European Journal of Clinical Nutrition (2017) 71, 1101–1107

www.nature.com/ejcn

ORIGINAL ARTICLE

Milk-cereal and whole-grain dietary patterns protect against low bone mineral density among male adolescents and young adults

S Shin[1,2,3], S-H Kim[4], H Joung[3] and MJ Park[4]

BACKGROUND/OBJECTIVES: Evidence supporting the possible effect of dietary factors on adult bone health has emerged in recent decades. The purpose of this study was to ascertain the influence of different dietary patterns on bone mineral density (BMD) among Korean male youth.
SUBJECTS/METHODS: Data were extracted from the Korean National Health and Nutrition Examination Survey (KNHANES) during 2008–2011. The subjects included 1351 male aged 10–25 years. We defined 'low BMD group' as subjects with a BMD *Z*-score of − 2.0 or less. Dietary patterns were derived from 20 food groups via factor analysis.
RESULTS: Three dietary patterns—meat and vegetable, white rice and kimchi, milk-cereal and whole grain—were derived. The 'milk-cereal and whole-grain' dietary pattern score showed positive association with energy, protein, fat, calcium, phosphorus, potassium, riboflavin and vitamin C intakes. Participants in the top tertile of the milk-cereal and whole-grain pattern were less likely to have low BMD, compared with subjects in the bottom tertile (odds ratio = 0.36, 95% confidence interval = 0.16–0.81, $P = 0.018$).
CONCLUSIONS: Our findings suggest that the milk-cereal and whole-grain dietary pattern may have a benign influence on bone health in the Korean male youth.

European Journal of Clinical Nutrition (2017) **71,** 1101–1107; doi:10.1038/ejcn.2017.81; published online 31 May 2017

INTRODUCTION

Low bone mineral density (BMD) and premature bone accrual in children and adolescents may obstruct optimal peak bone mass and increase the risk of adult bone disorder.[1,2] Bone mass increases throughout early life, childhood and adolescence, peaking during early adulthood.[3] Therefore, maximizing peak bone mass during adolescence is a crucial strategy for decreasing the risk of osteoporotic fracture later in life.[4] In addition to genetic determinants, environmental factors, including diet, regulate bone accretion early in life.[5,6]

Most studies have studied the relationships between diet and bone quality, concentrating on the effects of individual nutrients, foods or food groups.[7] However, studies of single nutrients, food or food groups may not verify the complex effect among various nutrients or food as a whole. Thus, there is a need for another approach to investigate the effect of overall diet quality on chronic diseases. This approach can explain each individual's diet pattern based on the combinations of foods consumed, rather than analyzing each specific nutrient or food.[7–9]

There have been many studies focusing on the influence of dietary pattern on bone health in adults and elderly people,[10–15] but the reports on this issue are limited among adolescents and youth.[16–18] Only a few studies have shown that a 'nut- and meat-based diet'[17] and 'dark-green and deep-yellow vegetables-based diet'[18] may have a beneficial effect on bone health in children and adolescents. Dietary patterns related to bone health may vary among populations due to differences in geography, socio-economic status, food cultures, food availability and preferences.[7] Traditionally, Korean diet is rice-based with vegetables, legumes and fish and low portions of meats and dairy products in comparison to the Western diet. However, since the 2000s, this traditional diet has been transitioning from a rice-based to a Western diet style composed of meat, fast food and dairy products since 2000s, particularly among children and adolescents.[19] Lifetime dietary patterns are established among children and adolescents, and diets in this period in a life cycle are recognized as important on lifelong health. However, researches on the dietary pattern that promote optimal BMD during adolescence are scarce.

In this study, we aimed to verify the associations between dietary patterns and BMD in Korean youth using the Korean nationally representative survey data.

SUBJECTS AND METHODS

Design and subjects

Since 1998, the KNHANES has been conducted to examine the health and nutritional status of Koreans. This study was a cross-sectional design and nationally representative survey, conducted by the Division of Chronic Disease Surveillance, Korean Centres for Disease Control and Prevention. The current study used data collected from KNHANES (from 2008 to 2011), which included BMD measurements. The survey administered through the cluster sampling method is composed of the following three parts: a

