



Original Article

Osteoporosis, vitamin C intake, and physical activity in Korean adults aged 50 years and over

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Abstract. [Purpose] To investigate associations between vitamin C intake, physical activity, and osteoporosis among Korean adults aged 50 and over. [Subjects and Methods] This study was based on bone mineral density measurement data from the 2008 to 2011 Korean National Health and Nutritional Examination Survey. The study sample comprised 3,047 subjects. The normal group was defined as T-score ≥ -1.0 , and the osteoporosis group as T-score ≤ -2.5 . The odds ratios for osteoporosis were assessed by logistic regression of each vitamin C intake quartile. [Results] Compared to the lowest quartile of vitamin C intake, the other quartiles showed a lower likelihood of osteoporosis after adjusting for age and gender. In the multi-variate model, the odds ratio for the likelihood of developing osteoporosis in the non-physical activity group significantly decreased to 0.66, 0.57, and 0.46 (p for trend = 0.0046). However, there was no significant decrease (0.98, 1.00, and 0.97) in the physical activity group. [Conclusion] Higher vitamin C intake levels were associated with a lower risk of osteoporosis in Korean adults aged over 50 with low levels of physical activity. However, no association was seen between vitamin C intake and osteoporosis risk in those with high physical activity levels.

Key words: Osteoporosis, Vitamin C intake, Physical activity

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INTRODUCTION

Osteoporosis is a chronic, asymptomatic, and osteometabolic disease characterized by decreased bone mass and microarchitectural alterations of bone tissue^{1, 2)}. It is considered a complex health problem because it is associated with poor bone quality and increased fracture risk²⁾. In particular, fractures in the elderly associated with osteoporosis can induce musculoskeletal disorders, chronic pain, and impairment of activities of daily living, leading to deterioration in quality of life and socioeconomic status³⁾. Osteoporosis is thought to affect more than 200 million people in the world⁴⁾. In Korea, an estimated 200,000 people were affected by this disease in 2010 according to the Korean Community Health Survey⁵⁾.

The pathogenic mechanisms of bone mineral density loss in osteoporosis are related to aging. It is well known that the most important factor for osteoporosis in women is the menopause, because the decrease in estrogen caused by loss of ovarian function interrupts the balance between bone resorption and formation^{6, 7)}. In men, aging also decreases bone mineral density due to the reduction in testosterone⁸⁾. Therefore, these sex hormones are regarded as a critical indicator for the prediction and prevention of osteoporosis-related fractures in the elderly^{6, 8)}.

Many pharmacological and non-pharmacological strategies can be applied to prevent osteoporosis and its related complications, including sufficient dietary intake of calcium and vitamins, physical activity, and various interventions to prevent bone loss¹⁾. Calcium and vitamin D are regarded as especially important factors in anti-osteoporotic medications⁹⁾. Recent studies have reported that vitamin C supplementation also plays a key role in the prevention of osteoporosis in humans¹⁰⁾. Vitamin C functions as a primary antioxidant to remove reactive oxygen and nitrogen species, decreasing oxidative stress, which is

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related to osteoporosis¹¹).

Physical activity is also widely known as an effective factor to reduce bone mass loss in the elderly. However, physical activity might increase the production of reactive oxygen and nitrogen species through the contraction processes of skeletal muscles. This phenomenon limits the physical activity-induced positive effect¹¹). Thus, the combination of physical activity and vitamin C supplementation in the elderly may be important to prevent osteoporosis, because the elderly have additional difficulties in neutralizing reactive species due to aging. However, current evidence on the effects of physical activity and vitamin C supplementation on osteoporosis is not sufficient. Therefore, the purpose of the present study was to investigate the association between vitamin C intake and osteoporosis prevalence among Korean men and women aged 50 years and over. In addition, this association was examined in subgroups by level of physical activity.

