보건학박사 학위논문

Dietary Patterns Associated with Bone Health among Korean Population

한국인의 식사패턴과 골건강에 관한 연구

2013 년 8 월

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이 논문을 보건학 박사 학위논문으로 제출함

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Dietary Patterns Associated with Bone Health among Korean Population

A dissertation submitted in partial fulfilment of the requirement for the degree of Doctor of Philosophy in Public Health

To the Faculty of the Graduate School of Public Health at Seoul National University

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Abstract

Dietary Patterns Associated with Bone Health among Korean Population

Introduction: Osteoporosis is a systemic skeletal disease characterized by low bone mass and micro-architectural deterioration of bone tissue, leading to enhanced bone fragility and a consequent increase in risk of fracture. With an aging population, osteoporosis is widely considered as a global public health and financial burden, and is set to increase over the next 50 years. Low bone mineral density is an important predisposing factor of osteoporosis and increased the risk of osteoporotic fractures. The accumulation and loss of bone mass have influenced from various factors such as age, sex, weight, ethnicity, heredity, lifestyle (physical activity, smoking, and alcohol consumption), and nutrition (calcium, protein, and vitamin D). With regard to nutrients or diet, most previous studies have focused on a single nutrient or food and examined the association between nutrient intake and the status of bone health. Recently, dietary pattern analysis has been widely applied to identify the relationship between overall diet quality and health outcomes in field of nutrition research. However, information about the association between dietary pattern and BMD or osteoporosis in Asian populations was limited. Although several previous studies examined the relationship between dietary patterns and bone health, most studies have focused on adults and elderly population. Because dietary patterns in Asian countries are different from those in Western countries and also dietary pattern have distinct characteristics according to age groups, the association between dietary pattern and bone health among Koreans in various age groups are necessary.

Objectives: We hypothesized that specific dietary patterns may be prevalent according to various age groups and that certain dietary patterns may be related to bone health. In addition, the effect of dietary patterns on bone health might be identified after consideration of genetic factor from family relationship. Thus, the purpose of this study was to identify dietary patterns in diverse population and examine the association between dietary patterns and bone health among Korean population.

The aim of first study was to identify major dietary patterns and their associations with bone mineral density among Korean adolescents using multiple days of dietary intake data. The purpose of the second 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. The aim of third study was to examine the effects of dietary pattern on BMD using the data from the Korean twin and family study, controlling for the effects of shared family and genetic influences.

Methods: The first study was conducted on 196 adolescents aged 12 to 15years old. Information on the general characteristics of the subjects was obtained through a questionnaire, and dietary intake was assessed with 6-day food records. Bone mineral

density (BMD) of the lumbar spine and femur were measured by dual-energy X-ray absorptiometry. Dietary patterns were derived from twenty-four food groups using factor analysis.

The second cross-sectional study included 3,735 postmenopausal women who completed a health interview, nutrition survey, and a health examination including bone mineral density (BMD) measurements from the Korean Health and Nutrition Examination Survey 2008-2010. The general characteristics and dietary intakes of the participants were obtained using a standardised questionnaire and a 24-h recall method, respectively. The BMDs of the femoral neck and lumbar spine were measured using dual-energy X-ray absorptiometry; osteoporosis was defined based on WHO T-score criteria.

The subjects were 716 men and 1102 women from the Healthy Twin study. General information was obtained through a questionnaire, and dietary intake was assessed with 3-day food records. BMD was measured with dual-energy X-ray absorptiometry. The 'low BMD group' was defined as subjects with a T-score of -1.0 or less. Linear mixed models considering familial correlations were used for analysis.

Results: In the first study, four distinct dietary patterns - traditional Korean, fast food, milk and cereal, and snacks – were identified and accounted for 28.4% of the total variance. After adjusting for gender, age, body mass index (BMI) percentiles, weight loss attempts, pubertal status, and regular exercise, the adolescents in the highest tertile (T3) of the 'milk and cereal' dietary pattern score had significantly a reduced likelihood of having low BMD compared with those in the lowest tertile (T1) of this diet at the lumbar spine (OR: 0.36, 95% CI: 0.14 - 0.93, P = 0.0461). The other dietary patterns were not associated with the BMD of Korean adolescents.

In the second study, four dietary patterns were identified using factor analysis (‘meat, alcohol, and sugar’, ‘vegetables and soy sauce’, ‘white rice, kimchi, and seaweed’, and ‘dairy and fruit’), and accounted for 30.9% of the variance in total 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 associated negatively with bone health (OR = 1.40; 95% CI = 1.03-1.90, p for trend = 0.0479).

In the final study, Four dietary patterns were identified using factor analysis (Rice and kimchi; Egg, meat, and flour; Fruit, milk, and whole grain; Fast food and soda), and these patterns account for 31.1% of the variance in total food intake. The ‘fruit, milk, and whole grain’ dietary pattern was associated with a reduced risk of having low BMD in men (OR: 0.37; 95% CI: 0.21, 0.65) and women (OR: 0.45; 95% CI: 0.28, 0.72) after adjusting for possible confounding factors. The ‘Fruit, milk, and whole grain’ pattern was positively associated with the BMD of most measured sites, and the ‘Rice and kimchi’ pattern had a positive association with whole-arm BMD in both men and women when adjusting for confounding effects of genetic factors using a mixed linear model.

Conclusion: We identified dietary patterns in various age groups and certain dietary patterns were associated with bone health in Korean population. Results of the first study indicate that the intake of milk and cereal is important for the bone health of Korean adolescents, whose diets are composed mainly of grains and vegetables. In the second study, increased intake of dairy foods and fruits the traditional Korean diet, based on white rice and vegetables, may decrease the risk of osteoporosis in Korean postmenopausal women. The findings of final study suggest that a good-quality diet with high intakes of dairy products, fruits, vegetables, mushrooms, whole grain, and nuts may contribute to improved bone health in the Korean population and provide evidence that will contribute to potential dietary pattern-based strategies for bone health.

Keywords: dietary pattern, bone mineral density, osteoporosis, factor analysis

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Chapter 1. Introduction

1-1. Bone health epidemiology

Osteoporosis is a disease characterized by low bone mass and micro-architectural deterioration of bone tissue, leading to enhanced bone fragility and a consequent increase in risk of fracture [(1)]. Osteoporosis is commonly referred to as a 'silent disease' because there are no symptoms until the facture occurs. Osteoporotic tic fractures are a major cause of morbidity and disability in older people and can lead to premature death [(2)]. As the population grows older, the burden from osteoporosis becomes more significant with an imperative to identify modifiable risk factors [(3)]. It is estimated that 10 million individuals have osteoporosis and another 34 million suffer from low bone density. In addition, about 61 million individuals will be estimated to develop osteoporosis or low bone density and annual direct care costs for osteoporotic fracture reached almost 18 billion dollars [(4,5)].

Asian population were reported to have lower bone mass than Caucasians even after the differences between the body sizes of Asian people and Caucasians were considered [(6)]. The prevalence of osteoporosis is high, 34.9% in Korean postmenopausal women and 7.8% in elderly men aged ≥ 50 years at 2010 [(7)]. Particularly, in the case of Korean postmenopausal women, the prevalence of osteoporosis at femoral neck or lumbar spine is about three times greater than that of postmenopausal women in USA (21.3% vs. 7.7% at femoral neck and 28.8% vs. 9.9% at lumbar spine) [(8)].

Bone modelling begins with the development of the skeleton during fetal life and continues until the end of the second decade, when the epiphyseal growth plates are closed and longitudinal growth of the skeleton is completed (9). While bone remodelling starts during fetal life, the highest level of remodelling is achieved during adolescence. Peak bone mass (PBM), which is defined as the amount of bone present in the skeleton at the end of its maturation process, is considered to be achieved by the end of the second decade of life (10). Bone mineral mass gain during childhood and adolescence is influenced by many factors including heredity and ethnicity, sex, diet (calcium and protein intake), physical activity, endocrine status (such as sex hormones, vitamin D , growth hormone, and insulin-like growth factor), as well as exposure to risk factors such as cigarette smoking and alcohol intake (11,12) (figure 1-1).