[1]Institute of Environmental Medicine, Seoul National University Medical Research Center, Seoul, Republic of Korea; [2]Department of Preventive Medicine, Seoul National University College of Medicine, Seoul, Republic of Korea; [3]Graduate School of Public Health, Institute of Health and Environment, Seoul National University, Seoul, Republic of Korea and [4]Department of Pediatrics, Sanggye Paik Hospital, Inje University College of Medicine, Seoul, Republic of Korea. Correspondence: Professor H Joung, Graduate School of Public Health, Institute of Health and Environment, Seoul National University, 599 Gwanak-ro, Gwanak-gu, Seoul 151-742, Republic of Korea or Dr MJ Park, Department of Pediatrics, Sanggye Paik Hospital, Inje University College of Medicine, 1342 Dongil-ro, Nowon-gu, Seoul 139-707, Republic of Korea.
E-mail: hjjoung@snu.ac.kr or PMJ@paik.ac.kr
Received 5 January 2016; revised 6 March 2017; accepted 20 April 2017; published online 31 May 2017

questionnaire interview, a health check-up, and a nutrition assessment. The interviews and standardized health examinations were completed in mobile examination centers. A total of 1377 young males aged 10–25 years completed the interview, the nutrition assessment and the health check-up with BMD measurements between February 2008 and December 2011. Among the 1377 subjects, those with extreme energy values ($<$ 500 or $>$ 5000 kcal/day) were excluded to avoid skewing of the data,[19–21] in accordance with previous KNHANES studies. In total, 1351 young males were eligible for analysis.

This study was IRB-approved by the Korean Centres for Disease Control and conducted based on the guidelines outlined in the Declaration of Helsinki. Informed consent was obtained from all participants.

Dietary patterns

To evaluate dietary intakes, we used data from a 1-day 24-h recall method. The survey consisted of specifics such as food consumption, food recipes and food brands. For dietary pattern analyses, food items were classified as 20 food groups based on the Korean Nutrient Database classification.[22] Nutrient intakes were assessed using food composition tables of the Rural Development Administration and the Korean Health and Industry of Development Institute.[23]

To assess dietary patterns, we applied factor analysis. First, we calculated each participant's average daily intake and the energy percentage from the 20 food groups. Next, we performed principal component analyses. To retain a simple structure and increase interpretability, we applied orthogonal transformation on each factor. To determine the number of factors, eigenvalues (>1.3) and a scree plot were used in the current study. Finally, each individual's factor score was calculated by summing the intake of each food group, weighted by the factor loading. Each participant was categorized into tertile group according to his or her factor score. Higher factor scores indicated greater representation of the dietary pattern each participant possessed; on the other hand, lower scores indicated lower inclination the participant had for a dietary pattern.

Health check-up and BMD

For subjects aged $<$ 19 years, obesity level was determined via age- and sex-specific percentiles for BMI of the Korean national reference standard, and the subjects were classified as follows:[24] underweight ($<$ 5th percentile), normal weight (5– $<$ 85th percentile), overweight (85– $<$ 95th percentile) and obese (⩾95th percentile or BMI ⩾ 25 kg/m^2). For youth aged ⩾ 19 years, obesity was determined according to the criteria defined by the International Obesity Task Force for adults in the Asian and Pacific regions[25] using BMI values (kg/m^2) as follows: underweight ($<$ 18.5), normal weight (18.5–22.9 kg/m^2), overweight (23–24.9 kg/m^2) and obese (⩾25).

The BMDs (g/cm^2) of the lumbar spine (L1-4 spine), whole body and whole body less head were collected through the dual-energy X-ray absorptiometry (DISCOVERY-W fan-beam densitometer; Hologic Inc., Bedford, MA, USA) at the examination site. As the peak bone mass is not acquired until the second or third decade of life, it is not appropriate to compare the BMDs of adolescents with that of young adults.[26] Therefore, a BMD *Z*-score was calculated, comparing with sex- and age-matched controls. The subject with a BMD *Z*-score of − 2.0 or less was defined as having low BMD according to the ISCD guidelines.[27] The subjects having low BMD at one or more sites from the three different sites of measured BMD were assigned as the 'low BMD group'

The participants' socio-demographic variables included age, sex, residential area and family income. Physical activity was based on the participant's engagement in 'moderate–intense' activity at least three times per week. 'Moderate–intense' activity was considered as an activity resulting in increased breathing or heat rate for at least 10 min.

Statistical analyses

The odds ratio (OR) and 95% confidence interval (CI) for low BMD across the tertile groups for each dietary pattern score were applied to multivariate logistic regression analyses, adjusting for potential confounding variables related to BMD. Body size adjustment is necessary because individuals demonstrate difference in body sizes and different tempos of growth, which affect measured BMD of adolescents and youth. Thus, we used height *Z*-score and weight *Z*-score according to each age group based on Korean reference data[24] as a parameter of body size. Model 1 controlled for age and body size (height *Z*-score and weight *Z*-score according to each age group); Model 2 controlled for age, obesity level and potential confounders, including energy intake and serum 25(OH)D levels; final model adjusted for additional covariates, including residential region, household income and physical activity level. SAS software (v.9.4; SAS Institute, Inc., Chicago, IL, USA) was used for all statistical analyses.