SUBJECTS AND METHODS

This study was based on the bone mineral density measurement data from the 2008, 2009, 2010, and 2011 Korean National Health and Nutritional Examination Survey (KNHANES), which was provided by the Korea Centers for Disease Control and Prevention (KCDC). Bone mineral density was measured from July 2008 to June 2009 for subjects aged 19 and over and from July 2009 to May 2011 for subjects aged 10 and over. We used the “dx_ost” variable to define osteoporosis, which was provided in the dataset. The variable of dx_ost was used for the criteria and grouping of osteoporosis for those in their fifties and over. In the case of women, only menopausal women were included in the analysis. Overall, 2,078 subjects were categorized as having osteoporosis (T-score ≤ -2.5), 4,076 as having osteopenia ($-2.5 < \text{T-score} < -1.0$), and the remaining 2,272 as normal (T-score ≥ -1.0), as shown in the 2008–2011 KNHANES dataset. We excluded those who were diagnosed with or were receiving treatment for osteoporosis at the time of the survey in order to reduce any causal relationship. We also excluded those with osteopenia in order to evaluate the association between osteoporosis and vitamin C intake. The number of subjects who participated in the health examination was 1,523 for the osteoporosis group and 2,131 for the normal group. Among them, the participants who reported extreme daily total energy intake levels (< 500 kcal or $\geq 6,000$ kcal per day) ($n = 3,286$) were excluded. We further excluded subjects with missing information regarding income, education level, postmenopausal hormone use, physical activity, and vitamin D levels. Overall, 3,047 subjects were included in the final analysis. The study was conducted in accordance with the Ethical Principles for Medical Research Involving Human Subjects, as defined by the Declaration of Helsinki. All study subjects were provided with written informed consent for the survey. Identifying information was removed from all data used in the study.

The height and weight of subjects were measured with participants wearing light clothing and no shoes. Body mass index (BMI) was calculated as weight (in kilograms) divided by height (in meters squared). Daily energy and nutrient intakes were assessed using one-day 24-hour recall. Blood vitamin D levels and other covariates were measured by using blood samples as described by previous studies^{6, 12}). Subjects' income was categorized into quartiles (lowest, low, high and highest; as defined by KCDC). Smoking was also categorized by status as non-smoker, ex-smoker, or current smoker. Alcohol drinking frequency was categorized as non-drinking, less than 2 times per week, and 2 times or more per week.

Means and standard errors (SEs) of continuous variables were calculated in the normal and osteoporosis groups. Proportions of each covariate in categorical variables were calculated for each group. The difference between the groups was tested by the ANOVA/Duncan test for continuous variables and by the χ^2 test for categorical variables in the normal and osteoporosis groups. The age and gender-adjusted and multi-variate odds ratios for the association between osteoporosis prevalence and vitamin C intake were assessed using logistic regression. Vitamin C intake was categorized automatically into quartiles using the ‘PROC RANK’ procedure. The multi-variate model was adjusted for age, gender, income, education, smoking, alcohol drinking frequency, postmenopausal hormone use, survey year, energy and calcium intakes, and blood vitamin D level. Linear trends across vitamin C intake categories were tested by using the median vitamin C intakes within each category in the logistic regression analysis. In addition, we conducted analysis of the association between osteoporosis and vitamin C intake in non-physical activity and regular physical activity groups. For this, we divided subjects into regular physical activity and non-regular physical activity groups. The physical activity group included subjects who undertook regular walking or moderate to vigorous exercise, the data on which were provided in the KNHANES dataset. All analyses were performed using SAS statistical software (version 9.4; SAS Institute Inc., Cary, NC, USA).

RESULTS

The basic characteristics according to prevalence of osteoporosis are presented in [Table 1](#). Among the 3,047 subjects, the numbers of subjects in the normal (T-score ≥ -1.0) and the osteoporosis groups (T-score ≤ -2.5) were 1,835 and 1,212, respectively. There were significant differences in most variables including age (normal group, 60.2 ± 0.2 vs. osteoporosis group, 69.0 ± 0.3 years), BMI (25.0 ± 0.1 vs. 22.9 ± 0.1 kg/m²), dietary energy intake ($2,093.8 \pm 18.2$ vs. $1,547.9 \pm 16.7$ kcal/day), vitamin C (113.1 ± 2.0 vs. 81.0 ± 2.1 mg/day) and calcium intakes (567.8 ± 8.8 vs. 378.9 ± 8.1 mg/day), and serum vitamin D levels (21.0 ± 0.2 vs. 18.8 ± 0.2 ng/ml) between the normal and the osteoporosis groups ($p < 0.0001$). The proportion of subjects who were male (75.3 vs. 20.1%) or who were women with postmenopausal hormone use (24.1 vs. 6.2%), were significantly different between the two groups ($p < 0.0001$). Moreover, there were significant differences in terms of income,

