British Journal of Nutrition (2013), **110**, 1926–1933
doi:10.1017/S0007114513001219

A dairy and fruit dietary pattern is associated with a reduced likelihood of osteoporosis in Korean postmenopausal women

Sangah Shin[1] and Hyojee Joung[1,2]*

[1]*Graduate School of Public Health, Seoul National University, 599 Gwanak-ro, Gwanak-gu, Seoul 151-742, Korea*
[2]*Institute of Health and Environment, Seoul National University, Seoul, Korea*

(Submitted 26 September 2012 – Final revision received 4 February 2013 – Accepted 8 March 2013 – First published online 12 April 2013)

Abstract

The aim of the present study was to identify the association of dietary patterns with osteoporosis in Korean postmenopausal women from the Korean Health and Nutrition Examination Survey 2008–10. The present cross-sectional analysis included 3735 postmenopausal women who completed a health interview, nutrition survey and a health examination including bone mineral density (BMD) measurements. The general characteristics and dietary intakes of the participants were obtained using a standardised questionnaire and a 24 h recall method, respectively. The BMD of the femoral neck and lumbar spine was measured using dual-energy X-ray absorptiometry; osteoporosis was defined based on the WHO *T*-score criteria. Overall, we identified four dietary patterns using factor analysis as follows: 'meat, alcohol and sugar', 'vegetables and soya sauce', 'white rice, kimchi and seaweed' and 'dairy and fruit', which accounted for 30·9 % of the total variance in food intake (11·3, 7·7, 6·0 and 5·9 %, respectively). The subjects in the highest quintile of the 'dairy and fruit' pattern showed a decreased risk of osteoporosis of the lumbar spine (53 %) compared with those in the lowest quintile, after adjusting for covariates (OR 0·47, 95 % CI 0·35, 0·65, *P* for trend< 0·0001). In contrast, the 'white rice, kimchi and seaweed' dietary pattern was negatively associated with bone health (OR 1·40, 95 % CI 1·03, 1·90, *P* for trend= 0·0479). The present results suggest that an increased intake of dairy foods and fruits in the traditional Korean diet, based on white rice and vegetables, may decrease the risk of osteoporosis in Korean postmenopausal women.

Key words: **Osteoporosis: Dietary patterns: Bone mineral density: Postmenopausal women**

Osteoporosis is a systemic skeletal disease, characterised by low bone mass and micro-architectural deterioration of bone tissue, with a subsequent increase in bone fragility and susceptibility to fractures[1]. As the global elderly population increases, the prevalence of osteoporosis and the incidence of osteoporosis-related fractures are becoming a major social and medical concern in both developed and developing countries[2].

In particular, as the 'baby boomers' of Asia grow older, osteoporosis and its resulting fractures are becoming a considerable cause of morbidity, leading to increased household, societal and economic burdens[3–5]. A previous study has reported that Asian women have a lower bone mineral density (BMD) than white or black women due to their relatively small body size, genetics, lifestyle and culture[6]. The prevalence of osteoporosis among Korean elderly women is high, 34·9 % in 2010[7], and has been increasing gradually[8].

Dietary behaviours are important factors in regulating bone loss in postmenopausal women as well as in achieving peak bone mass in adolescents. Most previous studies on diet and bone health have focused on a single nutrient, such as Ca or vitamin D[9–11] with protein, vitamin K, K and caffeine, or on foods, including fruits, vegetables and milk[12–19]. However, these classical approaches may not thoroughly explain the complex interactions and synergistic effects among nutrients and foods on bone health outcomes.

Recently, methods of dietary pattern analysis have been used to examine possible relationships between overall diet quality and health outcomes in the field of nutrition research[20]. Dietary pattern analysis evaluates subjects' overall tendencies to eat certain types of foods and meals, rather than a single food or nutrient[21].

Several studies have shown that specific dietary patterns are associated with osteoporosis or BMD. 'Healthy' dietary patterns were associated with a reduced risk of fractures or bone resorption among Canadian postmenopausal women and men[22] and Scottish women aged over 50 years[23]. Several studies have identified positive associations between dietary patterns and BMD in diverse age groups: a 'nutrient-dense' pattern in Canadian younger men[24], a 'nuts and meat' pattern in Northern Irish young adults[25] and a dietary pattern characterised by a high intake of dark-green and deep-yellow vegetables in young children in the USA[26]. On

Abbreviations: 25(OH)D, 25-hydroxyvitamin D; BMD, bone mineral density; KNHANES, Korea National Health and Nutrition Examination Survey.

* **Corresponding author:** H. Joung, fax +82 2 883 2832, email hjjoung@snu.ac.kr

the other hand, inverse associations between 'energy-dense, nutrient-poor' dietary pattern in Australian women[27], a 'refined' pattern in Northern Irish young adults[25] and a 'traditional English' dietary pattern in UK postmenopausal women[28], and BMD have been reported.

Because little information on the association between dietary patterns and osteoporosis in Asian populations has been reported to date, and because dietary patterns in Western countries differ from those in Asian countries, these reported results are of limited value in the prevention or management of osteoporosis in Asian populations. The traditional Korean diet is composed primarily of grains, vegetables and fermented foods with salt, and seldom includes dairy items, such as milk and yogurt, resulting in a high intake of Na and a low intake of Ca.

Although the dietary pattern in Korea has recently been changing to a more Western diet, most adults still consume a rice-based diet with low dairy food and Ca contents[29]. The mean Ca intake among 50- to 64-year-old women was 506·8 mg/d, only 72·4 % of the recommended intake (700 mg/d)[30]. Moreover, the prevalence of low Ca intake is especially high among the elderly[7]. Additionally, the mean frequency of milk intake was as low as 1·5 times per week[7], which may negatively affect bone health.