RESULTS

Three distinctive dietary patterns were derived using the 20 food groups via factor analysis (Table 1). The positive loading score indicated a positive correlation between the given food groups and the derived factors, whereas a negative loading score indicated negative associations between food groups and factors. The 'meat and vegetable' pattern consisted of high intakes of vegetables, potatoes, mushrooms, oils, seasonings, meat and meat

Table 1. The factor-loading[a] matrix for the food groups consumed by Korean males aged 10–25 years

	Factor 1: Meat and vegetable	*Factor 2: White rice and kimchi*	*Factor 3: Milk-cereal and whole grain*	
White rice		0.68		
Whole grain			0.35	
Noodles and ramen	0.24	− 0.50		
Cereal			0.58	
Bread and cake			0.22	
Pizza and hamburger		− 0.20		
Sweet snack			0.25	
Soy and soy products		0.36		
Kimchi		0.51	− 0.23	
Vegetable, potato and mushroom	0.72			
Fruits		0.20		
Meat and meat products	0.57			
Eggs	0.25		0.22	
Fish		0.35		
Shellfish	0.21			
Seaweed		0.32		
Milk and dairy products			0.77	
Oils	0.68			
Beverages	0.34	− 0.35		
Seasonings	0.63	0.23		
% variance explained	10.7	8.1	6.9	Σ25.7

[a]Factor-loading scores of − 0.20 and +0.20 are not shown.

Table 2. Characteristics of the study participants across tertiles (T) for three dietary patterns

	Meat and vegetable					*White rice and kimchi*					*Milk-cereal and whole grain*				
	T1 (n = *450*)		*T3* (n = *450*)		P[a]	*T1* (n = *450*)		*T3* (n = *450*)		P	*T1* (n = *450*)		*T3* (n = *450*)		P
	Means or %	*s.d.*	*Means or %*	*s.d.*		*Means or %*	*s.d.*	*Means or %*	*s.d.*		*Means or %*	*s.d.*	*Means or %*	*s.d.*	
Age (years)	16.0	4.8	16.8	4.6	0.218	16.4	4.7	16.5	4.6	0.894	16.7	4.7	16.2	4.7	0.712
Height (cm)	164.8	13.8	168.6	10.8	0.980	166.1	13.0	167.5	11.5	0.266	167.2	12.1	166.2	12.4	0.093
Weight (kg)	58.6	17.8	63.4	15.6	0.129	60.1	16.2	62.1	16.4	0.153	61.0	16.8	60.3	16.2	0.644
Total body fat percent (%)	22.5	7.5	22.6	7.8	0.311	22.6	7.7	22.3	7.9	0.935	22.2	7.8	22.3	7.3	0.704
Serum 25(OH)D (ng/ml)	17.0	5.8	17.4	5.2	0.385	17.0	5.4	17.4	5.8	0.417	16.9	5.8	17.7	5.6	0.098
Region															
Urban	88.2		86.3		0.195	88.0		85.6		0.379	84.9		86.3		0.552
Rural	11.8		13.8			12.0		14.4			15.1		13.8		
Household income															
Quartile 1	13.7		12.4		0.171	15.4		13.0		0.755	19.6		8.6		< .0001
Quartile 2	27.9		21.9			26.9		24.5			27.4		25.0		
Quartile 3	31.5		31.5			28.7		31.5			25.2		31.3		
Quartile 4	27.0		34.2			29.0		31.0			27.9		35.1		
Obesity level															
Underweight	7.8		4.9		0.445	6.2		6.0		0.804	7.8		4.7		0.134
Normal	64.6		65.0			64.1		64.5			65.7		67.9		
Overweight/Obese	27.6		30.2			29.6		29.5			26.5		27.5		
Physical activity															
No	49.9		55.6		0.201	54.6		51.7		0.430	54.8		50.4		0.387
Yes	51.1		44.4			45.4		48.3			45.2		49.6		

[a]Calculated using the generalized linear model.

products, noodles and ramen, eggs, shellfish and beverages. The 'white rice and kimchi' pattern showed a high consumption with white rice, soy and soy products, kimchi, fruits, fish, seaweed and seasonings, whereas a negative loading score was observed with noodles and ramen, pizza and hamburgers, and beverages. The 'milk-cereal and whole-grain' pattern had high positive loadings with milk and dairy products, whole grains, cereals, bread and cakes, sweet snacks and eggs, but negative loadings for kimchi. The three dietary patterns accounted for 25.7% of the total variance in food consumption.

The characteristics of our subjects across the tertiles of each dietary pattern are shown in Table 2. The subject of top tertile (T3) of the 'milk-cereal and whole-grain' pattern was associated with higher household income levels ($P < 0.0001$) than those of whom in the lowest tertile. No significant differences in height, weight, obesity status and serum 25(OH)D levels were observed among three dietary patterns.