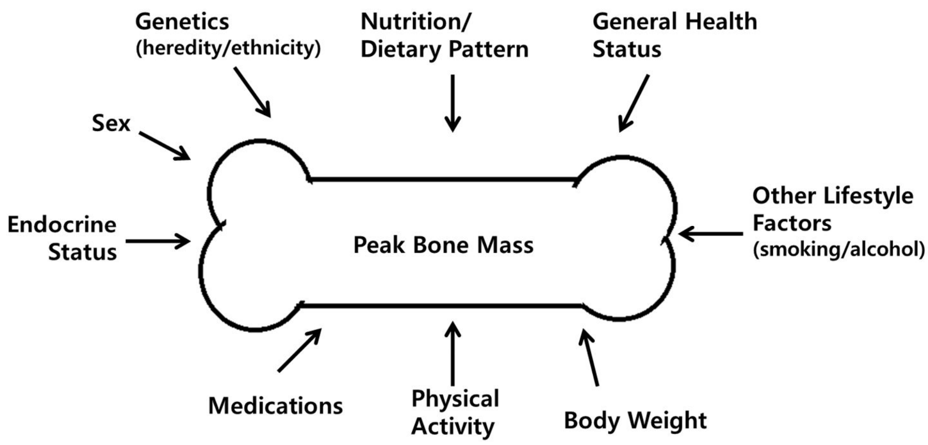

Figure 1-1. Factors affecting peak bone mass. Revised citation from previous study (13)

Ageing is associated with changes in the bone remodelling process, characterized by an increase in the resorption/formation ratio, leading to a progressive loss of bone [3]. It occurs as a result of increased bone breakdown by osteoclasts and decreased bone formation by osteoblasts [14]. Oestrogen deficiency after menopause leads to a loss of osteoclasts apoptosis and an increased bone loss, and bone mass in elderly men is also positively related to oestrogen levels. In addition, vitamin D insufficiency and secondary hyperparathyroidism are common in elderly people and may contribute on bone loss. Other possible factors are reduced physical activity with ageing and decreased production of insulin-like growth factors [15]. Although genetic factors contribute strongly PBM [16], the remainder may be amenable to interventions aimed at maximizing PBM within its genetically predefined variance [17]. As a 10% increase in PBM corresponds to a gain of on standard deviation in BMD in adulthood, osteoporotic fracture risk may be reduced by up to 50% by interventions aimed at maximizing PBM in sustainable manner [18]. Therefore, strategies for optimizing bone health throughout the life cycle and reducing risk of osteoporosis in later life are very important.

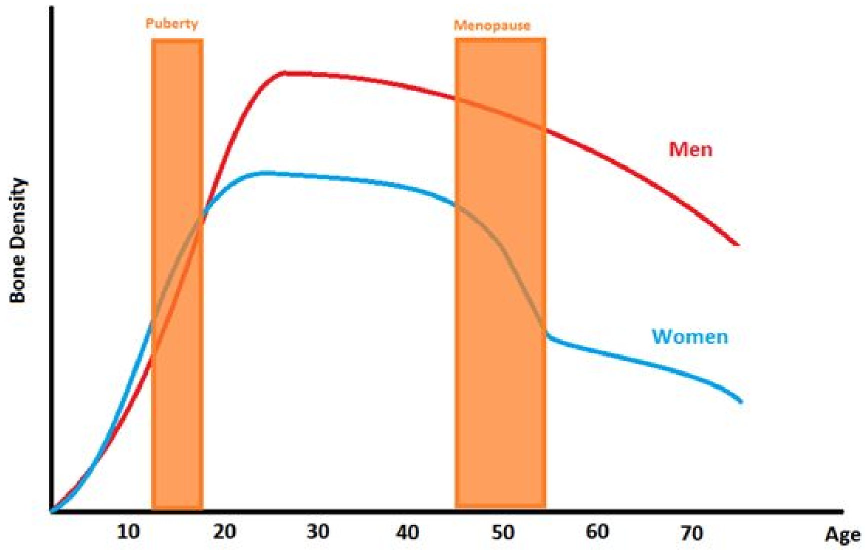

Figure 1-2. Age related changes in bone mass throughout life in women and men[19].

1-2. Genetics of bone health

Predisposing factors of bone mineral density and osteoporosis include both environmental and genetic factors. Many factors influence the risk of osteoporosis and achieving of PBM, including diet, physical activity, medication use, and coexisting disease. However, one of the most important clinical risk factors is familial history, emphasizing the importance of genetics in the pathogenesis of the disease [20,21]. Among the established risk factors for osteoporotic fracture, family history indicates the importance of the genetic background of osteoporosis. Twin studies supported the heritability of BMD [22], which is the most valuable indicator of bone strength. Studies including twins or families to evaluate the heritability of BMD have shown that approximately 50-85% of BMD variance is determined by genetic factors [23-26]. The heritability of BMD ranged 63-90% in Chinese family studies [27-29]. Moreover, the results of the studies in Western population had shown considerably high heritability of BMD; 0.26-0.90 in Americans [30-32], 0.44-0.84 in the British [33,34], 0.61-0.66 in Iceland adults [20], 0.72-0.93 in Finnish people [35,36], 63-79% in Australian [37,38], 25-80% in Mexican [39]. In the Korean population, after adjusting for the covariate effects, the heritability of BMD at the whole body, whole ribs, whole pelvis, whole arms, and whole legs were 0.76, 0.72, 0.73, 0.71, 0.51, and 0.75, respectively [40]. The pair-wise correlation of BMD was the highest within monozygotic twin pairs, followed by dizygotic twin pairs, sibling pairs, and parent-child pairs [40]. Although this relatively high heritability of BMD was verified in the various ethnic populations, heritability of BMD was frequently found to differ among the specific bone sites of measurement. Furthermore, the accurate mechanism for measuring different genetic effects by specific bone site is still uncertain [40].

Twin studies have also confirmed significant heritable components to other phenotypes relevant to the pathogenesis of osteoporosis, such as the ultrasound properties of bone [33], biochemical markers of bone turnover [41,42], and bone geometry [33,43]. Recently, several approaches have been used to identify the genes responsible for osteoporosis, including linkage studies [44,45], animal studies [46-49], candidate genes association studies [50-55], and genome-wide association studies (GWAS) [56-58]

1-3. Nutrition and bone health

Nutrition and dietary behaviour are significant factors in regulating bone metabolism in elderly adults as well as achieving peak bone mass in adolescents. Numerous nutrients are essential for growth and development of the skeleton. Until recently, the principal focus for nutrition effects on osteoporosis and BMD has been almost exclusively calcium and vitamin D. In recent years, interests have been shifted to the role of other nutrients in preventing osteoporosis and determining BMD [(59)]. These studies was concerned about the role of protein, minerals (such as potassium and magnesium), vitamins (such as vitamin K, vitamin B complex, and antioxidant vitamin D), and carotenoids. The studies relevant to relationship between consumption of certain food or food group (including fruit and vegetables, carbonated beverages, alcohol and coffee) and bone health have recently been examined.

The study with young Japanese women showed that calcium intake had positive and significant association with BMD in the distal radius adjusted for covariates [(60)]. Another study reported that higher intake of calcium was associated with significant gains in BMD of whole body and hip in 125 young female cross-country runners [(61)]. However, recent meta-analysis of prospective cohort studies and randomized controlled trials found no effects of calcium on hip fracture risk in men and women [(62)].

In the NHANES III survey, older non-Hispanic white adults with serum 25-hydroxyvitamin D values exceeding 62.5 nM had significantly lower risk of hip fracture (RR=0.64) compared to those with values below this level [(63)]. Conversely, in the Framingham Osteoporosis Study, average 4-year BMD loss for men and women was not affected by serum 25-hydroxyvitamin D values [64]. A recent meta-analysis reported that low dose vitamin D (<400 IU daily) was not effective, while high dose vitamin D (≥ 700 IU daily) was effective in decreasing hip fracture in only institutionalized individuals [65].

Several population-based studies have shown beneficial effects of magnesium and potassium on bone health. In the Framingham Osteoporosis Study, magnesium and potassium intakes were associated with grater BMD in men and women, and demonstrated protective effects against 4-year bone loss in men [66]. A prospective cohort study of elderly postmenopausal women showed that subjects in the highest quartile of urinary potassium excretion had significantly 4% to 11% higher BMD at 5 years [67].

Although excess protein intake might lead to negative calcium balance, low protein intake has also been associated with increased risk of fracture in the elderly [59]. In the Iowa women's cohort study, the risk of hip fracture was negatively associated with total protein intake, and the relative risks of hip fracture decreased across increasing quartiles of intake of animal protein [68]. In the Framingham osteoporosis study, subjects in the lowest protein intake quartile had significantly greater 4-year bone less at the femur and spine than those in the highest quartile of protein intakes [69]. In addition, previous studies reported that the effect of vitamin C [70,71], vitamin K [72-74], vitamin B [75,76], and carotenoids [77,78] on bone health.

In the NHANES III survey, Caucasian women with low milk consumption (< 1 serving of milk/week) during childhood and adolescence had low bone density in adulthood and greater risk of fracture [(79)]. In addition, Coulding *et al.,* reported that New Zealand children who avoided cow's milk had 1.7 times higher risk for pre-pubertal fracture [(80)].