Thus, the purpose of the present study was to identify dietary patterns associated with osteoporosis in Korean postmenopausal women using data from the Korea National Health and Nutrition Examination Survey (KNHANES), a nationwide survey of Korean residents.

Experimental methods

Study design and population

The KNHANES has been performed periodically since 1998 to investigate the health and nutritional status of Koreans; BMD measurements were first included in the second year (2008) of KNHANES IV. The present study was based on the data from the fourth (2008 and 2009) and fifth (2010) KNHANES (IV and V), which were cross-sectional and nationally representative surveys performed by the Division of Chronic Disease Surveillance, Korea Centres for Disease Control and Prevention. The survey used a stratified, multistage, clustered probability sampling method and consisted of a health interview survey, a health examination survey and a nutrition survey. Data were collected by household interviews and through standardised physical examinations conducted in mobile examination centres. In total, 16 326 individuals completed the health interview survey, the nutrition survey and the health examination survey, including BMD measurements. Menopausal status was categorised as pre- or postmenopausal. Postmenopausal status was defined as not having had a menstrual period during the previous 12 months, and included surgical menopause. Among the 3786 postmenopausal women, we excluded those who reported implausibly low or high daily energy intakes (< 2092 or > 20 920 kJ/d). In total, 3735 postmenopausal women were ultimately eligible for analysis.

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Institutional Review Board at the Korea Centres for Disease Control. Written informed consent was obtained from all participants.

Dietary patterns

Dietary intakes were assessed using data from a single 24 h recall. A nutrition survey was conducted through in-person interviews at participants' homes by trained dietitians using supplemental instruments, such as measuring cups, spoons and a ruler. Information on the dishes, food items, the amount of food intake, preparation methods, recipes and brand names that were consumed on the day before the survey was collected. For dietary pattern analysis, food items consumed by subjects were categorised into twenty food groups based on common food groups classified in the Korean Nutrient Database[30]. Consumption of grains and grain products is typically very high among Korean adults. As a result, this group was divided into four subgroups to address the following types of staple foods[31]: white rice; whole grains; noodles and dumplings; flour and bread. Kimchi (traditional Korean fermented cabbage) was placed in a separate group because it is commonly eaten as a side dish in Korea. Nutrient intakes were estimated from the food composition tables of the Rural Development Administration in combination with the nutrient database of the Korea Health and Industry of Development Institute[30].

Dietary patterns were derived using factor analysis, based on the percentage of total daily energy intake from each food group. The average daily intake of the twenty foods or food groups was calculated for each participant, and the percentage of energy obtained from each food or food group was calculated. Finally, the twenty food variables were used as input variables for each participant in the next dietary pattern analysis. To identify dietary patterns, we conducted principal component analysis, entering the twenty food groups into the FACTOR PROCEDURE. The factors were rotated by orthogonal transformation (varimax rotation function in SAS) to achieve a simpler structure with greater interpretability. The number of factors was determined based on eigenvalues (> 1·5), a scree plot and interpretability of the factors derived. The factor scores for each dietary pattern and for each individual were determined by summing the intake of each food group, weighted by the factor loading. Each individual was categorised by factor score into groups using quintiles. Quintile categories of pattern scores were used in the present analysis because they reflected the distinct characteristics of each dietary pattern within a large sample, and were used in previous studies[32–34].

Health examination and bone mineral density measurements

Height and body weight were measured by standard methods, with subjects wearing light clothes and no shoes as part of the health examination survey. BMI was calculated as weight divided by height squared (kg/m^2). The cut-off point for obesity (BMI ≥ 25 kg/m^2) was that defined by the International Obesity Task Force for adults in Asian and Pacific regions[35].

British Journal of Nutrition

The BMD (g/cm^2) of the lumbar spine (L1–4 spine) and five regions of the femur (femoral neck, trochanter, intertrochanter, Ward's triangle and total) were obtained using dual-energy X-ray absorptiometry (DISCOVERY-W fan-beam densitometer; Hologic, Inc.) at the health examination site. BMD measurements were performed according to a standardised protocol based on the 2007 International Society for Clinical Densitometry official positions and guidelines[36]. The CV in BMD measurements, based on reproducibility scans, was 1·9 % for the L1–4 spine and 2·5 % for the femoral neck[37]. We used the L1–4 spine and femoral neck values for BMD analysis. The definition of osteoporosis was made using the WHO *T*-score criteria (*T*-score ≤ − 2·5), and we used the maximum BMD value for Asian (Japanese) patients as a reference[38].

Covariates

Demographic variables including current age, household income and education level were obtained using a self-reported questionnaire. Education level was classified into three categories: elementary school or less; middle or high school; college or more. The equivalent household monthly income was calculated by dividing the obtained monthly household income by the square root of family size. The equivalent income was categorised as one of three levels: low (<710 000 Korean won (KRW)); middle (710 000–1 400 000 KRW); high (≥1 410 000 KRW)[39]. Health-related behavioural risk variables included smoking status (current smoker, ex-smoker or none), frequency of alcohol consumption (never or up to one drink per month, <4 times per month or ≥3 times per week), moderate physical activity per week (≥5 times or <5 times) and supplement consumption (no or yes more than 2 weeks during the most recent 1 year, including any type of vitamin or mineral supplement). Women's health variables included oral contraceptive use and ovarian reserve. Laboratory tests related to bone health included serum levels of parathyroid hormone and serum 25-hydroxyvitamin D (25(OH)D) levels. The level of parathyroid hormone was measured by a chemiluminescence immunoassay using LIAISON (DiaSorin). Serum 25(OH)D levels were measured using a gamma counter (1470 WIZARD; Perkin Elmer) with a RIA kit (DiaSorin)[37].