The correlations of the three dietary pattern scores with the nutrient intakes and the measured BMDs are shown in Table 3. The 'meat and vegetable' dietary pattern score showed positive association with intakes of energy, protein, fat, phosphorus, iron, sodium, potassium, vitamin A, thiamine, riboflavin, niacin and vitamin C intake and negative association with intake of carbohydrate. Greater diet score of 'white rice and kimchi' resulted in a greater value of the whole-body BMD and the intake of the following nutrients: energy, protein, carbohydrate, calcium, phosphorus, iron, sodium, potassium, niacin, and vitamin C, and less fat intake. Greater diet score of the 'milk-cereal and whole-grain' dietary pattern resulted in a greater BMD of the lumbar spine and the whole body less head. This dietary pattern also resulted in higher nutrient intake of energy, protein, fat, calcium, phosphorus, potassium, riboflavin and vitamin C intakes, and less intake of sodium. The top tertile group (T3) for the 'milk-cereal and whole-grain' pattern had the highest intake of calcium and accordingly had the highest percentage uptake of calcium-recommended nutrient intake compared to those in the highest tertile groups of 'meat and vegetable' and 'white rice and kimchi' dietary patterns.

Table 4 and Figure 1 show the multivariable-adjusted ORs for low BMD across the tertile categories for the three dietary pattern scores. The participants with mostly a 'milk-cereal and whole-grain'-based diet (T3) were less likely to have a low BMD compared to those who consumed least amount of milk-cereal and whole-grain foods (T1) (OR = 0.39, 95% CI = 0.18–0.86, $P = 0.019$) adjusting for age, body size, energy intake and serum 25(OH)D. This significant association also continued after additional adjustments for potential confounding variables, including residence area, family income and moderate–intense activity level (OR = 0.36, 95% CI = 0.16–0.81, $P = 0.018$). The 'meat and vegetable'- and 'white rice and kimchi'-based diets were not associated with a risk of low BMD in Korean youth.

DISCUSSION

In the current study, we confirmed three distinct dietary patterns among Korean youth aged 10–25 years ('meat and vegetable', 'rice and kimchi' and 'milk-cereal and whole grain'). We found that the 'milk-cereal and whole-grain' dietary pattern, including a high intake of dairy foods, cereal, whole grains, bread and snacks, fruits and eggs, reduced the risk of having low BMD.

In most studies conducted in children and adolescents, dietary patterns involving high levels of milk and calcium intake showed a positive impact on bone health. Previous study in freshman from a Chinese college showed that a higher consumption of milk and

Table 3. Correlation coefficients among the three dietary pattern scores, nutrient intakes and BMD

	r[a]	*Meat and vegetable*				*White rice and kimchi*					*Milk-cereal and whole grain*				
		T1		*T3*		r	*T1*		*T3*		r	*T1*		*T3*	
		Mean	*s.d.*	*Mean*	*s.d.*		*Mean*	*s.d.*	*Mean*	*s.d.*		*Mean*	*s.d.*	*Mean*	*s.d.*
Nutrient intake (per day)															
Energy (kcal)	0.644***	1774.5	640.0	2931.2	741.2	0.112***	2235.4	851.4	2491.5	791.6	0.290***	2089.1	783.7	2575.1	821.4
Protein (g)	0.518***	56.7	24.0	115.1	38.3	0.089**	78.0	40.1	93.1	36.7	0.103**	73.9	38.6	94.4	36.9
Fat (g)	0.228***	41.3	23.0	82.8	36.7	−0.323***	65.0	35.6	57.2	33.8	0.124***	49.8	31.7	69.5	34.0
Carbohydrate (g)	−0.090**	287.3	106.3	417.8	123.4	0.262***	319.7	119.3	394.0	122.1	0.049	323.7	115.1	387.3	126.3
Calcium (mg)	NS	453.5	331.7	679.7	352.0	0.183***	484.1	325.8	656.1	365.5	0.594***	352.3	228.2	804.7	359.1
Phosphorus (mg)	0.269***	974.2	415.4	1685.9	515.3	0.379***	1128.7	500.5	1542.5	531.5	0.385***	1085.7	469.2	1580.2	541.7
Iron (mg)	0.196***	10.0	7.7	18.6	9.6	0.140***	12.6	10.8	16.4	8.7	NS	12.7	9.5	15.4	9.1
Sodium(mg)	0.312***	3460.5	1819.4	6321.2	3025.7	0.193***	4359.8	2405.2	5617.0	2856.9	−0.121***	4653.4	2527.0	4999.8	2736.0
Potassium (mg)	0.449***	2050.3	887.9	3938.2	1331.0	0.306***	2521.0	1247.7	3468.7	1382.4	0.189***	2516.5	1232.2	3397.5	1410.0
Vitamin A (mg)	0.107**	579.8	797.3	1195.4	1500.7	NS	850.4	1928.8	924.8	833.3	NS	711.7	1107.3	989.1	1593.8
Thiamine (mg)	0.246***	1.2	0.5	2.2	1.0	NS	1.5	0.8	1.8	1.0	NS	1.5	1.0	1.7	0.8
Riboflavin (mg)	0.126***	1.2	0.7	1.9	0.8	NS	1.4	0.7	1.6	0.8	0.500***	1.1	0.6	2.0	0.8
Niacin (mg)	0.381***	12.7	6.7	24.9	9.2	0.162***	16.0	8.9	20.8	9.3	NS	16.9	9.4	19.8	8.9
Vitamin C (mg)	0.165***	73.6	87.3	136.6	123.2	0.140***	81.3	85.6	124.6	121.9	0.110**	87.3	92.3	119.3	111.6
% calcium of RNI	NS	53.7	40.2	79.1	41.5	0.173***	56.9	39.4	76.6	43.7	0.575***	41.6	28.9	93.9	42.1
% phosphorus of RNI	0.199***	110.5	52.2	192.3	69.8	0.353***	127.7	60.2	176.1	71.3	0.370***	124.6	61.5	179.3	70.0
BMD															
Lumbar spine (g/cm2)	NS	0.826	0.194	0.870	0.175	NS	0.843	0.185	0.861	0.181	0.066*	0.856	0.187	0.844	0.186
Whole body (g/cm2)	NS	0.912	0.161	0.953	0.150	0.080**	0.927	0.155	0.939	0.149	NS	0.932	0.163	0.929	0.152
Sub-total (whole body less head) (g/cm2)	NS	0.821	0.160	0.857	0.150	NS	0.838	0.158	0.843	0.146	0.084**	0.840	0.161	0.837	0.150