Fruit and vegetables are major food contributors of magnesium and potassium, which may maintain an acid-base balance, as well as vitamin V, carotenoids, and other food constituents that may contribute to antioxidant protection. Macdonald *et al.* [(81)] found that calcium and several nutrients found in fruit and vegetables (potassium, vitamin C, and magnesium) were positively correlated with BMD and negatively correlated with bone loss in Scottish women.

Thus, a well-balanced, high-quality diet with an adequate intake of calcium and vitamin D are crucial factors in preventing bone loss and osteoporosis.

1-4. Dietary pattern and bone health

In the last decades, most studies have conducted to evaluate the relationship between the consumptions of foods and food groups as well as intake of macro- and micro-nutrients and the bone health [(82)], although distinct relationships have not been elucidated. One reason for this inconsistency may be the traditional single nutrient- or food-based approach. Most people eat mixture of foods that contain a combination of nutrients that reflected their food preferences, which may be influenced by a mixture of cultural, social, environmental, health, economic, and lifestyle factors [83]. Thus, the classical approach, which examines single nutrients or foods, might not adequately account for complex interactions and synergetic effects and might results in the results of erroneous associations between dietary patterns and bone health [84]. Dietary patterns approaches could examine the effects of several foods to be studied simultaneously and could overcome methodological problems concerning the high inter-correlation among foods and nutrients in diet and multiple testing [82]. This methodology provides an overall characteristic of dietary behaviour and a more comprehensive approach by focusing on the entire diet rather than just a single food or nutrient [82].

Dietary patterns have been shown to be reproducible and valid, and have been used to identify associations between diet and bone health. Several studies identified positive associations between dietary patterns and bone health in various ethnic and age groups: 'health' (fruit and vegetables, white meat, white and oily fish and dairy products) pattern in Scottish women [85], 'nutrient-dense' dietary pattern in Canadian women [86], pattern characterized by high consumption of fish and olive oil and low intake of red meat in Mediterranean women, pattern with high loading green and yellow vegetables, mushrooms, fish and shellfish, and fruit in premenopausal Japanese farmwomen [87], dietary pattern characterised by a high intake of dark-green and deep-yellow vegetables in young children in the USA [88], and 'milk and cereal' dietary pattern in Korean adolescents [89]. On the other hand, inverse associations between 'energy dense' pattern in Canadian men 25-49 years old [90], 'traditional English' dietary pattern in UK postmenopausal women [91], ‘candy’ dietary pattern in elderly women in the Framingham osteoporosis study [92], and ‘refined’ pattern in northern Irish young adults [93] and BMD have been reported.

Up to date information about the association between dietary pattern and BMD or osteoporosis in Asian populations was restricted. Several previous studies focused on adults and elderly population examined the relationship between dietary patterns and bone health. Dietary patterns and age-specific dietary patterns in Asian countries are different from those in Western countries.

Recently, dietary patterns in Korea have been changing from a traditional diet consisting of mainly grains and vegetables to a Western style diet, characterized by high consumption of meat, dairy foods, and fast food. This change in dietary pattern is occurring faster in adolescents than adults [94]. Despite the changing diet, the current Korean diet still is a rice-based diet with low dairy food and calcium [95]. The mean calcium intake in Korean was 529.9 mg/d, only 74.0 % of the Recommended Intake. The prevalence of low calcium intake is especially high among 12- to 18 years old adolescents (57.9 %) and elderly adults aged ≥ 65 years old (60.7%) [7]. The mean frequency milk intake was as low as 2.9 times per week [7], may negatively affect bone health.

Some evidence regarding the associations among nutrients or food and bone health has been reported up to date, yet limited information is available on current dietary patterns related to bone health among Korean population. We hypothesized that prevalent age-specific dietary patterns and certain dietary patterns may be related to bone health. In addition, the effect of dietary patterns on bone health might be identified after consideration of genetic factors from family relationships.

1-5. Objectives

Thus, the purpose of this study was to identify dietary patterns in diverse population and associate dietary patterns to bone health using data based on the Korean population. This study consisted of three sub-studies.

In the first study, we identified major dietary patterns in Korean adolescents. We examined the association between dietary patterns and the risk of having low bone mineral density among Korean adolescents using multiple days of dietary intake data. A total of 95 boys and 101 girls completed measurements of femur and lumbar spine BMD and 6-day food record. We hypothesized that specific dietary patterns are prevalent among Korean adolescents and that certain dietary patterns may be related to bone mineral density. Thus, the purpose of this study was to identify major dietary patterns and their associations with bone mineral density among Korean adolescents using the multiple days of dietary intake data.

In the second study, we assessed distinct dietary patterns in Korean menopausal women and examined the relationship between dietary patterns and risk of osteoporosis using data from the Korea National Health and Nutrition Examination Survey (KNHANES) IV and V. In total, 3,735 postmenopausal women were ultimately eligible for analysis. Thus, the purpose of this 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).

In the third study, we examined the association between dietary patterns and risk of having low BMD using data from the Korean twin and family study. After adjusting the effects of shared family and genetic influence and other confounding variables, we assessed the effects of dietary pattern on BMD. A total of 1,818 (716 male subjects and 1,102 female subjects) were included as participants. The aim of this study was to examine the effects of dietary pattern on BMD using the data from the Korean twin and family study, controlling for the effects of shared family and genetic influences.

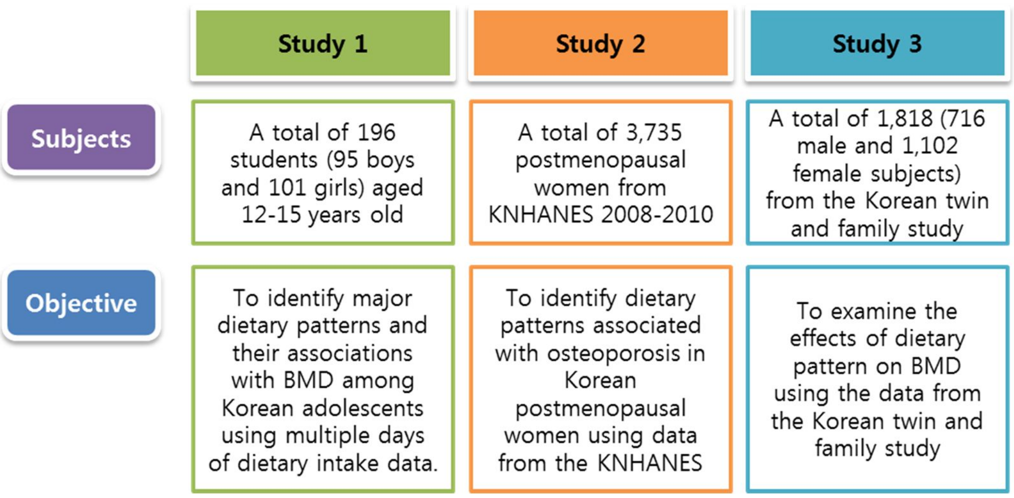

Figure 1-3. Construction of this research

Chapter 2. A Milk and Cereal Dietary Pattern is Associated with the Likelihood of Having Low Bone Mineral Density of the Lumbar Spine in Korean Adolescents

Abstract

The traditional rice-based Korean diet has been changing toward a Western-style diet. This change has been especially rapid among adolescents. The purpose of this study was to investigate the association between dietary patterns and bone health among Korean adolescents. This cross-sectional study was conducted on 196 adolescents aged 12 to 15. Information on the general characteristics of the subjects was obtained through a questionnaire, and dietary intake was assessed with 6-day food records. Bone mineral density (BMD) of the lumbar spine and femur were measured by dual-energy X-ray absorptiometry. Dietary patterns were derived from twenty-four food groups using factor analysis. Four distinct dietary patterns - Traditional Korean, Fast food, Milk and cereal, and Snacks – were identified and accounted for 28.4% of the total variance. After adjusting for gender, age, body mass index (BMI) percentiles, weight loss attempts, pubertal status, and regular exercise, the adolescents in the highest tertile (T3) of the 'Milk and cereal' dietary pattern score had significantly a reduced likelihood of having low BMD compared with those in the lowest tertile (T1) of this diet at the lumbar spine (OR: 0.36, 95% CI: 0.14 - 0.93, $P = 0.0461$). The other dietary patterns were not associated with the BMD of Korean adolescents. These results indicate that the intake of milk and cereal is important for the bone health of Korean adolescents, whose diets are composed mainly of grains and vegetables.

2-1. Introduction

Bone modeling begins during prenatal life with the growth of the skeleton and continues through the late teens, when most of the growth of the bones has been completed [9]. The peak bone mass (PBM), which is defined as the amount of bony tissue present at the end of skeletal maturation [96], is considered to be 90% complete by the end of the teen years [97]. Thus, adolescence is a critical period for the development of PBM, and risk factors for the growth of bony tissue may have long-term effects on bone health [97-99].