Statistical analyses

Categorical data are expressed as percentages and continuous data as means and standard deviations. Correlations between dietary patterns and BMD and nutrient intakes were calculated by partial Pearson's correlations, including age, BMI and energy intake as covariates. Multivariable-adjusted logistic regression analysis was conducted to examine the OR and 95 % CI for osteoporosis across the quintile categories of each dietary pattern score, adjusting for covariates known to be related to bone health in postmenopausal women. Model 1 of logistic regression was adjusted for age, BMI and energy intake. Model 2 was adjusted for the variables in model 1 as well as potential confounders (parathyroid hormone and serum 25(OH)D) relevant to the regulation of women's bone health. Model 3 was adjusted for additional covariates, such as smoking, alcohol intake, moderate physical activity, supplement use and oral contraceptive use. Trends of association were assessed by a logistic regression model, assigning scores to the levels of the independent variable. All statistical analyses were performed using SAS software (version 9.3; SAS Institute, Inc.). Statistical significance was set at $P<0·05$.

Table 1. General characteristics of the study subjects

(Mean values and standard deviations; number of subjects and percentages)

	n	%
Total subjects (*n*)	3735	
Demographic characteristics		
Age (years)		
Mean	64·1	
SD	9·5	
Height (cm)		
Mean	152·9	
SD	5·9	
Weight (kg)		
Mean	56·5	
SD	8·5	
BMI (kg/m^2)		
Mean	24·1	
SD	3·2	
Household income		
High (≥ 1 410 000 KRW)	652	17·8
Middle (710 000–1 400 000 KRW)	1612	43·9
Low (<710 000 KRW)	1410	38·7
Educational level		
Elementary school or less	2487	67·2
Middle or high school	1042	28·2
College or more	170	4·6
Health-related lifestyles		
Alcohol consumption frequency		
Never or not more than 1 per month	2044	55·3
< 4 times per month	1440	39·0
≥ 3 times per week	211	5·7
Smoking status		
Current smoker	265	7·2
Ex-smoker	53	1·4
None	3390	91·4
Moderate physical activity (yes)	531	14·4
Obesity (BMI ≥25 kg/m^2)	1386	37·2
Supplement use* (yes)	472	12·6
Health status and bone indices		
Serum 25(OH)D (ng/ml)		
Mean	19·1	
SD	7·2	
Prevalence of vitamin D deficiency†	2338	62·6
PTH (pg/ml)		
Mean	70·8	
SD	34·3	
Osteoporosis prevalence		
Femoral neck	827	22·1
Lumbar spine	1132	30·3
Femoral neck BMD (g/cm^2)		
Mean	0·618	
SD	0·110	
Lumbar spine BMD (g/cm^2)		
Mean	0·796	
SD	0·140	

KRW, Korean Won; 25(OH)D, 25-hydroxyvitamin D; PTH, parathyroid hormone; BMD, bone mineral density.

* No or yes: more than 2 weeks during the most recent 1 year, consumption of any type of vitamin or mineral supplement.

† Serum 25(OH)D <20 ng/ml.

British Journal of Nutrition

Table 2. Factor loading* matrix of food groups for major factors in Korean postmenopausal women

	Dietary patterns			
	Factor 1	Factor 2	Factor 3	Factor 4
Food or food groups	Meat, alcohol and sugar	Vegetables and soya sauce	White rice, kimchi and seaweed	Dairy and fruit
Oils	0·34			
Starch syrup and sugar	0·34			
Meat and its products	0·31			
Alcohol	0·33			
Vegetables and mushrooms		0·46		
Soya sauce and red pepper		0·40		
Garlic and onion		0·25		
Legumes	−0·21	0·23		0·22
White rice		0·30	0·34	
Seaweed			0·37	
Kimchi			0·32	
Fish and shellfish			0·22	
Whole grains			−0·20	
Potatoes			−0·20	
Eggs			−0·21	
Noodles and dumplings			−0·34	
Milk and dairy foods				0·44
Flour and bread				0·44
Fruits				0·31
Nuts				0·22
Variance of intake explained (%)	11·3	7·7	6·0	5·9

* Factor loading scores of −0·20 and +0·20 are not shown.

Results

The general characteristics and bone health status of the study participants are summarised in Table 1. The average age and BMI for the subjects were 64·1 years and 24·1 kg/m^2, respectively. Among the subjects, 5·7 % consumed alcohol three times or more per week and 7·2 % were current smokers. The prevalence of osteoporosis was 22·1 % at the femoral neck and 30·3 % at the lumbar spine, according to the WHO *T*-score criteria for Asian (Japanese) patients[38]. The prevalence of vitamin D deficiency was 62·6 %.

