women,[16 44] will be a major factor of increasing hip fracture incidence in the near future. Compared with the ongoing increase in the prevalence of alcohol consumption among young women in Korea, the awareness of alcohol-related harm on women's health, including osteoporosis, is low[44] and the drinking, moreover, is becoming more and more socially acceptable among women: the main social supply of alcohol to Korean female high school students is from mothers.[45] Consequently, it is crucial to provide Korean women, from teenagers to adults, with educational programmes at the school and community levels to promote the awareness of alcohol harm on bone health, focusing on the attainment of PBM. At the same time, the deficiency of vitamin D and calcium among Korean young women also suggests that appropriate dietary guidelines need to be established for young people to prevent its adverse impact on bone health in later years.

This cross-sectional study has several limitations. First, it cannot evaluate the causality between alcohol consumption and low BMD. Prospective studies are needed to clarify the relationship. Second, for drinking frequency and amount, only the last year's experience was considered, and therefore the present results cannot fully reflect alcohol's effect on bones by the extent and duration of alcohol exposure. Third, our definition of abstainers can lead to biased result from previous studies. According to the threshold of moderate drinking in previous studies, however, less than one per month with 1–2 glasses at a sitting is small enough to be categorised into abstainers. Finally, self-reported alcohol intake, AUDIT scores and smoking status may be underreported due to recalling and social desirability bias.[46 47] A relatively small number of smokers and a small number of the outcome cases decreased the precision of the OR estimate in the study. A larger study with more cases should be considered for a more precise estimate of the association between alcohol consumption and young Korean women's bone health. Despite these limitations, the study has several strengths. Our study is the first to investigate the association between alcohol consumption and young female bone health at TF, FN and LB, using a sample population representative of Korean young women in their twenties. Additionally, the study was able to assess the adverse role of alcohol in bone development more accurately than previous studies by selecting only healthy Korean young female adults free of any disease, which can deteriorate BMD by influencing bone metabolism, such as diabetes mellitus, hypertension, dyslipidaemia, chronic kidney disease and various cancers.

In conclusion, low BMD of young Korean women was related to drinking frequency, amounts consumed and AUDIT scores, after adjusting for covariates. Of the three sites, this association was most evident in FN: the more drinks, the lower the BMD at FN and with higher AUDIT scores, the higher the chance of osteopenia or osteoporosis. Since alcohol's effect on bone is complex with cumulative effects of many factors on bone health

over the years, and there is a scarcity of studies on young women in their twenties, rigorous prospective studies are needed that focus on the effects of alcohol on optimal bone mass attainment with carefully measured confounders.

Author affiliations
[1]Department of Health-Bio Convergence, Sahmyook University, Seoul, South Korea
[2]Korean Institute on Alcohol Problems, Sahmyook University, Seoul, South Korea
[3]Department of Health Management, Sahmyook University, Seoul, South Korea
[4]Faculty of Science, Asia-Pacific International University, Muak Lek, Saraburi, Thailand

Acknowledgements The authors thank the Korea Centers for Disease Control and Prevention, who performed the KNHANES.

Contributors SS contributed to the study concept, analysis and interpretation. SS was the lead writer while SC and MY provided contributions to intellectual content for alcohol and nutrition variables, respectively, and MAN assisted the writing of the manuscript and reviewed the overall content. All the authors approved the final version of the manuscript.

Funding This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Ethics approval Korea Centers for Disease Control and Prevention.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Cross-sectional data from Korea National Health and Nutrition Examination Survey by Korea Centers for Disease Control and Prevention and Korean Ministry of Health and Welfare. The data, therefore, are freely available at: https://knhanes.cdc.go.kr/knhanes/index.do