Abbreviations: BMD, bone mineral density; NS, not significant; RNI, recommended nutrient intake. **P* < 0.05, ***P* < 0.01 and ****P* < 0.00. [a]Partial Pearson's correlation coefficient, including age, BMI and energy intake (excluding energy variables) as covariates.

Table 4. Multivariate ORs and 95% CIs for the likelihood of having low BMD[a], according to the tertiles (T) of subjects' dietary patterns

		T1	*T2*	*T3*	*P for trend*
		OR	*OR (95% CI)*	*OR (95% CI)*	
Meat and vegetable	Model 1[b]	1.00 (ref)	0.53 (0.27, 1.06)	0.67 (0.33, 1.38)	0.246
	Model 2[c]	1.00 (ref)	0.55 (0.26, 1.15)	0.80 (0.33, 1.95)	0.680
	Model 3[d]	1.00 (ref)	0.54 (0.26, 1.14)	0.75 (0.30, 1.84)	0.623
White rice and kimchi	Model 1	1.00 (ref)	1.26 (0.65, 2.44)	0.66 (0.30, 1.45)	0.447
	Model 2	1.00 (ref)	1.30 (0.67, 2.51)	0.63 (0.28, 1.41)	0.539
	Model 3	1.00 (ref)	1.45 (0.73, 2.84)	0.68 (0.30, 1.53)	0.649
Milk-cereal and whole grain	Model 1	1.00 (ref)	0.60 (0.31, 1.16)	0.36 (0.17, 0.78)	0.006
	Model 2	1.00 (ref)	0.62 (0.32, 1.20)	0.39 (0.18, 0.86)	0.019
	Model 3	1.00 (ref)	0.56 (0.29, 1.11)	0.36 (0.16, 0.81)	0.018

Abbreviations: BMD, bone mineral density; CIs, confidence intervals; ORs, odds ratios. [a]Low BMD was defined as a BMD *Z*-score of −2.0 or less, according to the ISCD guidelines.[27] The 'low BMD group' was defined as subjects having low BMD at one or more sites from the three different sites where BMD values were measured. [b]Model 1 adjusted for age (continuous) and body size (height *Z*-score and weight *Z*-score according to each age group (continuous)). [c]Model 2 adjusted as model 1+ energy intake (log transformation, continuous) and serum 25(OH)D (log transformation, continuous). [d]Model 3 adjusted as model 2+ residence region (categorical), household income (categorical) and physical activity level (categorical).