The factor loading scores, which reflect correlation coefficients between food groups and dietary patterns, are presented in Table 2. The following four dietary patterns were identified by factor analysis, named according to the food groups that had high positive loadings: 'meat, alcohol and sugar'; 'vegetables and soya sauce'; 'white rice, kimchi and seaweed'; 'dairy and fruit' patterns. The 'meat, alcohol and sugar' dietary pattern had high positive loadings for oils, starch syrup and sugar, meat and its products, and alcohol, and a negative loading for legumes. The 'vegetables and soya sauce' pattern loaded highly for vegetables and mushrooms, soya sauce and red pepper, garlic and onion, legumes, and white rice. The 'white rice, kimchi and seaweed' dietary pattern featured high positive loadings for white rice, seaweed, kimchi, and fish and shellfish, but negative loadings for whole grains, potatoes, eggs, and noodles and dumplings. The 'dairy and fruit' pattern was characterised by high positive loadings for legumes, milk and dairy foods, flour and bread, fruits and nuts. These patterns explained 30·9 % of the total variance in food intake (11·3 % in 'meat, alcohol and sugar',

Table 3. Correlation coefficients† among the four dietary pattern scores and bone mineral density (BMD) and nutrient intakes

	Factor 1	Factor 2	Factor 3	Factor 4
	Meat, alcohol and sugar	Vegetables and soya sauce	White rice, kimchi and seaweed	Dairy and fruit
BMD				
Total femur	0·005	0·006	0·006	0·054**
Trochanter	0·008	0·015	0·011	0·041*
Intertrochanter	0·004	0·008	−0·009	0·052**
Femoral neck	0·003	0·010	−0·014	0·052**
Ward	0·005	0·024	−0·040*	0·067***
Lumbar spine	0·031	−0·019	−0·040*	0·109***
Nutrient intakes				
Energy (kJ)	0·256***	0·504***	0·123***	0·311***
Protein (g)	0·288***	0·222***	−0·035*	0·208***
Fat (g)	0·430***	0·008	−0·141***	0·291***
Carbohydrates (g)	−0·520***	0·002	0·076***	−0·154***
Ca (mg)	0·000	0·242***	0·021	0·268***
P (mg)	−0·001	0·349***	0·025	0·325***
Fe (mg)	−0·025	0·151***	−0·015	0·074***
Na (mg)	0·206***	0·308***	0·130***	−0·129***
K (mg)	−0·005	0·221***	−0·111***	0·242***
Vitamin A (μg RE)	0·066***	0·145***	0·039*	0·079***
Thiamin (mg)	0·170***	0·160***	−0·087***	0·109***
Riboflavin (mg)	0·194***	0·048**	−0·053**	0·403***
Niacin (mg)	0·347***	0·143***	0·047**	0·051**
Vitamin C (mg)	−0·047**	0·105***	−0·109***	0·196***

RE, retinol equivalents.
* $P<0·05$, ** $P<0·01$, *** $P<0·001$.
† Partial Pearson's correlation, including age, BMI and energy intake (excluding energy variables) as covariates.

British Journal of Nutrition

Table 4. Risk for osteoporosis of the femoral neck and lumbar spine across the quintile (Q) categories of the dietary pattern scores in Korean postmenopausal women

(Odds ratios and 95 % confidence intervals)

			Q3		Q5		
		Q1	OR	95 % CI	OR	95 % CI	*P* for trend
Factor 1: meat, alcohol and sugar							
Femoral neck	Model 1*	1 (reference)	1·01	0·76, 1·34	1·02	0·75, 1·41	0·4197
	Model 2†	1 (reference)	0·79	0·56, 1·12	0·87	0·60, 1·27	0·7588
	Model 3‡	1 (reference)	0·77	0·54, 1·09	0·89	0·60, 1·31	0·6602
Lumbar spine	Model 1	1 (reference)	0·72	0·57, 0·93	0·75	0·51, 1·03	0·0631
	Model 2	1 (reference)	0·78	0·58, 1·05	0·76	0·56, 1·04	0·0605
	Model 3	1 (reference)	0·77	0·57, 1·04	0·78	0·57, 1·07	0·1988
Factor 2: vegetables and soya sauce							
Femoral neck	Model 1	1 (reference)	0·82	0·60, 1·12	0·94	0·66, 1·33	0·1831
	Model 2	1 (reference)	0·69	0·48, 1·01	0·81	0·53, 1·23	0·0821
	Model 3	1 (reference)	0·69	0·47, 1·02	0·79	0·51, 1·21	0·0689
Lumbar spine	Model 1	1 (reference)	1·03	0·79, 1·35	1·12	0·84, 1·51	0·7606
	Model 2	1 (reference)	1·17	0·85, 1·61	1·25	0·88, 1·77	0·9573
	Model 3	1 (reference)	1·17	0·85, 1·61	1·22	0·86, 1·74	0·9823
Factor 3: white rice, kimchi and seaweed							
Femoral neck	Model 1	1 (reference)	0·70	0·52, 0·94	0·98	0·73, 1·31	0·5684
	Model 2	1 (reference)	0·71	0·50, 1·01	1·08	0·76, 1·53	0·9992
	Model 3	1 (reference)	0·73	0·51, 1·05	1·14	0·80, 1·64	0·9435
Lumbar spine	Model 1	1 (reference)	0·94	0·73, 1·22	1·20	0·93, 1·54	0·0780
	Model 2	1 (reference)	0·95	0·70, 1·29	1·34	0·99, 1·81	0·0663
	Model 3	1 (reference)	0·99	0·73, 1·35	1·40	1·03, 1·90	0·0479
Factor 4: dairy and fruit							
Femoral neck	Model 1	1 (reference)	0·95	0·72, 1·26	0·76	0·55, 1·04	0·1812
	Model 2	1 (reference)	1·09	0·78, 1·53	0·82	0·55, 1·20	0·2360
	Model 3	1 (reference)	1·10	0·78, 1·55	0·80	0·54, 1·19	0·1763
Lumbar spine	Model 1	1 (reference)	0·67	0·53, 0·86	0·44	0·33, 0·57	<0·0001
	Model 2	1 (reference)	0·73	0·55, 0·97	0·46	0·33, 0·63	<0·0001
	Model 3	1 (reference)	0·75	0·56, 1·00	0·47	0·34, 0·65	<0·0001

* Model 1 adjusted for age, BMI and energy intake.
† Model 2 adjusted as model 1 + parathyroid hormone and serum 25-hydroxyvitamin D.
‡ Model 3 adjusted as model 2 + smoking, alcohol intake, moderate physical activity, supplement use and oral contraceptive use.