The accumulation of bone mineral mass during adolescence is a multi-factorial process influenced by age, gender, heredity, ethnicity, and lifestyle (such as physical activity, smoking, and alcohol intake), as well as nutrition (such as calcium, protein, and vitamin D) [11,12,16]. Although genetics has a critical role in modulating the BMD in the achievement of PBM [40], adequate nutritional intake may mediate the expression of bone-related phenotypes [100].

Most nutritional epidemiologic approaches to bone health have focused on a single nutrient, such as calcium, phosphorus, or vitamin D [101,102], or a food group such as fruit, vegetables, and dairy products [103-106]. These approaches may not be adequate to explain the complex interactions among nutrients or foods. Recently, dietary patterns have been used to elucidate possible associations among typical dietary pattern and health outcomes. Dietary pattern analysis evaluates subjects' overall tendencies to eat certain types of foods and meals, rather than a single food or nutrient. They have been applied broadly to epidemiological studies of the associations between health outcomes and overall dietary quality [107]. Dietary pattern analysis should be based on a person's usual intake, using multiple days of dietary data collected by an open-ended method that represent a person's usual intake with high accuracy, instead of data from food frequency questionnaires [108].

Although many previous studies have examined the relationship between dietary patterns and bone health, most studies have focused on adults and elderly populations [107,109-112]. 'Healthy dietary patterns' characterized by high consumption of fish, olive oil, fruits, and vegetables and low consumption of red meat and candy were positively associated with BMD in Mediterranean [113], American [92], and Japanese [87] adults, while a 'Western dietary pattern' was negatively associated with BMD in premenopausal Japanese women [87]. To the best of our knowledge, few studies have been performed to investigate the association between dietary patterns and bone health among adolescents.

Recently, dietary patterns in Korea have been changing from a traditional diet composed of mainly grains and vegetables to a Western-style diet, characterized by high intake of meat, dairy products, and fast food. Although the change in dietary patterns to the Western-style diet is occurring faster in adolescents, most adolescents still consume rice-based diets with low dairy food and calcium contents [94] that negatively influence their bone health. Although some evidence regarding the association among nutrients or food and bone health has been reported so far, very limited information is available on current dietary patterns related to bone health among Korean adolescents. We hypothesized that specific dietary patterns are prevalent among Korean adolescents and that certain dietary patterns may be related to bone mineral density. Thus, the purpose of this study was to identify major dietary patterns and their associations with bone mineral density among Korean adolescents using multiple days of dietary intake data.

2-2. Subjects and methods

Subjects and study design

Five hundred ninety-five students (319 boys, 276 girls) aged 12-15 years completed the questionnaire and anthropometric measurements in a junior high school in Seoul. We randomly selected 95 boys and 101 girls for measuring femur and lumbar spine bone mineral density and collected 6-day food records. All students gave written consent to participate in the study. The institutional review board at the Graduate School of Public Health at Seoul National University approved the study protocol.

Questionnaire

Before the survey, we explained the outline of this study to the schools' principals and teachers, sent a letter to the students' parents, and obtained written consent from the students and their parents. The questionnaire was distributed to the students during the first visit to the participating school. Completed questionnaires were collected a few days later and reviewed by trained staff. The questionnaire solicited general information on the student's birth date, weight loss attempts, pubertal status, and regular exercise. The data on weight loss attempts were acquired by asking whether the student tried to lose weight in the last six months. Pubertal status was assessed by asking the age of first menstrual period for girls and by asking boys when their voice first started breaking. Regular exercise was checked by asking participants whether they performed moderate physical activity such as bicycling or swimming at a regular pace or doubles tennis at least three times a week.

Anthropometric measurements

The weight, fat mass, and lean body mass of subjects were measured using bioelectrical impedance analysis (Inbody 4.0; Biospace Co., Ltd., Seoul, Korea). Body weight (kg) was measured to the nearest 0.1 kg with the participant in light clothing and wearing no shoes. Height (cm) was measured to the nearest 0.1 cm using a stadiometer while the subject stood with heels together, legs straight, shoulders relaxed, and head positioned so that the gaze was straight ahead. Body mass index (BMI) was calculated as the weight divided by the height squared (kg/m^2).

The bone mineral density (BMD) of the lumbar spine (L1-L4) and femur were measured using dual-energy X-ray absorptiometry (DEXA, Lunar Prodigy Advance;

GE Healthcare, USA). The BMD of adolescents cannot be compared with that of young adults for the assessment of their bone health because peak bone mass is not acquired until the second or third decade of life [114]. Therefore, calculation of a BMD Z-score was adopted, which represents the SD score compared with age-matched controls [115]. The 'low BMD group' was defined as subjects with -1.0 or less of Z-score using a published pediatric database of sex and age-matched controls by Lim et al [116].

Dietary pattern analyses

Dietary intake was assessed using consecutive 6-day (5 weekdays, 1 weekend day) food records before the measurement of BMD. A trained dietician provided detailed instructions to students on keeping a food diary. School lunch recipes were obtained from the school dietician to check the records. The dietician reviewed and confirmed the completed 6-day food records using three-dimensional food models and supplemental instruments during face-to-face interviews to increase accuracy. Nutrient intakes were calculated from the dietary intake data using the food composition database of the Korean Nutrition Society (Canpro 3.0, 2002).

For dietary pattern analysis, food items consumed by subjects for 6 days were categorized into 24 foods, which were based on the 18 food groups of the Korean Nutrient Database (Korean Nutrition Society, 2002). Grains and grain products was divided into nine subgroups - white rice, other grains, noodles and wheat flour, cereal, snacks, bread, hamburgers, pizza, and sandwiches - to encompass the food items typically consumed by adolescents. Soy sauce was separated from the legumes, and vegetables, fruits, and mushrooms were combined into fruit and vegetables. Kimchi (traditional Korean fermented cabbage) was separated into a single vegetable group because kimchi is a major traditional Korean side dish. The meats were divided into pork and beef, fried chicken, and chicken and eggs. Chocolate, ice cream, candy, and chewing gum were separated as a single sugar group. The food groups and food items used in this study are shown in Table 2-1.

We conducted an exploratory factor analysis to identify the major dietary patterns based on the percentages of total daily energy intake of the 24 food groups. Factors were rotated by orthogonal transformation to provide a simpler structure and to improve interpretation. The number of factors was determined by eigen-values of > 1.25 and scree plots. Correlation coefficients between factor scores and nutrient intakes were calculated.

Statistical analyses

All analyses were performed using SAS software (SAS 9.1; SAS institute Inc., Cary, NC, USA). Statistical significance was defined as $P < .05$. We tested the mean differences in anthropometric measurements and nutrient intakes between gender groups using the General Linear Model and adjusting for age. The distributional differences of general characteristics between gender groups were assessed using chi-square tests.

The subjects were divided into three categories according to tertiles of the four dietary pattern scores. The Odds Ratios (ORs) and their 95% Confidence Intervals (CIs) to assess the strength of the associations between dietary patterns and the likelihood of having of low BMD were assessed using multiple logistic regression analysis adjusting for age (continuous), gender (categorical), BMI percentile (continuous), weight loss attempts (categorical), pubertal status (categorical), and regular exercise (categorical).

2-3. Results

The anthropometric measurements, BMD, nutrient intakes, and covariates (pubertal status, experience of weight control, and regular exercise) of the study subjects are summarized in Table 2-2. The mean age of the adolescents was 14.2 ± 0.9 years, and the percentage of girls was 51.5 %. The means of BMD of lumbar spine and femur were 0.994 ± 0.149, 0.958 ± 0.125 g/cm^2, respectively. Height, weight, lean body mass, fat percentage, and BMD of the lumbar spine were significantly different between boys and girls ($p < .05$). Daily mean energy, carbohydrates, and calcium intake were 1632.1 ± 372.4, 254.4 ± 58.1, and 376.8 ± 178.2 g, respectively, and each parameter was significantly higher in boys than in girls ($p < .05$). The proportion who had attempted to lose weight differed significantly between boys and girls ($p < .05$).

Factor loadings for the four dietary patterns are shown in Table 2-3. Four dietary patterns were named according to the food groups that had high positive loadings or the characteristics of the food group that composed the dietary pattern. The 'Traditional Korean' dietary pattern featured a high consumption of rice and other grains, fish and shellfish, legumes, soy sauce and soybean pastes, seaweed, and kimchi. The 'Fast food' dietary pattern was characterized by high loadings for carbonated drinks, French fries, hamburgers, biscuits and cookies, pizza, and fried chicken. The 'Milk and cereal' dietary pattern showed high loadings for milk and yogurt, cereal, and bread, but negative loading for carbonated drinks and meats. The 'Snacks' dietary pattern had high positive loadings for sauce and seasonings, chocolate, ice cream, gum and candy, seeds and nuts, fruits and vegetables, sandwiches, and simple sugars. The four dietary patterns accounted for 28.4 % of total variance: 9.9, 6.8, 6.1, and 5.6 %, respectively.