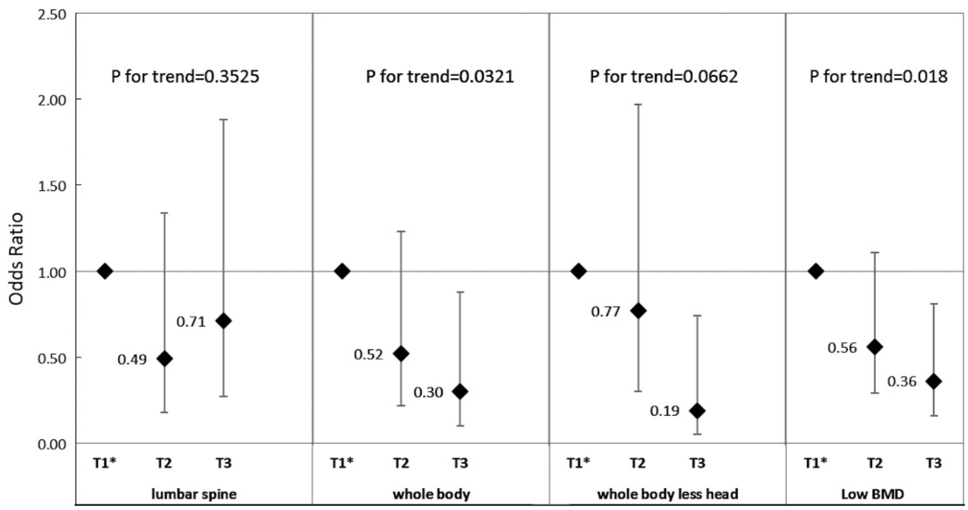

Figure 1. ORs for low BMD according to the tertiles of the 'milk-cereal and whole-grain' dietary pattern adjusted for age (continuous), body size (height *Z*-score and weight *Z*-score according to each age group (continuous)), energy intake (log transformation, continuous), serum 25(OH)D (log transformation, continuous), residence region (categorical), household income (categorical) and physical activity level (categorical). Error bars represent 95% CIs. *T1: reference group. †Low BMD of each measured bone site was defined as a BMD *Z*-score of − 2.0 or less, according to the ISCD guidelines.[27] The 'low BMD group' was defined as subjects having low BMD at one or more sites from the three different sites where BMD values were measured.

dairy foods, legumes, fruits, eggs, fish and sea foods was associated with a decreased risk of osteopenia and osteoporosis.[28] In our previous study of Korean adolescents, a high level of milk and cereal consumption led to a 64% decline in the probability of having low BMD in the lumbar spine.[16] Noh *et al.*[29] reported that subjects who had a high score for FNMBEG (that is, a high intake of fruits, nuts, seeds, milk and dairy products, beverages, eggs and grains) had a higher level of BMD over the 22 months surveyed.

Calcium intake during growth is crucial for maximizing of bone mass, which will prevent osteoporosis and osteopenia during adulthood.[30] Dairy foods are the main resources of calcium, leading to up 70% of the calcium intake in Western countries;[31] however, most Korean children and adolescents consume low amount of milk, yogurt and cheese. Our previous study reported that the status of calcium intake of Korean youth was very low, in which the percentage of subject less than the estimated average requirement was 75.0% in KNHANES (2007–2010), and dairy products contribute to only 35% of the daily calcium intake among Korean adolescents.[32] In the present study, the 'milk-cereal and whole-grain' pattern had a high consumption of dairy foods and subsequent high calcium intake showed inverse association with a risk of having low BMD in Korean male youth. Therefore, we suggest that strategies to encourage consumption of dairy products are needed to promote bone health.

In the current study, the 'milk-cereal and whole-grain' pattern had more strong association with riboflavin (vitamin B2) intake than the 'meat and vegetable' pattern. This finding is interesting because B-vitamins act as cofactors for enzymes maintaining low homocysteine levels. Increased homocysteine levels have shown to interfere with collagen crosslinking, and they also increase osteoclast activity;[33] thus, lowering homocysteine levels with B-vitamins has been suggested to be one of the promising preventive strategies against osteoporotic fractures.[34] Although both the above dietary patterns include the major food sources of riboflavin (meat versus milk), the amount of riboflavin intake in Korean youth appears to be more dependent on dairy food consumption than meat consumption. Regretfully, in this study, we did not assess whether a positive relationship between the 'milk and whole-grain' pattern and BMD is under the influence of calcium intake itself, or increased riboflavin intake also has an additive beneficial impact on BMD. Until now, the studies for association between low riboflavin intake and low BMD or fracture risk were only conducted in elderly populations.[35–37] Further studies are needed to elucidate possible contributions of riboflavin to the beneficial impacts of dairy consumption on BMD.

In our study, male youth in the top tertile (T3) of the 'milk-cereal and whole-grain' dietary pattern have a higher intake of whole grain compared to those in the bottom tertile (T1) of this pattern. Whole grains provide magnesium, iron, vitamin B complex and other bioactive compounds, such as phytochemicals and antioxidants, which may benefit bone health.[38,39]

Current study had several limitations with cross-sectional design and somewhat subjectivity of dietary pattern approach. In addition, 1-day 24-h recall may not accurately represent the individual's usual intake. Food frequency questionnaire used in KNHANES cannot evaluate usual intake, because it has not yet been validated. Hence, dietary intake data from 1-day 24-h recall were used in the current analysis. In addition, studies consisting of a more precise measurement of usual intake are needed to support these results. Nevertheless, to our knowledge, the present study is the first to conduct a nation-wide analysis examining the associations between dietary patterns and the risk of low BMD determined by the ISCD guidelines in Korean youth.[27]

Acquiring the highest possible peak bone mass within one's genetic potential is a crucial strategy for protecting against osteoporosis during adulthood.[40] Although genetic factors explained ~80% of the variance of bone mass observed among the population,[40] dietary factors, exercise, physical condition, hormone status and other environments have an important influence on bone mass accumulation early in life.[41] In the current study, the 'milk-cereal and whole-grain' pattern showed high consumptions of calcium, protein and diverse minerals and vitamins including riboflavin. On the basis of our results, a well-balanced and high-quality diet is a crucial factor for building the highest peak bone mass during adolescence, and this might prevent bone loss and osteoporosis later in life.