7·7 % in 'vegetables and soya sauce', 6·0 % in 'white rice, kimchi and seaweed' and 5·9 % in 'dairy and fruit').

Correlations between the dietary factor scores and BMD and nutrient intakes, after adjusting for age, BMI and energy intake, are presented in Table 3. The 'white rice, kimchi and seaweed' dietary pattern score was significantly negatively associated with the BMD of Ward's triangle ($P<0·05$) and the lumbar spine ($P<0·05$). The 'dairy and fruit' dietary pattern showed positive associations with the five regions of the femur (femoral neck, trochanter, intertrochanter, Ward's triangle and total) and the lumbar spine. However, no association was found between the 'meat, alcohol and sugar' pattern and the 'vegetables and soya sauce' pattern, and BMD. The 'white rice, kimchi and seaweed' dietary pattern score was positively associated with energy, carbohydrates, Na and niacin, but showed no association with minerals or vitamins, including Ca, P and Fe. The 'dairy and fruit' dietary pattern score was positively associated with most nutrient intakes, except carbohydrates and Na. The 'meat, alcohol and sugar' pattern score was positively associated with energy, protein, fat, Na, vitamin A, thiamin, riboflavin and niacin, while it was negatively associated with carbohydrates and vitamin C. The 'vegetables and soya sauce' dietary pattern score was positively associated with the intake of most nutrients, except fat and carbohydrates.

Table 4 shows the multivariate-adjusted OR of having osteoporosis of the femoral neck and lumbar spine across the four dietary patterns. The subjects in the highest quintile of the 'dairy and fruit' pattern showed a decreased likelihood of osteoporosis of the lumbar spine compared with those in the lowest quintile, after adjusting for parathyroid hormone, serum 25(OH)D, smoking, alcohol intake, moderate physical activity, supplement use and oral contraceptive use (OR 0·47, 95 % CI 0·35, 0·65, P for trend$<0·0001$). The 'white rice, kimchi and seaweed' pattern was associated with an increased risk of osteoporosis of the lumbar spine after adjustment for potentially confounding factors (multivariate OR 1·40, 95 % CI 1·03, 1·90, P for trend$=0·0479$).

Discussion

We identified four distinct dietary patterns ('meat, alcohol and sugar', 'vegetables and soya sauce', 'white rice, kimchi and seaweed' and 'dairy and fruit') among Korean postmenopausal women using data from the KNHANES. After adjusting for potentially confounding factors, subjects with high scores on the 'dairy and fruit' pattern had a 53 % lower risk of osteoporosis in the lumbar spine, while those with high scores on the 'white rice, kimchi and seaweed' pattern had a 40 % higher risk of osteoporosis in the lumbar spine.

In the present study, the four identified dietary patterns explained 30·9 % of the total variance in food intake. Most dietary pattern studies concerning bone health have used a threshold eigenvalue of 1·0 to verify two to five dietary patterns, explaining 17·1–30·3 % of the total variance[20,22–25,40]. Although the dietary pattern in the present study cannot be directly compared with those of others, due to differences in the protocols used, such as the number of food records and food group classifications, the dietary patterns derived in the present study are similar to those reported previously[29,41,42].

The 'dairy and fruit' dietary pattern identified in the present study is similar to the 'healthy' dietary pattern obtained from elderly adults aged 69–93 years in the Framingham Osteoporosis Study and in a study of Scottish early postmenopausal women, which were characterised by high positive loadings of fruit, vegetable, dairy foods and cereals, and showed a positive association with BMD[23,43]. Additionally, both the 'dairy and fruit' dietary pattern in the present study and the 'healthy diet' pattern in previous studies had high loadings of milk and dairy foods, which are Ca-rich[23,43]. Ca is a crucial component of the bone matrix and a determining factor in bone metabolism. It has been shown that the milk food group component of the Healthy Eating Index had a significant negative linear relationship with urinary N-telopeptides:creatinine (Cr), a biomarker of bone resorption in American postmenopausal women. Subjects in the lowest tertile of the milk intake group had a significantly higher N-telopeptide:creatinine level than did those in the middle and highest tertiles[44]. Postmenopausal white women consuming dairy products at least once per d were 62 % less likely to have osteoporosis than those consuming dairy products less than twice per week[45].

Our 'dairy and fruit' dietary pattern was positively associated with a variety of minerals and vitamins, including Fe, K, vitamin A, thiamin, riboflavin, niacin and vitamin C, which have recently received significant attention with regard to bone health, as well as Ca. Macdonald *et al.*[19] found that Ca and several nutrients found in fruit and vegetables (K, vitamin C and Mg) were positively correlated with BMD and negatively correlated with bone loss in Scottish women. Furthermore, a previous cross-sectional study showed that the intakes of Mg and K were positively associated with the BMD of elderly men and women in the Framingham Osteoporosis Study[46]. Thus, we conclude that the 'dairy and fruit' dietary pattern may have reduced the risk of osteoporosis in our subjects, through interactions and synergistic effects of the nutrients included in this dietary pattern. The effects of the 'dairy and fruit' dietary pattern on bone health would be more beneficial if vitamin D status improves simultaneously, because the prevalence of vitamin D deficiency among Korean menopausal women is very high. Pfeifer *et al.*[47] reported that supplementation with vitamin D and elemental Ca is effective in reducing the risk of osteoporotic fracture in European older people with serum 25(OH)D levels below the desirable range.