Table 1. The basic characteristics of subjects in normal and osteoporosis group

Variables	Normal (n=1,835)	Osteoporosis (n=1,212)
Age (years) *	60.2±0.2	69.0±0.3
Body mass index (kg/m ²) *	25.0±0.1	22.9±0.1
Man (%) *	75.3	20.1
Postmenopausal hormone use in women (%) *	24.1	6.2
Total energy intake (kcal/day) *	2,093.8±18.2	1,547.9±16.7
Vitamin C intake (mg/day) *	113.1±2.0	81.0±2.1
Calcium intake (mg/day) *	567.8±8.8	378.9±8.1
Serum vitamin D level (ng/ml) *	21.0±0.2	18.8±0.2
Income (%) *		
1st (lowest)	22.0	28.3
2nd	23.2	25.5
3rd	24.1	25.2
4th (highest)	30.7	21.0
Education (%) *		
Elementary school	30.0	76.9
Middle school	23.2	11.2
High school	26.4	8.0
College or higher	20.4	3.9
Smoking (%) *		
Non	45.9	77.8
Ex	26.3	9.5
Current	27.8	12.7
Alcohol consumption (%)		
Non	26.7	56.3
Less than 2 times per week	40.9	33.3
2 times or more per week	32.4	10.5
Physical activity *		
Yes	64.4	53.8
No	34.5	46.1

Each value represents mean ± standard error or number (%) of participants measured during the survey. Normal (T-score ≥ -1.0), osteoporosis (T-score ≤ -2.5); the variable on osteoporosis was provided in the 2008–2011 KNHNES dataset. P value was calculated by t-test for continuous variables and χ^2 test for frequency variables. * < 0.05

education level, smoking, and physical activity between the two groups ($p < 0.0001$); however, there was no difference with respect to alcohol drinking frequency ($p > 0.05$).

In the non-physical activity and regular physical activity groups, vitamin C intakes were categorized into quartiles for each group. Table 2 shows the association between vitamin C intake and osteoporosis prevalence in all subjects and in the subgroups by the presence of physical activity. Among the 1,212 subjects in the osteoporosis group, 578 performed daily regular physical activity, whilst 634 did not.

Vitamin C intake was analyzed according to intake quartile. In the overall cohort, the first quartile defined as dietary vitamin C intake < 45.0 mg/day (median, 28.3), the second as ≥ 45.0 and < 77.6 mg/day (median 61.7), the third as ≥ 77.6 and < 128.0 mg/day (median 99.9), and the fourth as ≥ 801.5 mg/day (median 187.5). The overall prevalence of osteoporosis was 452, 308, 250, and 202 in each quartile respectively. In the non-physical activity group, the first quartile was defined as having a dietary vitamin C intake of < 42.0 mg/day (median, 25.9), the second as ≥ 42.1 and < 75.0 mg/day (median 57.4), the third as ≥ 75.0 and < 121.2 mg/day (median 93.1), and the fourth as ≥ 684.7 mg/day (median 174.8). The prevalence of osteoporosis was 236, 155, 136, and 107 in each quartile respectively for the non-physical activity group. In the regular physical activity group, the first quartile was defined as having a dietary vitamin C intake < 48.0 mg/day (median, 30.7), the second as ≥ 48.0 and < 81.0 mg/day (median 64.3), the third as ≥ 81.0 and < 134.4 mg/day (median 104.7), and the fourth as ≥ 801.5 mg/day (median 198.2). The prevalence of osteoporosis was 215, 142, 120, and 101 in each quartile respectively for the physical activity group.