Table 2-4 presents Pearson's correlation coefficients between factor scores and nutrient intakes and BMD with age and gender as covariates. The factor score for the 'Traditional Korean' diet was positively associated with iron (r = 0.143, $P < .05$), sodium (r = 0.153, $P < .05$), folate (r = 0.197, $P < .001$), and dietary fiber (r = 0.241, $P < .001$) and negatively associated with lipids (r = -0.229, $P < .001$). The 'Fast food' diet was positively associated with energy (r = 0.165, $P < .05$), protein (r = 0.292, $P < .0001$), and lipids (r = 0.317, $P < .0001$). The 'Milk and cereal' dietary pattern was positively associated with carbohydrates (r = 0.189, $P < .001$) and calcium (r = 0.385, $P < .0001$). The factor score for the 'Snacks' pattern was positively associated with sodium (r = 0.225, P < .001), vitamin A (r = 0.202, P < .001), vitamin C (r = 0.362, P < .0001), folate (r = 0.291, P < .0001), and dietary fiber (r = 0.297, P < .0001).

Multivariate ORs and CIs for low bone mineral density according to the tertiles of dietary pattern scores are presented in Table 2-5. After adjusting for gender, age, BMI percentiles, weight loss attempts, pubertal status, and regular exercise, the adolescents in the highest tertile (T3) of the 'Milk and cereal' pattern had significantly lower likelihood of having of low BMD compared with those in the lowest tertile (T1) at the lumbar spine (OR: 0.36, 95% CI: 0.14 - 0.93, P = 0.0461). The other dietary patterns were not associated with the BMD of Korean adolescents.

2-4. Discussion

Among Korean adolescents, we derived four distinct dietary patterns from the 6-day dietary records and found that a 'Milk and cereal' dietary pattern was associated with a decreased likelihood of having low BMD in the lumbar spine. To our knowledge, this is the first study to confirm the association between specific dietary patterns and bone health among adolescents. In the present study, adolescents with high scores of the 'Milk and cereal' dietary pattern had a 64% reduction in the likelihood of having low BMD at the lumbar spine after adjusting for potentially confounding factors. In addition, the BMD of lumbar spine (1.055 ± 0.174 g/cm^2) of subjects in the highest tertile (T1) of the 'Milk and cereal' pattern was significantly higher than that (0.974 ± 0.146 g/cm^2) of subjects in the lowest tertile (T1) (P = 0.0005). The positive association we observed may be due to the higher calcium intake. The calcium intake (461.2 ± 234.3 g) of the adolescents in the highest tertile (T3) of the ‘Milk and cereal’ pattern was significantly higher compared with that (320.1 ± 117.8 g) of subjects in the lowest tertile (T1) (P < .0001) (data not shown).

During adolescence, calcium requirements increase for rapid bone growth and muscle development [(117)]. At least 90% of the PBM is attained by the age of 18 years. Sufficient calcium intake during adolescence is particularly essential to attain the maximal PBM, which protects against osteoporosis and osteopenia in adulthood and old age. Dairy products, especially milk from cows, are an important source of calcium [(118)]. Calcium intake is typically low among Korean adolescents because dairy foods are not popular in Korea and are rarely consumed by most adolescents. The Korean National Health and Nutrition Examination Survey [(119)] reported a mean calcium intake of 528.4 mg/day among 13- to 19-year-old students (55.4% of the Adequate Intake), and the proportion of Korean adolescents who drink milk, a calcium-rich food, more than two times every day is 16.4 % [(120)]. The mean calcium intake of our subjects was as low as 400.7 mg/day in boys and 355.3 mg/day in girls. Thus, increased intake of calcium-rich dairy products may enhance the accumulation of bone mass in Korean adolescents.

In this study, although three patterns (fast food, milk and cereal, and snacks) could be regarded as modified Western diets, most adolescents with these patterns still consume considerable amounts of rice and kimchi. Thus, the ‘Milk and cereal’ pattern in the rice-based Korean diet may have more beneficial effects on the BMD of Korean adolescents compared to the other dietary patterns, such as fast food, Western, and snack dietary patterns. Previous studies conducted in Japanese adolescents [(118)], Chinese adolescents [(98,121)], and Caucasian girls [(122)] reported that milk and dairy product consumption was positively associated with BMD and that avoiding milk was significantly associated with lower BMD [(123)].

We carried out additional analysis to identify the sole effect of calcium and milk intake on the likelihood of having low BMD. The ORs for low BMD according to tertiles of the milk (*P* for trend = 0.0692 at lumbar spine and 0.0715 at femur) and calcium intake (*P* for trend = 0.0765 at lumbar spine and 0.0975 at femur) were not significantly decreased. The reason why the 'Milk and cereal' dietary pattern had a beneficial effect on adolescents' bone health, while calcium or milk consumption only was not associated with the likelihood of having a low BMD, may be complex and potentially involves a synergic effect from the mixture of foods that contain calcium as well as other beneficial nutrients for bone health. In addition, the effects of these combinations on the bone health of adolescents reflect whole diet patterns, which may be driven by a mixture of social, cultural, environmental, health, economic and lifestyle factors [(83)].

In our study, the 'Milk and cereal' dietary pattern only had an effect on the lumbar spine, not the femur, and the reason cannot be explained by our results. A meta-analysis of the impact of dairy products and dietary calcium on bone health in children identified that increased consumption of calcium and dairy products significantly improved bone health for the total body and lumbar spine in children, but not for the femur, pelvis and radius [105], which is consistent with our results. Further research on the reason for the effects of milk and cereal consumption on specific bone sites is needed.

In the present study, the four identified dietary patterns ('Traditional Korean', 'Fast food', 'Milk and cereal', 'Snacks') explained 28.4 % of the total variance. Most studies [87,107,109-112] have used a threshold eigen-value of 1.0 to identify the two to four dietary patterns explaining 21.7-29.2 % of total variance. Although our results are not directly comparable with other studies due to differences in the study protocol, such as the number of food records and food group classifications, the dietary patterns derived in this study are very similar to those of previous studies. Li et al [112] identified four dietary patterns in Korean adolescents: 'Rice and kimchi' (white rice, kimchi, vegetables, and garlic), 'Shellfish and processed meat' (shellfish, processed meat, and bread), 'Pizza and drinks' (carbohydrate-rich drinks, hamburgers, fruit, and cookies), and 'Milk and cereal' (milk and dairy products, cereal, and fish). Other studies carried out in Korean adolescents reported a 'Traditional' pattern, with high consumption of rice, kimchi, and vegetables, and a 'Western' pattern, with high intake of pizza, hamburgers, meat, and soft drinks [94,124], which are similar to dietary patterns (Korean traditional and fast food, respectively) identified in our study.

The major strength of our study is the 6-day food record method used to assess dietary patterns. A food record method is considered to give reasonably accurate measurements of the actual dietary intake, and a 5-7 day record seems to give representative measures of the usual dietary intake [125]. In most epidemiological studies, dietary assessments are conducted using food frequency questionnaires (FFQ) or short-term (generally less than 3 days) food records, whereas our study used a 6-day food record to assess dietary patterns among adolescents. Additionally, we used a specific, comparatively homogenous study population composed of Korean adolescents aged 12-15 years. This study may assist in providing dietary guidelines for bone health in this age group.

However, several limitations also need to be considered in the interpretation of our findings. First, the results do not indicate a causal relationship between dietary patterns and bone mineral density due to the cross-sectional design. Thus, these results need to be confirmed by longitudinal studies. Second, the definition of the 'low BMD group' may require caution in the interpretation of the results. An expert panel convened in 2003 suggested that a characterization of low bone density for chronologic age is the most appropriate terminology for children and adolescents (less than 20 year of age) when Z-scores are -2.0 or less using pediatric databases of age-matched controls [126]. We defined those subjects with Z-scores of -1.0 or less as the 'low BMD group' instead of using the criteria of Z-scores of -2.0 or less because the number of 'low bone density' subjects was very small (n=6). Third, vitamin D status, which is a critical factor for bone health, was not evaluated in our study. However, we measured daily sun exposure and found that BMDs in the lumbar spine and femur were not significantly different according to the duration of sun exposure ($P = 0.4077$, data not shown). Finally, the dietary pattern approach can be subjective and creates difficulties in replicating the results in other populations. In factor analysis, researchers generally make arbitrary decisions on, for example, the number of foods or food groups included, the number of factors, and the rotational method. To maintain comparability, we followed steps similar to those adopted in other epidemiological studies [112,127-129].