REFERENCES

1. Mithal A, Dhingra V, Lau E. *The Asian Audit Epidemiology, costs and burden of osteoporosis in Asia 2009*. International Osteoporosis Foundation, 2009.
2. Orimo H, Nakamura T, Hosoi T, *et al*. Japanese 2011 guidelines for prevention and treatment of osteoporosis-executive summary. *Arch Osteoporos* 2012;7:3–20.
3. Korean Statistical Information Service, Population Projections. http://kosis.kr/statPopulation/main.jsp# (accessed 1 Nov 2014).
4. Report by Healthcare Data & Information Analysis Dept., Health Insurance Review & Assessment Service. 24 Jan 2013. http://www.mw.go.kr/front_new/al/sal0301vw.jsp?PAR_MENU_ID=04&MENU_ID=0403&page=67&CONT_SEQ=281017
5. Ganry O, Baudoin C, Fardellone P. Effect of alcohol intake on bone mineral density in elderly women: the EPIDOS Study. Epidemiologie de l'Osteoporose. *Am J Epidemiol* 2000;151:773–80.
6. Tucker KL, Jugdaohsingh R, Powell JJ, *et al*. Effects of beer, wine, and liquor intakes on bone mineral density in older men and women. *Am J Clin Nutr* 2009;89:1188–96.
7. Hernandez ER, Revilla M, Rico H. Total body bone mineral and pelvis bone mineral content as parameters of bone mass in men. A dual-energy X-ray absorptiometry study. *Acta Anat* 1991;142:227–30.
8. Wezeman FH, Emanuele MA, Emanuele NV, *et al*. Chronic alcohol consumption during male rat adolescence impairs skeletal development through effects on osteoblast gene expression, bone mineral density, and bone strength. *Alcohol Clin Exp Res* 1999;23:1534–42.
9. Hogan HA, Sampson HW, Cashier E, *et al*. Alcohol consumption by young actively growing rats: a study of cortical bone histomorphometry and mechanical properties. *Alcohol Clin Exp Res* 1997;21:809–16.
10. Hogan HA, Argueta F, Moe L, *et al*. Adult-onset alcohol consumption induces osteopenia in female rats. *Alcohol Clin Exp Res* 2001;25:746–54.
11. Berg KM, Kunins HV, Jackson JL, *et al*. Association between alcohol consumption and both osteoporotic fracture and bone density. *Am J Med* 2008;121:406–18.
12. Kim MJ, Shim MS, Kim MK, *et al*. Effect of chronic alcohol ingestion on bone mineral density in males without liver cirrhosis. *Korean J Intern Med* 2003;18:174–80.
13. Sampson HW. Alcohol's harmful effect on bone. *Alcohol Health Res World* 1998;22:190–4.
14. Sampson HW. Alcohol and other factors affecting osteoporosis risk in women. *Alcohol Res Health* 2002;26:292–8.
15. Hernandez CJ, Beaupré GS, Carter DR. A theoretical analysis of the relative influences of peak BMD, age-related bone loss and menopause on the development of osteoporosis. *Osteoporos Int* 2003;14:843–7.
16. Korea Centers for Disease Control and Prevention. Korea Health Statistics 2012: Korea National Health and Nutrition Examination Survey (KNHANES V-3). 2013.
17. Ferrari S, Rizzoli R, Slosman D, *et al*. Familial resemblance for bone mineral mass is expressed before puberty. *J Clin Endocrinol Metab* 1998;83:358–61.
18. https://www.vitamindcouncil.org/further-topics/i-tested-my-vitamin-d-level-what-do-my-results-mean/ (accessed 10 Jan 2015).
19. Institute of Medicine of the national academies. Dietary reference intakes for calcium and vitamin D. 2011. http://iom.nationalacademies.org/Reports/2010/Dietary-Reference-Intakes-for-Calcium-and-Vitamin-D.aspx
20. Specker BL. Evidence for an interaction between calcium intake and physical activity on changes in bone mineral density. *J Bone Miner Res* 1996;11:1539–44.
21. Wosje KS, Kalkwarf HJ. Bone density in relation to alcohol intake among men and women in the United States. *Osteoporos Int* 2007;18:391–400.
22. Williams FM, Cherkas LF, Spector TD, *et al*. The effect of moderate alcohol consumption on bone mineral density: a study of female twins. *Ann Rheum Dis* 2005;64:309–10.
23. Ilich JZ, Brownbill RA, Tamborini L, *et al*. To drink or not to drink: how are alcohol, caffeine and past smoking related to bone mineral density in elderly women? *J Am Coll Nutr* 2002;21:536–44.
24. Rapuri PB, Gallagher JC, Balhorn KE, *et al*. Alcohol intake and bone metabolism in elderly women. *Am J Clin Nutr* 2000;72:1206–13.
25. Maurel DB, Boisseau N, Benhamou CL, *et al*. Alcohol and bone: review of dose effects and mechanisms. *Osteoporos Int* 2012;23:1–16.
26. Wild RA, Buchanan JR, Myers C, *et al*. Declining adrenal androgens: an association with bone loss in aging women. *Proc Soc Exp Biol Med* 1987;186:355–60.
27. Turner RT, Sibonga JD. Effects of alcohol use and estrogen on bone. *Alcohol Res Health* 2001;25:276–81.
28. de Lorimier AA. Alcohol, wine, and health. *Am J Surg* 2000;180:357–61.
29. Deong HW, Chen WM, Conway T, *et al*. Determination of bone mineral density of the hip and spine in human pedigrees by genetic and life-style factors. *Genet Epidemiol* 2000;19:160–77.
30. Maurel DB, Boisseau N, Benhamou CL, *et al*. Alcohol and bone: review of does effects and mechanisms. *Osteoporos Int* 2012;23:1–16.
31. Sampson HW, Chaffin C, Lange J, *et al*. Alcohol consumption by young actively growing rats: a histomorphometric study of cancellous bone. *Alcohol Clin Exp Res* 1997;21:352–9.
32. Sampson HW. The effect of alcohol consumption on adult and aged bone: a histomorphometric study of the rat animal model. *Alcohol Clin Exp Res* 1998;22:2029–34.
33. Stone KL, Seeley DG, Lui LY, *et al*. BMD at multiple sites and risk of fracture of multiple types: long-term fracture prediction. *J Bone Miner Res* 2003;18:1947–54.
34. Nguyen ND, Pongchaiyakul C, Center JR, *et al*. Identification of high-risk individuals for hip fracture: a 14-year prospective study. *J Bone Mineral Res* 2005;20:1921–8.
35. Prevention and management of osteoporosis. Report of a WHO Scientific Group. Geneva: World Health Organization, 2003.
36. Ray NF, Chan JK, Thamer M, *et al*. Medical expenditures for the treatment of osteoporotic fractures in the United States in 1995: report from the National Osteoporosis Foundation. *J Bone Miner Res* 1997;12:24–35.