The 'white rice, kimchi and seaweed' and 'vegetables and soya sauce' dietary patterns identified in the present study were similar to the traditional rice-based Korean dietary pattern that has been reported previously. However, the 'white rice, kimchi and seaweed' pattern showed a negative association only with osteoporosis. The 'white rice, kimchi and seaweed' pattern exhibited characteristics of high energy density and low nutrient density. Participants in the highest quintile of the 'white rice, kimchi and seaweed' dietary pattern consumed 76·6 % of their food energy from carbohydrates and 10·9 % from fat. On the other hand, even though the subjects in the highest quintile of the 'vegetables and soya sauce' dietary pattern consumed 73·7 % of their food energy from carbohydrates and 13·8 % from fat, this pattern was associated with the consumption of protein and various minerals and vitamins. It may have affected the non-significant association between the 'vegetables and soya sauce' pattern and the risk of osteoporosis.

A high-carbohydrate, low-fat diet is generally recommended to reduce cardiovascular risk; it has a relatively higher dietary acid load[48]. A diet with a high acid load can lead to an increased risk of chronic low-grade metabolic acidosis and can influence a negative Ca balance and increased bone loss[49]. Nowson *et al.*[48] found that a high-carbohydrate, low-fat diet increased the levels of indicators (N-terminal propeptide and type I procollagen) of an increased rate of bone turnover. Macdonald *et al.*[16] also suggested that a change in acid loads may have a significant adverse effect on bone health only if accompanied by a low-Ca diet. The low Ca intake (391·6 mg/d, 55·9 % of Ca recommended intake for Korean adults) in addition to their high-carbohydrate, low-fat diet could negatively affect the bone health of the subjects in the highest quintile.

In the present study, dietary patterns had an effect only on the lumbar spine, not on the femoral neck. Several meta-analysis studies of the effects of nutrition on bone health have reported that a high intake of Ca and dairy food significantly improved the bone health of the lumbar spine and total body, but not the femur, pelvis or radius in children[50]. Indeed, soya isoflavone extract increased the lumbar spine bone health of menopausal women, but had no significant effect on the femoral neck, hip total or trochanter bone health[51], consistent with the present results. Further research on the mechanism underlying the effect of nutrition factors on specific bone sites is needed.

The present study has several limitations. First, the results do not indicate a causal or resultant relationship between dietary patterns because the present study was of a cross-sectional design. Thus, the results need to be confirmed in longitudinal studies. Second, we assessed the dietary intakes of the subjects using a single 24 h recall, which might not represent the individual's usual intake. FFQ are commonly used in dietary pattern analysis; however, the FFQ used in the KNHANES was not developed to evaluate usual food intakes and has not yet been validated. Thus, dietary intake data from a single 24 h recall were used in the dietary pattern analysis. Third, the dietary pattern approach can be somewhat subjective and difficult to identify in other populations. In factor analysis for the derivation of dietary patterns from dietary data, researchers generally make arbitrary decisions on, for example, the number of foods or food groups included, the number of factors and the rotational method[52]. To minimise subjectivity, we defined the dietary patterns based on a

procedure used in previous studies[29,41,42]. Despite these limitations, the present study is the first to verify an association between Korean dietary patterns and the risk of osteoporosis in Korean postmenopausal women.

Recently, dietary patterns in Korea have been changing from the traditional diet, composed primarily of steamed white rice and kimchi, to a more Western-style diet[53]. However, this transition is occurring more rapidly in children and adolescents than in adults. Our subjects, postmenopausal women, typically still adhered to rice-based diets with high carbohydrate and low dairy food and Ca contents. The present dietary pattern analysis identified the complex nature of age- and culture-specific dietary behaviours and their associations with bone health in Korean postmenopausal women. Thus, the results may facilitate both the development of dietary guidelines to prevent osteoporosis and further research into the relationship between diet and bone health.

In conclusion, the present findings suggest that increased intakes of dairy foods and fruits in the traditional Korean diet – which is based on white rice and vegetables – may decrease the risk of osteoporosis in Korean postmenopausal women. The 'white rice, kimchi and seaweed' dietary pattern, however, had a negative influence on bone health in Korean postmenopausal women. Dietary guidance to Korean postmenopausal women should focus more on the desirable effects of various vitamins and minerals from the 'dairy and fruit' dietary pattern, whereas those sticking to the 'white rice, kimchi and seaweed' dietary pattern may require more careful attention for the prevention and management of osteoporosis.

Acknowledgements

The authors' responsibilities were as follows: H. J. conceived and designed the study and critically reviewed the manuscript; S. S. contributed to the data analyses and wrote the draft of the manuscript. The present study received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. The authors report no conflict of interest.