In summary, our study identified four dietary patterns (‘Traditional Korean’, ‘Fast food’, ‘Milk and cereal’, ‘Snacks’) based on the 6-day food records of Korean adolescents, and the ‘Milk and cereal’ dietary pattern was associated with a reduced likelihood of having low BMD of the lumbar spine. Therefore, the consumption of milk and dairy food may be beneficial for BMD in Korean adolescents whose diet is composed of mainly grains and vegetables.

Table 2-1. Food groups and items from the 6-day food records of 196 Korean adolescents

Food or food group	Food items
Rice and other grains	White rice, brown rice, proso millet, barley, sorghum, polished grain, foxtail millet, rye, rice cake
Fish and shellfish	Squid, octopus, anchovy, shrimp, crab, scallop, oyster, granulated ark shell, hard clam, little-neck clam, abalone, pen shell, ark shell, mussel, flatfish, hair tail, mackerel, Pacific saury, bastard halibut, common sea bass, pacific cod, tuna, sea bream, Alaska pollack, harvest fish, Spanish mackerel, common mullet, angler, salmon, eel, yellow croaker, fish paste
Legumes	Kidney beans, soybeans, green peas, red beans, soybean curd, soybean milk
Soy sauce and soybean pastes	Soybean sauce, soybean paste, mixed soybean and red pepper paste
Seaweed	Laver, sea tangle, sea mustard, sea lettuce
Kimchi (traditional Korean fermented cabbage)	Kimchi (cabbage, mustard leaves, young leafy radish, small radish, cubed radish roots), salted radish in rice bran, cucumber pickle
Noodles and wheat flour	Noodles (wheat flour, buckwheat flour), udong, ramyon, spaghetti, wheat flour products
Carbonated drinks	Soda, coffee, tea
French fries	French fries
Hamburgers	Hamburgers
Biscuits and cookies	Biscuits, nachos, snacks, cookies, crackers
Pizza	Pizza, hotdogs
Fried chicken	Fried chicken, chicken nuggets, chicken cutlets
Sauce and seasonings	Mayonnaise, mustard, hot pepper sauce, tomato ketchup, vinegar, pepper, curry sauce
Milk and yogurt	Milk, yogurt, cheese
Cereal	Cereal
Bread	Rolls, doughnuts, muffins, waffles, castella, croissants, croquettes, pastries, loaf bread, pie
Poultry and eggs	Eggs, quail's eggs, chicken meat, duck meat
Pork, beef, and fats	Pork, beef, ham, sausage, pork cutlets, meatballs, butter, corn oil, olive oil, soybean oil, margarine
Chocolate, ice cream, gum, candy	Chocolate, chocolate syrup, cocoa, ice cream, gum, candy, jelly, fruit juice
Seeds and nuts	Peanuts, acorns, chestnuts, almonds, gingko nuts, pine nuts, sunflower seeds, walnuts, pumpkin seeds, sesame seeds, perilla seeds
Fruits and vegetables	Persimmon, grape, strawberry, apricot, mango, banana, pear, peach, apple, pomegranate, watermelon, orange, oriental melon, kiwi, pineapple, passion fruit, potato, sweet potato, bracken, mung bean sprouts, lotus root, burdock, soybean sprouts, red pepper, carrot, garlic, radish, water dropwort, cabbage, Chinese chives, broccoli, lettuce, celery, spinach, cucumber, tomato, onion, paprika, pumpkin
Sandwiches	Sandwiches
Simple sugars	Starch syrup, yeot (crude maltose), jam, sugar

Table 2-2. Characteristics (anthropometric measurements, bone mineral densities at spine and hip, health behaviors, and nutrient intakes) of 196 Korean adolescents

	Subjects (n=196)
Age (yrs)	14.2 ± 0.9
Height (cm)	161.9 ± 7.5
Weight (kg)	60.5 ± 13.3
Fat mass (kg)	18.2 ± 7.9
Lean mass (kg)	42.3 ± 7.9
Percentage of fat (%)	29.1 ± 8.2
Body mass index (kg/m^2)	22.9 ± 4.1
Bone mineral density (g/cm^2)	
Lumbar spine	0.994 ± 0.149
Femur	0.958 ± 0.125
Nutrient intake (/day)	
Energy (kcal)	1632.1 ± 392.4
Carbohydrate (g)	245.4 ± 58.1
Protein (g)	60.6 ± 21.1
Lipid (g)	45.9 ± 15.1
Calcium (mg)	376.8 ± 178.2
Iron (mg)	12.0 ± 12.7
Sodium (mg)	4107.3 ± 2626.4
Zinc (mg)	7.6 ± 3.3
Vitamin A (μg RE)	485.9 ± 203.4
Vitamin C (mg)	67.2 ± 44.5
Folate (μg)	164.5 ± 68.1
Fiber (g)	13.1 ± 4.2
Girls (%)	101 (51.5)
Post pubertal stage (yes) [a] (%)	55 (65.5)
Experience of weight control (yes) [b] (%)	16 (17.4)
Regular exercise (yes) [c] (%)	30 (32.3)

Values are expressed as the means ± SD

[a] Pubertal status was assessed by asking the age of first menstrual period for girls and by asking boys when their voice first started breaking.

[b] Experiences with weight control were assessed by asking whether the student had tried to lose weight in the last six months.

[c] Regular exercise was assessed by asking whether the participant performed moderate physical activity such as bicycling or swimming at a regular pace or doubles tennis at least three times a week.

Table 2-3. Factor loading matrix [a] for the four dietary patterns [b] identified from 6-day food records using principal-component analysis

	Factor 1	Factor 2	Factor 3	Factor 4	
	Traditional Korean	Fast food	Milk and cereal	Snacks	
Rice and other grains	0.70	-0.30		-0.28	
Fish and shellfish	0.47				
Legumes	0.46				
Soy sauce and soybean pastes	0.38				
Seaweed	0.34				
Kimchi (traditional Korean fermented cabbage)	0.27	-0.26			
Noodles and wheat flour	-0.59	-0.26			
Carbonated drinks	-0.25	0.58	-0.26		
French fries		0.54			
Hamburgers		0.50			
Biscuits and cookies		0.39			
Pizza		0.38			
Fried chicken		0.29			
Sauce and seasonings		-0.37		0.31	
Milk and yogurt			0.65		
Cereal			0.62		
Bread			0.39		
Poultry and eggs			-0.33		
Pork, beef, and fats			-0.41		
Chocolate, ice cream, gum, candy				0.51	
Seeds and nuts				0.50	
Fruits and vegetables				0.44	
Sandwiches				0.43	
Simple sugars				0.41	
Percentage of variability	9.90	6.75	6.11	5.61	∑28.37

[a] The correlation among the food groups and each factor (dietary patterns). For simplicity, factor loading values <0.25 are not listed in the matrix
[b] Four dietary patterns were derived by principal component analysis after entering the 24 food groups into the FACTOR PROCEDURE. The factors were rotated by orthogonal transformations (Varimax rotation function in SAS), and the number of factors was determined based on eigenvalues (>1.25).

Table 2-4. Correlation coefficients [a] between factor scores and nutrient intake

	Dietary pattern			
	Traditional Korean	Fast food	Milk and cereal	Snacks
Energy (kcal)	-0.001	0.165 *	0.126	-0.007
Carbohydrates (g)	0.104	0.044	0.189 **	0.003
Protein (g)	0.035	0.292 ***	-0.073	-0.034
Lipids (g)	-0.229 **	0.317 ***	0.041	0.027
Calcium (mg)	0.074	0.111	0.385 ***	0.125
Iron (mg)	0.143 *	0.059	0.108	0.084
Sodium (mg)	0.153 *	-0.015	-0.075	0.225 **
Zinc (mg)	0.101	0.106	-0.037	-0.100
Vitamin A (RE)	0.074	0.068	0.109	0.202 **
Vitamin C (mg)	0.084	-0.129	0.047	0.362 ***
Folate (μg)	0.197 **	-0.077	0.093	0.291 ***
Dietary fiber (g)	0.241 **	-0.095	-0.067	0.297 ***

[a] Correlation coefficients were calculated using partial Pearson's correlation analysis adjusting for age and gender.