37. The Asia-Pacific Regional Audit. *Epidemiology, costs and burden of osteoporosis in 2013*. International Osteoporosis Foundation, 2013.
38. World Health Organization. Osteoporosis: both health organizations and individuals must act now to avoid an impending epidemic, 1999. http://www.who.int/inf-pr-1999/en/pr99-58.html (accessed 11 Mar 2013).
39. Lau EM, Cooper C. The epidemiology of osteoporosis: the oriental perspective in a world context. *Clin Orthop Relat Res* 1996;323:65–74.
40. Lim S, Koo BK, Lee EJ, *et al*. Incidence of hip fractures in Korea. *J Bone Miner Metab* 2008;26:400–5.
41. Kannus P, Niemi S, Parkkari J, *et al*. Hip fractures in Finland between 1970 and 1997 and predictions for the future. *Lancet* 1999;353:802–5.
42. Lau EM, Cooper C, Wickham C, *et al*. Hip fracture in Hong Kong and Britain. *Int J Epidemiol* 1990;19:1119–21.
43. Finsen V, Benum P. Changing incidence of hip fractures in rural and urban areas of central Norway. *Clin Orthop Relat Res* 1987;(218):104–10.
44. Lee HK, Lee BH. The Epidemiology of alcohol use disorders. *J Korean Diab* 2012;13:69–75.
45. Asante LS, Chun S, Yun M, *et al*. Social supply of alcohol to Korean high school students: a cross-sectional international alcohol control study. *BMJ Open* 2014;4:e003462.
46. Stockwell T, Donath S, Cooper-Stanbury M, *et al*. Under-reporting of alcohol consumption in household surveys: a comparison of quantity-frequency, graduated-frequency and recent recall. *Addiction* 2004;99:1024–33.
47. Park MB, Kim CB, Nam EW, *et al*. Does South Korea have hidden female smokers: discrepancies in smoking rates between self-reports and urinary cotinine level. *BMC Womens Health* 2014;14:156.