References

1. Anonymous (1993) Consensus development conference: diagnosis, prophylaxis, and treatment of osteoporosis. *Am J Med* **94**, 646–650.
2. Johnell O & Kanis JA (2006) An estimate of the worldwide prevalence and disability associated with osteoporotic fractures. *Osteoporos Int* **17**, 1726–1733.
3. Anonymous (2003) Prevention and management of osteoporosis. *World Health Organ Tech Rep Ser* **921**, 1–164, back cover.
4. Johnell O & Kanis JA (2004) An estimate of the worldwide prevalence, mortality and disability associated with hip fracture. *Osteoporos Int* **15**, 897–902.
5. Melton LJ 3rd (1993) Hip fractures: a worldwide problem today and tomorrow. *Bone* **14**, Suppl. 1, S1–S8.
6. Barrett-Connor E, Siris ES, Wehren LE, *et al.* (2005) Osteoporosis and fracture risk in women of different ethnic groups. *J Bone Miner Res* **20**, 185–194.
7. Korea Centers for Disease Control and Prevention (2010) *Korea Health Statistics 2010: Korea National Health and Nutrition Examination Survey (KNHANES V-1)*. Seoul: Ministry of Health & Welfare.
8. Shin A, Choi JY, Chung HW, *et al.* (2004) Prevalence and risk factors of distal radius and calcaneus bone mineral density in Korean population. *Osteoporos Int* **15**, 639–644.
9. Lowe NM, Ellahi B, Bano Q, *et al.* (2011) Dietary calcium intake, vitamin D status, and bone health in postmenopausal women in rural Pakistan. *J Health Popul Nutr* **29**, 465–470.
10. Jackson RD, Wright NC, Beck TJ, *et al.* (2011) Calcium plus vitamin D supplementation has limited effects on femoral geometric strength in older postmenopausal women: the Women's Health Initiative. *Calcif Tissue Int* **88**, 198–208.
11. Islam MZ, Shamim AA, Viljakainen HT, *et al.* (2010) Effect of vitamin D, calcium and multiple micronutrient supplementation on vitamin D and bone status in Bangladeshi premenopausal garment factory workers with hypovitaminosis D: a double-blinded, randomised, placebo-controlled 1-year intervention. *Br J Nutr* **104**, 241–247.
12. Hooshmand S, Chai SC, Saadat RL, *et al.* (2011) Comparative effects of dried plum and dried apple on bone in postmenopausal women. *Br J Nutr* **106**, 923–930.
13. Wong WW, Lewis RD, Steinberg FM, *et al.* (2009) Soy isoflavone supplementation and bone mineral density in menopausal women: a 2-y multicenter clinical trial. *Am J Clin Nutr* **90**, 1433–1439.
14. Binkley N, Harke J, Krueger D, *et al.* (2009) Vitamin K treatment reduces undercarboxylated osteocalcin but does not alter bone turnover, density, or geometry in healthy postmenopausal North American women. *J Bone Miner Res* **24**, 983–991.
15. Farrell VA, Harris M, Lohman TG, *et al.* (2009) Comparison between dietary assessment methods for determining associations between nutrient intakes and bone mineral density in postmenopausal women. *J Am Diet Assoc* **109**, 899–904.
16. Macdonald HM, Black AJ, Aucott L, *et al.* (2008) Effect of potassium citrate supplementation or increased fruit and vegetable intake on bone metabolism in healthy postmenopausal women: a randomized controlled trial. *Am J Clin Nutr* **88**, 465–474.
17. Zhu K, Devine A & Prince RL (2009) The effects of high potassium consumption on bone mineral density in a prospective cohort study of elderly postmenopausal women. *Osteoporos Int* **20**, 335–340.
18. Rapuri PB, Gallagher JC, Kinyamu HK, *et al.* (2001) Caffeine intake increases the rate of bone loss in elderly women and interacts with vitamin D receptor genotypes. *Am J Clin Nutr* **74**, 694–700.
19. Macdonald HM, New SA, Golden MH, *et al.* (2004) Nutritional associations with bone loss during the menopausal transition: evidence of a beneficial effect of calcium, alcohol, and fruit and vegetable nutrients and of a detrimental effect of fatty acids. *Am J Clin Nutr* **79**, 155–165.
20. Sugiura M, Nakamura M, Ogawa K, *et al.* (2011) Dietary patterns of antioxidant vitamin and carotenoid intake associated with bone mineral density: findings from post-menopausal Japanese female subjects. *Osteoporos Int* **22**, 143–152.
21. Schulze MB, Hoffmann K, Kroke A, *et al.* (2001) Dietary patterns and their association with food and nutrient intake in the European Prospective Investigation into Cancer and Nutrition (EPIC)-Potsdam study. *Br J Nutr* **85**, 363–373.
22. Langsetmo L, Hanley DA, Prior JC, *et al.* (2011) Dietary patterns and incident low-trauma fractures in postmenopausal women and men aged ≥50 y: a population-based cohort study. *Am J Clin Nutr* **93**, 192–199.
23. Hardcastle AC, Aucott L, Fraser WD, *et al.* (2011) Dietary patterns, bone resorption and bone mineral density in early