Statistical significance at the partial Pearson's correlation test at $^{*}P < .05$, $^{**}P < .01$, and $^{***}P < .001$

Table 2-5. Multivariate[a] odds ratios (ORs) and 95% confidence intervals (CIs) for the likelihood of having low BMD of the lumbar spine and femur according to the tertile of dietary pattern scores of Korean adolescents

Tertiles	T1[b]	T2		T3		*P* for trend [c]
Lumbar spine						
Traditional Korean	1.00	0.66	(0.26, 1.65)	0.58	(0.23, 1.48)	0.3556
Fast food	1.00	1.14	(0.47, 2.79)	0.81	(0.31, 2.10)	0.6281
Milk and cereal	1.00	0.62	(0.26, 1.52)	0.36	(0.14, 0.93)	0.0461
Snacks	1.00	2.47	(0.91, 6.73)	1.23	(0.47, 3.20)	0.8534
Femur						
Traditional Korean	1.00	0.83	(0.34, 2.07)	0.86	(0.35, 2.14)	0.8072
Fast food	1.00	1.29	(0.54, 3.12)	0.76	(0.29, 1.99)	0.5933
Milk and cereal	1.00	0.57	(0.23, 1.42)	0.71	(0.29, 1.72)	0.3705
Snacks	1.00	1.29	(0.49, 3.41)	1.27	(0.51, 3.15)	0.6707

[a] Multivariate regression model controlled for age (continuous), gender (categorical), BMI percentiles (continuous), weight loss attempts (categorical), pubertal status (categorical), and regular exercise (categorical).
[b] Reference group
[c] The trend test was performed using a generalized linear model.

Chapter 3. A dairy and fruit dietary pattern is associated with a reduced likelihood of osteoporosis in Korean postmenopausal women

Abstract

The aim of this study was to identify the association of dietary patterns with osteoporosis in Korean postmenopausal women from the Korean Health and Nutrition Examination Survey 2008-2010. This cross-sectional analysis included 3,735 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 BMDs of the femoral neck and lumbar spine were measured using dual-energy X-ray absorptiometry; osteoporosis was defined based on WHO T-score criteria. Four dietary patterns were identified using factor analysis (‘Meat, alcohol, and sugar’, ‘Vegetables and soy sauce’, ‘White rice, kimchi, and seaweed’, and ‘Dairy and fruit’), and accounted for 30.9% of the variance in total 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 associated negatively with bone health (OR = 1.40; 95% CI = 1.03-1.90, p for trend = 0.0479). Our results suggest that increased intake of dairy foods and fruits the traditional Korean diet, based on white rice and vegetables, may decrease the risk of osteoporosis in Korean postmenopausal women.

3-1. Introduction

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 incidence of osteoporosis-related fractures is becoming a major social and medical concern in both developed and developing countries [(130)].

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 [(131-133)]. A previous study reported that Asian women have 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 [(134)], and has been increasing gradually [(135)].

Dietary behaviours are important factors in regulating bone loss in postmenopausal women as well as in achieving peak bone mass in adolescents. Most previous researches on diet and bone health have focused on a single nutrient, such as calcium or vitamin D [(101,102,136)] with protein, vitamin K, potassium, and caffeine, or on foods, including fruits, vegetables, and milk [(67,81,106,137-141)]. 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 [142]. Dietary pattern analysis evaluates subjects' overall tendencies to eat certain types of foods and meals, rather than a single food or nutrient [143].

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 [86] and Scottish women aged over 50 years [85]. Several studies identified positive associations between dietary patterns and BMD in diverse age groups: a 'nutrient-dense' pattern in Canadian younger men [113], a 'nuts and meat' pattern in Northern Irish young adults [93], and a dietary pattern characterised by a high intake of dark-green and deep-yellow vegetables in young children in the USA [88]. On the other hand, inverse associations between 'energy-dense, nutrient-poor' in Australian women [144], a 'refined' pattern in Northern Irish young adults [93], and a 'traditional English' dietary pattern in UK postmenopausal women [91], 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 high intake of sodium and low intake of calcium.

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 calcium contents [95]. The mean calcium intake among 50- to 64- year-old women was 506.8 mg/d, only 72.4% of the Recommended Intake (700mg/d) [145]. Moreover, the prevalence of low calcium intake is especially high among the elderly [134]. Additionally, the mean frequency of milk intake was as low as 1.5 times per week [134], which may negatively affect bone health.

Thus, the purpose of this 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.

3-2. Subjects and methods

Study design and population

The KNHANES has been performed periodically since 1998 to investigate the health and nutritional status of Koreans; bone mineral density measurements were first included in the second year (2008) of KNHANES IV. This study was based on 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, nutrition survey, and 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 3,786 postmenopausal women, we excluded those who reported implausibly low or high daily energy intakes (< 2,092 or > 20,920 kJ/d). In total, 3,735 postmenopausal women were ultimately eligible for analysis.

This 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 single 24-h recall. A nutrition survey was conducted through in-person interviews at participants' homes by trained dieticians using supplemental instruments, such as measuring cups, spoons, and a ruler.

Information on the dishes, food items, 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 20 food groups based on common food groups classified in the Korean Nutrient database [(145)]. 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 [(146)]: white rice, whole grains, noodles and dumplings, and 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. The 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 [(145)].

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 20 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 20 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 20 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 this analysis because they reflected the distinct characteristics of each dietary pattern within a large sample, and were used in previous studies [(147-149)].

Health examination and BMD 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. Body mass index (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 the Asian and Pacific regions [(150)].

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 DXA (DISCOVERY-W fan-beam densitometer; Hologic Inc., Bedford, MA, USA) 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 [(151)]. The coefficient of variation in the BMD measurements, based on reproducibility scans, was 1.9% for the L1-4 spine and 2.5% for the femoral neck [(152)]. We used the L1-4 spine and femoral neck values for BMD analysis. The definition of osteoporosis was made using WHO T-score criteria

(T-score≤-2.5) and we used the maximum BMD value for Asian (Japanese) patients as a reference [153].

Covariates

The 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, and college or more. The equivalent household monthly income was calculated by dividing the obtained monthly household income by the square root of family size. Equivalent income was categorised as one of three levels: low (< 710,000 KRW), middle (710,000-1,400,000 KRW), and high (≥ 1,410,000 KRW) [154]. 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, < four times per month, or ≥ three times per week), moderate physical activity per week (≥ five times or < five 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 (PTH) and serum 25-hydroxyvitamin D (25[OH]D) levels. The level of PTH was measured by a chemiluminescence immunoassay using LIAISON (DiaSorin, Still Water, MN, USA). Serum 25(OH)D levels were measured using a gamma counter

(1470 WIZARD; PerkinElmer, Turku, Finland) with a radioimmunoassay kit (DiaSorin, Still Water, MN, USA) [152].

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 correlations, including age, BMI, and energy intake as covariates. Multi-variable adjusted logistic regression analysis was conducted to examine the odds ratios (ORs) and 95% confidence intervals (CIs) for osteoporosis across the quintile categories of each dietary pattern score, adjusting for covariates known to be related with 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 (PTH, 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 the SAS software (version 9.3; SAS Institute Inc., Cary, NC, USA). Statistical significance was set at $p < 0.05$.

3-3. Results

The general characteristics and bone health status of the study participants are summarised in Table 3-1. 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 [(153)]. 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 3-2. 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 soy sauce’, ‘White rice, kimchi, and seaweed’, and ‘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 soy sauce’ pattern loaded highly for vegetables and mushrooms, soy 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, 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’, 7.7% in ‘Vegetables and soy 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 3-3. 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 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 soy sauce’ pattern and BMD. The ‘White rice, kimchi, and seaweed’ dietary pattern score was positively associated with energy, carbohydrates, sodium, and niacin, but showed no association with minerals or vitamins, including calcium, phosphorus, and iron. The ‘Dairy and fruit’ dietary pattern score was associated positively with most nutrient intakes, except carbohydrates and sodium. The ‘Meat, alcohol, and sugar’ pattern score was associated positively with energy, protein, fat, sodium, vitamin A, thiamine, riboflavin, and niacin, while it was negatively associated with carbohydrates and vitamin C. The ‘Vegetables and soy sauce’ dietary pattern score was associated positively with intake of most nutrients, except fat and carbohydrates.

Table 3-4 shows the multivariate-adjusted OR of having osteoporosis of the femoral neck and lumbar spine across the four dietary patterns. 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 PTH, 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).

3-4. Discussion

We identified four distinct dietary patterns (Meat, alcohol, and sugar; Vegetables and soy 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 this 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 [85-87,93,113,142]. Although the dietary pattern in this study cannot be directly compared with those of other , due to differences in the protocols used, such as the number of food records and food group classifications, the dietary patterns derived in this study are similar to those reported previously [95,155,156].

The ‘Dairy and fruit’ dietary pattern identified in this 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 [85,92]. Additionally, both the ‘Dairy and fruit’ dietary pattern in this study and ‘healthy diet’ pattern in previous studies had high loadings of milk and dairy foods, which are calcium-rich [85,92]. Calcium 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*-telopetides/creatinine (uNTx/Cr), a biomarker of bone resorption in American postmenopausal women. Subjects in the lowest tertile of the milk intake group had a significantly higher uNTx/Cr level than did those in the middle and highest tertiles [157]. Postmenopausal white women consuming dairy products at least once per day were 62% less likely to have osteoporosis than those consuming dairy product less than twice per week [158].