In conclusion, we identified three different dietary food patterns (meat and vegetable, white rice and kimchi, and milk-cereal and whole grain) from 20 food groups using factor analysis in Korean male adolescents and young adults. The 'milk-cereal and whole-grain' dietary pattern rich in calcium, riboflavin and protein content may be helpful in adequate bone accrual in youth.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2014R1A6A3A03056928) and was supported by the 2013 Merck Serono research grant. Ministry of Education, Science and Technology and Merck Serono had no role in the design, analysis or writing of this article.

REFERENCES

1 Burge R, Dawson-Hughes B, Solomon DH, Wong JB, King A, Tosteson A. Incidence and economic burden of osteoporosis-related fractures in the United States, 2005-2025. *J Bone Miner Res* 2007; **22**: 465–475.
2 Li SJ, Paik HY, Joung H. Dietary patterns are associated with sexual maturation in Korean children. *Brit J Nutr* 2006; **95**: 817–823.
3 Cooper C, Melton LJ 3rd. Epidemiology of osteoporosis. *Trends Endocrinol Metab* 1992; **3**: 224–229.
4 Johnston CC, Slemenda CW. Peak bone mass, bone loss and risk of fracture. *Osteoporos Int* 1994; **4**: 43–45.
5 McGuigan FEA, Murray L, Gallagher A, Davey-Smith G, Neville CE, Van't Hof R *et al.* Genetic and environmental determinants of peak bone mass in young men and women. *J Bone Miner Res* 2002; **17**: 1273–1279.
6 Pettifor JM, Prentice A. The role of vitamin D in paediatric bone health. *Best Pract Res Clin Endocrinol Metab* 2011; **25**: 573–584.
7 Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol* 2002; **13**: 3–9.
8 Kant AK. Dietary patterns and health outcomes. *J Am Diet Assoc* 2004; **104**: 615–635.
9 Tucker KL. Dietary patterns, approaches, and multicultural perspective. *Appl Physiol Nutr Metab* 2010; **35**: 211–218.
10 Kontogianni MD, Melistas L, Yannakoulia M, Malagaris L, Panagiotakos DB, Yiannakouris N. Association between dietary patterns and indices of bone mass in a sample of Mediterranean women. *Nutrition* 2009; **25**: 165–171.
11 Langsetmo L, Poliquin S, Hanley DA, Prior JC, Barr S, Anastassiades T *et al.* Dietary patterns in Canadian men and women ages 25 and older: relationship to demographics, body mass index, and bone mineral density. *BMC Musculoskelet Disord* 2010; **11**: 20.
12 Okubo H, Sasaki S, Horiguchi H, Oguma E, Miyamoto K, Hosoi Y *et al.* Dietary patterns associated with bone mineral density in premenopausal Japanese farmwomen. *Am J Clin Nutr* 2006; **83**: 1185–1192.
13 Shin S, Joung H. A dairy and fruit dietary pattern is associated with a reduced likelihood of osteoporosis in Korean postmenopausal women. *Br J Nutr* 2013; **110**: 1926–1933.
14 Tucker KL, Chen HL, Hannan MT, Cupples LA, Wilson PWF, Felson D *et al.* Bone mineral density and dietary patterns in older adults: the Framingham Osteoporosis Study. *Am J Clin Nutr* 2002; **76**: 245–252.
15 Hardcastle AC, Aucott L, Fraser WD, Reid DM, Macdonald HM. Dietary patterns, bone resorption and bone mineral density in early post-menopausal Scottish women. *Eur J Clin Nutr* 2011; **65**: 378–385.
16 Shin S, Hong K, Kang SW, Joung H. A milk and cereal dietary pattern is associated with a reduced likelihood of having a low bone mineral density of the lumbar spine in Korean adolescents. *Nutr Res* 2013; **33**: 59–66.
17 Whittle CR, Woodside JV, Cardwell CR, McCourt HJ, Young IS, Murray LJ *et al.* Dietary patterns and bone mineral status in young adults: the Northern Ireland Young Hearts Project. *Br J Nutr* 2012; **108**: 1494–1504.
18 Wosje KS, Khoury PR, Claytor RP, Copeland KA, Hornung RW, Daniels SR *et al.* Dietary patterns associated with fat and bone mass in young children. *Am J Clin Nutr* 2010; **92**: 294–303.
19 Song Y, Park MJ, Paik HY, Joung H. Secular trends in dietary patterns and obesity-related risk factors in Korean adolescents aged 10-19 years. *Int J Obes (Lond)* 2010; **34**: 48–56.
20 Lee HA, Park H. Correlations between poor micronutrition in family members and potential risk factors for poor diet in children and adolescents using Korean National Health and Nutrition Examination Survey Data. *Nutrients* 2015; **7**: 6346–6361.
21 Hernandez E, Kim M, Kim WG, Yoon J. Nutritional aspects of night eating and its association with weight status among Korean adolescents. *Nutr Res Pract* 2016; **10**: 448–455.
22 Butler LM, Wu AH, Wang RW, Koh WP, Yuan JM, Yu MC. A vegetable-fruit-soy dietary pattern protects against breast cancer among postmenopausal Singapore Chinese women. *Am J Clin Nutr* 2010; **91**: 1013–1019.
23 National Rural Nutrition Institute. *Food Composition Tables*. National Rural Nutrition Institute: Seoul, 2012.
24 Moon JS, Lee SY, Nam CM, Choi JM, Choe BK, Seo JW *et al.* 2007 Korean National Growth Charts: review of developmental process and an outlook. *Korean J Pediatr* 2008; **51**: 1–25.
25 World Health Organization. *The Asia-Pacific Perspective: Redefining Obesity and Its Treatment*. The International Obesity Task Force, Health Communications Australia Pty Ltd: Brisbane, Australia, 2000.
26 Henry YM, Fatayerji D, Eastell R. Attainment of peak bone mass at the lumbar spine, femoral neck and radius in men and women: relative contributions of bone size and volumetric bone mineral density. *Osteoporos Int* 2004; **15**: 263–273.
27 Lewiecki EM, Gordon CM, Baim S, Leonard MB, Bishop NJ, Bianchi ML *et al.* International Society for Clinical Densitometry 2007 Adult and Pediatric Official Positions. *Bone* 2008; **43**: 1115–1121.
28 Mu M, Wang SF, Sheng J, Zhao Y, Wang GX, Liu KY *et al.* Dietary patterns are associated with body mass index and bone mineral density in Chinese freshmen. *J Am Coll Nutr* 2014; **33**: 120–128.
29 Noh HY, Song YJ, Lee JE, Joung H, Park MK, Li SJ *et al.* Dietary patterns are associated with physical growth among school girls aged 9-11 years. *Nutr Res Pract* 2011; **5**: 569–577.
30 Mesías M, Seiquer I, Navarro MP. Calcium nutrition in adolescence. *Crit Rev Food Sci Nutr* 2011; **51**: 195–209.