Of all of the subjects with osteoporosis, compared to the first quartile, the second, third and the highest quartiles showed

Table 2. Prevalence of osteoporosis in study subjects categorized by vitamin C intake and according to physical activity

Quartile	Number	Median	Age and gender-adjusted		Multi-variaded	
			OR	95% CI	OR	95% CI
Total (n=1,212)						
Q 1 (0.0–45.0)	452	28.3	reference		reference	
Q 2 (45.0–77.6)	308	61.7	0.66	0.50–0.88	0.83	0.60–1.14
Q 3 (77.6–128.0)	250	99.9	0.55	0.42–0.74	0.77	0.55–1.09
Q 4 (128.1–801.5)	202	187.5	0.46	0.34–0.61	0.67	0.47–0.97
Non-physical activity (n=634)						
Q 1 (0.5–42.0)	236	25.9	reference		reference	
Q 2 (42.1–75.0)	155	57.4	0.53	0.34–0.81	0.66	0.41–1.08
Q 3 (75.1–121.2)	136	93.1	0.49	0.32–0.75	0.57	0.34–0.95
Q 4 (121.6–684.7)	107	174.8	0.40	0.26–0.62	0.46	0.27–0.79
Physical activity (n=578)						
Q 1 (0.0–48.0)	215	30.7	reference		reference	
Q 2 (48.0–81.0)	142	64.3	0.75	0.52–1.10	0.98	0.63–1.52
Q 3 (81.1–134.4)	120	104.7	0.63	0.43–0.92	1.00	0.63–1.62
Q 4 (134.5–801.5)	101	198.2	0.54	0.36–0.80	0.97	0.58–1.64

Number of subjects and median values are shown. The odds ratios (OR) for osteoporosis according to vitamin C intake were estimated by using logistic regression for the non- and physical activity groups. The multi-variate models were adjusted for age, gender, income, education, smoking, alcohol drinking frequency, physical activity (not applicable to the non-physical activity subgroup analysis), postmenopausal hormone use, survey year, energy and calcium intakes, and blood vitamin D level. Odds ratios for each factor in each model were calculated with 95% Wald's confidence intervals (CI).

a lower likelihood of developing osteoporosis with odds ratios of 0.66 (95% Wald's confidence intervals (CI), 0.50–0.88), 0.55 (95% CI, 0.42–0.74), and 0.46 (95% CI, 0.34–0.61) respectively after adjusting for age and gender. In the subjects with no physical activity, compared to the first quartile, the rest of the quartiles displayed a lower likelihood of developing osteoporosis with odds ratios of 0.53 (95% CI, 0.34–0.81), 0.49 (95% CI, 0.32–0.75), and 0.40 (95% CI, 0.26–0.62) respectively after adjusting for age and gender. In the subjects with physical activity, compared to the first quartile, the rest of the quartiles showed a lower likelihood of developing osteoporosis, with odds ratios of 0.75 (95% CI, 0.53–1.10), 0.63 (95% CI, 0.43–0.92), and 0.54 (95% CI, 0.36–0.80) after adjusting for age and gender.

All of the p values for trends were significant in the age and gender-adjusted models as seen above. In the multi-variate model, higher intakes of vitamin C were significantly associated with a decreased prevalence of osteoporosis for all subjects (OR = 0.83; 95% CI: 0.60–1.14 for the second quartile, OR = 0.77; 95% CI: 0.55–1.09) for the third quartile, OR = 0.67; 95% CI: 0.47–0.97 for the highest quartile, p for trend = 0.0371). The odds ratio and 95% confidence intervals for the likelihood of developing osteoporosis in the non-physical activity group decreased to 0.66 (95% CI, 0.41–1.08), 0.57 (95% CI, 0.34–0.95), and 0.46 (95% CI, 0.27–0.79) according to vitamin C intake level. This trend was significant in the non-physical activity group (p for trend = 0.0046). However, there was no such significant association in the physical activity group (OR = 0.98; 95% CI: 0.63–1.52 for the second quartile, OR = 1.00; 95% CI: 0.63–1.62 for the third quartile, OR = 0.97; 95% CI: 0.58–1.64 for the highest quartile, p for trend = 0.9418) compared to the lowest quartile. The significances for all the models were significant (p < 0.0001) and the c statistic as the explanation of the power of the model was between 0.83 and 0.91.

DISCUSSION

Osteoporosis is a complex health problem because it is associated with poor bone quality and increased fracture risk. It is related to aging and sex hormones including estrogen are regarded as critical indicators to regulate bone density loss and to develop strategies to prevent osteoporotic fractures in the elderly. Moreover, the relationship between physical activity and vitamin C supplementation in the elderly is important in the prevention and prevalence of osteoporosis. However, reports about the effects of physical activity and vitamin C supplementation on osteoporosis are not sufficient. Therefore, the purpose of the present study was to investigate the association between vitamin C intake and osteoporosis prevalence among Korean men and women aged 50 and over, and further to investigate this association in subgroups categorized by the presence of physical activity.