post-menopausal Scottish women. *Eur J Clin Nutr* **65**, 378–385.
24. Kontogianni MD, Melistas L, Yannakoulia M, *et al.* (2009) Association between dietary patterns and indices of bone mass in a sample of Mediterranean women. *Nutrition* **25**, 165–171.
25. Whittle CR, Woodside JV, Cardwell CR, *et al.* (2012) Dietary patterns and bone mineral status in young adults: the Northern Ireland Young Hearts Project. *Br J Nutr* **108**, 1494–1504.
26. Wosje KS, Khoury PR, Claytor RP, *et al.* (2010) Dietary patterns associated with fat and bone mass in young children. *Am J Clin Nutr* **92**, 294–303.
27. McNaughton SA, Wattanapenpaiboon N, Wark JD, *et al.* (2011) An energy-dense, nutrient-poor dietary pattern is inversely associated with bone health in women. *J Nutr* **141**, 1516–1523.
28. Fairweather-Tait SJ, Skinner J, Guile GR, *et al.* (2011) Diet and bone mineral density study in postmenopausal women from the TwinsUK registry shows a negative association with a traditional English dietary pattern and a positive association with wine. *Am J Clin Nutr* **94**, 1371–1375.
29. Kim J, Jo I & Joung H (2012) A rice-based traditional dietary pattern is associated with obesity in Korean adults. *J Acad Nutr Diet* **112**, 246–253.
30. The Korean Nutrition Society (2010) *Dietary Reference Intake for Korean*. Seoul: Hanareum Press.
31. Kim J & Jo I (2011) Grains, vegetables, and fish dietary pattern is inversely associated with the risk of metabolic syndrome in South Korean adults. *J Am Diet Assoc* **111**, 1141–1149.
32. Esmaillzadeh A, Kimiagar M, Mehrabi Y, *et al.* (2007) Dietary patterns, insulin resistance, and prevalence of the metabolic syndrome in women. *Am J Clin Nutr* **85**, 910–918.
33. Song S, Paik HY & Song Y (2012) High intake of whole grains and beans pattern is inversely associated with insulin resistance in healthy Korean adult population. *Diabetes Res Clin Pract* **98**, e28–e31.
34. Heidemann C, Scheidt-Nave C, Richter A, *et al.* (2011) Dietary patterns are associated with cardiometabolic risk factors in a representative study population of German adults. *Br J Nutr* **106**, 1253–1262.
35. World Health Organization (2000) *The Asia-Pacific Perspective: Redefining Obesity and its Treatment*. Brisbane: The International Obesity Task Force, Health Communications Australia Pty Ltd.
36. Lewiecki EM, Gordon CM, Baim S, *et al.* (2008) International Society for Clinical Densitometry 2007 Adult and Pediatric Official Positions. *Bone* **43**, 1115–1121.
37. Korea Centers for Disease Control and Prevention (2010) *Guide to the Utilization of the Data from the Third Korea National Health and Nutrition Examination Survey* (In Korean). Seoul: Korea Centers for Disease Control and Prevention.
38. Orimo H, Hayashi Y, Fukunaga M, *et al.* (2001) Diagnostic criteria for primary osteoporosis: year 2000 revision. *J Bone Miner Metab* **19**, 331–337.
39. Jang SY, Kim IH, Ju EY, *et al.* (2010) Chronic kidney disease and metabolic syndrome in a general Korean population: the Third Korea National Health and Nutrition Examination Survey (KNHANES III) Study. *J Public Health (Oxf)* **32**, 538–546.
40. Okubo H, Sasaki S, Horiguchi H, *et al.* (2006) Dietary patterns associated with bone mineral density in premenopausal Japanese farmwomen. *Am J Clin Nutr* **83**, 1185–1192.
41. Hong S, Song Y, Lee KH, *et al.* (2012) A fruit and dairy dietary pattern is associated with a reduced risk of metabolic syndrome. *Metabolism* **61**, 883–890.
42. Song Y & Joung H (2012) A traditional Korean dietary pattern and metabolic syndrome abnormalities. *Nutr Metab Cardiovasc Dis* **22**, 456–462.
43. Tucker KL, Chen H, Hannan MT, *et al.* (2002) Bone mineral density and dietary patterns in older adults: the Framingham Osteoporosis Study. *Am J Clin Nutr* **76**, 245–252.
44. Hamidi M, Tarasuk V, Corey P, *et al.* (2011) Association between the Healthy Eating Index and bone turnover markers in US postmenopausal women aged ≥45 y. *Am J Clin Nutr* **94**, 199–208.
45. Matthews VL, Knutsen SF, Beeson WL, *et al.* (2011) Soy milk and dairy consumption is independently associated with ultrasound attenuation of the heel bone among postmenopausal women: the Adventist Health Study-2. *Nutr Res* **31**, 766–775.
46. Tucker KL, Hannan MT, Chen H, *et al.* (1999) Potassium, magnesium, and fruit and vegetable intakes are associated with greater bone mineral density in elderly men and women. *Am J Clin Nutr* **69**, 727–736.
47. Pfeifer M, Begerow B, Minne HW, *et al.* (2009) Effects of a long-term vitamin D and calcium supplementation on falls and parameters of muscle function in community-dwelling older individuals. *Osteoporos Int* **20**, 315–322.
48. Nowson CA, Patchett A & Wattanapenpaiboon N (2009) The effects of a low-sodium base-producing diet including red meat compared with a high-carbohydrate, low-fat diet on bone turnover markers in women aged 45–75 years. *Br J Nutr* **102**, 1161–1170.
49. Lemann J Jr, Litzow JR & Lennon EJ (1966) The effects of chronic acid loads in normal man: further evidence for the participation of bone mineral in the defense against chronic metabolic acidosis. *J Clin Invest* **45**, 1608–1614.
50. Huncharek M, Muscat J & Kupelnick B (2008) Impact of dairy products and dietary calcium on bone-mineral content in children: results of a meta-analysis. *Bone* **43**, 312–321.
51. Taku K, Melby MK, Takebayashi J, *et al.* (2010) Effect of soy isoflavone extract supplements on bone mineral density in menopausal women: meta-analysis of randomized controlled trials. *Asia Pac J Clin Nutr* **19**, 33–42.
52. Martinez ME, Marshall JR & Sechrest L (1998) Invited Commentary: factor analysis and the search for objectivity. *Am J Epidemiol* **148**, 17–19.
53. Kim S, Moon S & Popkin BM (2000) The nutrition transition in South Korea. *Am J Clin Nutr* **71**, 44–53.