31 Nicklas TA. Calcium intake trends and health consequences from childhood through adulthood. *J Am Coll Nutr* 2003; **22**: 340–356.
32 Im JG, Kim SH, Lee GY, Joung H, Park MJ. Inadequate calcium intake is highly prevalent in Korean children and adolescents: the Korea National Health and Nutrition Examination Survey (KNHANES) 2007-2010. *Public Health Nutr* 2014; **17**: 2489–2495.
33 Herrmann M, Widmann T, Colaianni G, Colucci S, Zallone A, Herrmann W. Increased osteoclast activity in the presence of increased homocysteine concentrations. *Clin Chem* 2005; **51**: 2348–2353.
34 Dai Z, Koh WP. B-vitamins and bone health--a review of the current evidence. *Nutrients* 2015; **7**: 3322–3346.
35 Abrahamsen B, Madsen JS, Tofteng CL, Stilgren L, Bladbjerg EM, Kristensen SR *et al.* Are effects of MTHFR (C677T) genotype on BMD confined to women with low folate and riboflavin intake? Analysis of food records from the Danish osteoporosis prevention study. *Bone* 2005; **36**: 577–583.
36 Macdonald HM, McGuigan FE, Fraser WD, New SA, Ralston SH, Reid DM. Methylenetetrahydrofolate reductase polymorphism interacts with riboflavin intake to influence bone mineral density. *Bone* 2004; **35**: 957–964.
37 Yazdanpanah N, Uitterlinden AG, Zillikens MC, Jhamai M, Rivadeneira F, Hofman A *et al.* Low dietary riboflavin but not folate predicts increased fracture risk in postmenopausal women homozygous for the MTHFR 677T allele. *J Bone Miner Res* 2008; **23**: 86–94.
38 Ilich JZ, Kerstetter JE. Nutrition in bone health revisited: a story beyond calcium. *J Am Coll Nutr* 2000; **19**: 715–737.
39 Vicente-Rodriguez G, Ezquerra J, Mesana MI, Fernandez-Alvira JM, Rey-Lopez JP, Casajus JA *et al.* Independent and combined effect of nutrition and exercise on bone mass development. *J Bone Miner Metab* 2008; **26**: 416–424.
40 Nelson DA. Peak bone mass. *Osteoporosis Int* 2000; **11**: S47–S48.
41 Golden NH, Abrams SA, Nutr C. Optimizing bone health in children and adolescents. *Pediatrics* 2014; **134**: E1229–E1243.