The pathological mechanism of osteoporosis involves age, hormonal, nutritional, environmental, and genetic and life style factors, amongst others⁹). The results of the present study showed that significant differences between the normal and osteoporosis groups were present in environmental and life style factors including monthly household income, education level, and smoking. Moreover, there were significant differences were present between the normal and osteoporosis groups

in intake of dietary calcium and serum vitamin D. Previous studies showed that lack of free 25 (OH) vitamin D is involved in bone loss. Calcium is important to prevent bone loss, and calcium absorption is affected by vitamin D^{8, 13}. Accordingly, these two factors influence osteoporosis, which was shown in our results.

The results of the present study showed that significant differences between the normal and osteoporosis groups were present in age and gender ratio. Age-related bone loss is related to decreased levels of sex hormones and many studies have reported the effects of the menopause on osteoporosis in women⁸. The decrease of estrogen in postmenopausal women induces an increase in bone turnover, which is associated with a reduction in bone formation at the cellular level. The imbalance between bone formation and resorption leads to osteoporosis¹⁴. This phenomenon could occur due to a decline in estrogen, which acts as natural antioxidant. Oxidative stress influences bone loss during aging in both women and men^{6, 15}. Therefore, the dietary consumption of antioxidants is considered to benefit osteoporosis in men and women with estrogen deficiency because they support to decrease oxidative stress within the body⁷.

In this respect, vitamin C intake may play an important role in the prevention of osteoporosis in the elderly¹⁶. Our results showed that the prevalence of osteoporosis was diminished with increasing vitamin C intake levels. Arslan et al.¹⁷ suggested that vitamin C supplementation may provide alterations regarding improvement in oxidative stress and bone mineral density values. In addition, it was reported that vitamin C promotes the formation of collagen and the increase of calcium absorption¹⁰. The mechanical molecule signaling of vitamin C on bone density has not yet been investigated properly; however, vitamin C might have a critical role in prevention of bone loss by osteoclasts and in the stimulation of bone formation by osteoblasts¹¹. Its inhibitory effects on bone loss are related to suppression of the receptor activator of nuclear factor κ -B ligand (RANKL), Runx2 promoter that has a key role in osteoclast differentiation, and peroxisome proliferator activated receptor gamma (PPAR γ) which induces the transition of osteoblasts to adipocyte^{6, 18, 19}. Moreover, vitamin C also inhibits the nuclear factor kappa-light-chain enhancer of activated B cell (NF- κ B) proteins for osteoclastogenesis, which are activated oxidative stress⁶.

In the present results, the prevalence of osteoporosis in physically active individuals was diminished by increasing vitamin C intake; however, there were not significant in the value to adjust for age, gender, income, education, smoking habit, alcohol drinking frequency, postmenopausal hormone use, energy and calcium intakes, and blood vitamin D level. Physical activity has preventive effects on age-related bone mass loss^{1, 20}. Additionally, physical activity helps bone formation and enhances the bone density²¹. However, these beneficial effects could be restricted by physical activity-induced oxidative stress in the elderly. Exercise produces oxidative stress during contraction of skeletal muscle²². Although the effects of oxidative stress during exercise are reduced by adaptive responses in young people, these adaptive responses diminish with aging²³. Hence, antioxidant nutrients are required in exercising elderly subjects for their beneficial effect on bone mineral density²⁴. However, it was reported that this associative effect was not observed when combining resistance training with antioxidant supplements such as calcium, vitamin D, vitamin E, and vitamin C²³, which is similar to our results. These facts imply that the combination of physical activity and vitamin C intake does not necessarily induce positive effects on osteoporosis in patients aged 50 years and over.

The aim of the present study was to confirm that the prevalence of osteoporosis was diminished with increasing levels of vitamin C intake. However, combining vitamin C intake with physical activity did not significantly decrease the prevalence of osteoporosis in Korean men and women aged 50 years and over. For the improvement and prevention of osteoporosis, more studies are needed into appropriate vitamins and physical activity for the elderly.

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