Our ‘Dairy and fruit’ dietary pattern was positively associated with a variety of minerals and vitamins, including iron, potassium, vitamin A, thiamin, riboflavin, niacin, and vitamin C, which have recently received significant attention with regard to bone health, as well as calcium. Macdonald *et al*. [81] found that calcium and several nutrients found in fruit and vegetables (potassium, vitamin C, magnesium) 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 magnesium and potassium were positively associated with the BMD of elderly men and women in the Framingham Osteoporosis Study [66]. 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 'Dairy and fruit' dietary pattern on bone health would be more beneficial if the vitamin D status improves simultaneously, because the prevalence of vitamin D deficiency among the Korean menopausal women is very high. Pfeifer *et al.* [159] reported that supplementation with vitamin D and elemental calcium id 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 soy sauce' dietary patterns identified in this 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 a 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 soy sauce' dietary patterns consumed 73.7% of their food energy from carbohydrates and 13.8% from fat, this pattern was associated with consumption of protein and various minerals and vitamins. It may have affected the non-significant association between the 'Vegetables and soy sauce' pattern and the risk of osteoporosis.

A high-carbohydrate low-fat (HCLF) diet is generally recommended to reduce cardiovascular risk; it has a relatively higher dietary acid load [(160)]. A diet with a high acid load can lead to an increased risk of chronic low-grade metabolic acidosis and can influence a negative calcium balance and increased bone loss [(161)]. Nowson *et al.* found that a HCLF diet increased levels of indicators (N-terminal propeptide and type I procollagen) of an increased rate of bone turnover [(160)]. Macdonald *et al.* also suggested that a change in acid loads may have a significant adverse effect on bone health only if accompanied by a low calcium diet [(106)]. The low calcium intake (391.6 mg/d, 55.9% of calcium RI) in addition to their high-carbohydrate, low-fat diet could negatively affect the bone health of subjects in the highest quintile.

In this study, dietary patterns had an effect on only the lumbar spine, not the femoral neck. Several meta-analysis studies of the effects of nutrition on bone health reported that high intake of calcium and dairy food significantly improved bone health of the lumbar spine and total body, but not the femur, pelvis, or radius in children [(105)]. Indeed, soy 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 [(162)], consistent with our results. Further research on the mechanism underlying the effect of nutrition factors on specific bone sites is needed.

This study has several limitations. First, the results do not indicate a causal or resultant relationship between dietary patterns because this 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 single 24-h recall, which might not represent the individual's usual intake. Food frequency questionnaires (FFQs) are commonly used in dietary pattern analysis; however, the FFQ used in KNHANES was not developed to evaluate usual food intakes and has not yet been validated. Thus, dietary intake data from 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 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[163]. To minimise subjectivity, we defined dietary patterns based on a procedure used in previous studies [95,155,156]. Despite these limitations, this 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 [164]. 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 calcium contents. Our 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 development of dietary guidelines to prevent osteoporosis and further research into the relationship between diet and bone health.

In conclusion, our 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.

Table 3-1. General characteristics of the study subjects.

	n	%
Total number of subjects	3735	
Demographic characteristics		
Age (years), Mean SD	64.1	9.5
Height (cm), Mean SD	152.9	5.9
Weight (kg), Mean SD	56.5	8.5
BMI (kg/m^2), Mean SD	24.1	3.2
Household income		
Low (< 710,000 KRW)	652	17.8
Middle (710,000-1,400,000 KRW)	1612	43.9
High (≥ 1,410,000 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 SD	19.1	7.2
Prevalence of vitamin D deficiency[†]	2338	62.6
PTH (pg/mL), Mean SD	70.8	34.3
Osteoporosis prevalence		
Femoral neck	827	22.1
Lumbar spine	1132	30.3
Femoral neck BMD (g/cm^2), Mean SD	0.618	0.110
Lumbar spine BMD (g/cm^2), Mean SD	0.796	0.140

[*] 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.

Table 3-2. Factor loading* matrix of food groups for major factors in Korean postmenopausal women.

Food or food groups	Dietary patterns			
	Factor 1	Factor 2	Factor 3	Factor 4
	Meat, alcohol, and sugar	Vegetables and soy sauce	White rice, kimchi, and seaweed	Dairy and fruit
Oils	0.34			
Starch syrup and sugar	0.34			
Meat and its products	0.31			
Alcohols	0.33			
Vegetables and mushrooms		0.46		
Soy sauce and red peppers		0.40		
Garlic and onions		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.

Table 3-3. Correlation coefficients† among four dietary pattern scores and BMD and nutrient intakes.

	Factor 1	Factor 2	Factor 3	Factor 4
	Meat, alcohol, and sugar	Vegetables and soy 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 (kcal)	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 ***
Calcium (mg)	0.000	0.242 ***	0.021	0.268 ***
Phosphorus (mg)	-0.001	0.349 ***	0.025	0.325 ***
Iron (mg)	-0.025	0.151 ***	-0.015	0.074 ***
Sodium (mg)	0.206 ***	0.308 ***	0.130 ***	-0.129 ***
Potassium (mg)	-0.005	0.221 ***	-0.111 ***	0.242 ***
Vitamin A (μgRE)	0.066 ***	0.145 ***	0.039 *	0.079 ***
Thiamine (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 ***

† Partial Pearson's correlation, including age, BMI, and energy intake (excluding energy variables) as covariates.

* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Table 3-4. ORs and 95% CIs for osteoporosis of the femoral neck and lumbar spine across quintile categories of dietary pattern scores in Korean postmenopausal women.

		Q1	Q3			Q5			p for trend
			OR	95% CI		OR	95% CI		
Factor 1: Meat, alcohol, and sugar									
Femoral neck	model 1*	1 (ref)	1.01	(0.76,	1.34)	1.02	(0.75,	1.41)	0.4197
	model 2†	1 (ref)	0.79	(0.56,	1.12)	0.87	(0.60,	1.27)	0.7588
	model 3‡	1 (ref)	0.77	(0.54,	1.09)	0.89	(0.60,	1.31)	0.6602
Lumbar spine	model 1	1 (ref)	0.72	(0.57,	0.93)	0.75	(0.51,	1.03)	0.0631
	model 2	1 (ref)	0.78	(0.58,	1.05)	0.76	(0.56,	1.04)	0.0605
	model 3	1 (ref)	0.77	(0.57,	1.04)	0.78	(0.57,	1.07)	0.1988
Factor 2: Vegetables and soy sauce									
Femoral neck	model 1	1 (ref)	0.82	(0.60,	1.12)	0.94	(0.66,	1.33)	0.1831
	model 2	1 (ref)	0.69	(0.48,	1.01)	0.81	(0.53,	1.23)	0.0821
	model 3	1 (ref)	0.69	(0.47,	1.02)	0.79	(0.51,	1.21)	0.0689
Lumbar spine	model 1	1 (ref)	1.03	(0.79,	1.35)	1.12	(0.84,	1.51)	0.7606
	model 2	1 (ref)	1.17	(0.85,	1.61)	1.25	(0.88,	1.77)	0.9573
	model 3	1 (ref)	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 (ref)	0.70	(0.52,	0.94)	0.98	(0.73,	1.31)	0.5684
	model 2	1 (ref)	0.71	(0.50,	1.01)	1.08	(0.76,	1.53)	0.9992
	model 3	1 (ref)	0.73	(0.51,	1.05)	1.14	(0.80,	1.64)	0.9435
Lumbar spine	model 1	1 (ref)	0.94	(0.73,	1.22)	1.20	(0.93,	1.54)	0.0780
	model 2	1 (ref)	0.95	(0.70,	1.29)	1.34	(0.99,	1.81)	0.0663
	model 3	1 (ref)	0.99	(0.73,	1.35)	1.40	(1.03,	1.90)	0.0479
Factor 4: Dairy and fruit									
Femoral neck	model 1	1 (ref)	0.95	(0.72,	1.26)	0.76	(0.55,	1.04)	0.1812
	model 2	1 (ref)	1.09	(0.78,	1.53)	0.82	(0.55,	1.20)	0.2360
	model 3	1 (ref)	1.10	(0.78,	1.55)	0.80	(0.54,	1.19)	0.1763
Lumbar spine	model 1	1 (ref)	0.67	(0.53,	0.86)	0.44	(0.33,	0.57)	<0.0001
	model 2	1 (ref)	0.73	(0.55,	0.97)	0.46	(0.33,	0.63)	<0.0001
	model 3	1 (ref)	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 + PTH and serum 25(OH)D.

‡ Model 3 adjusted as Model 2 + smoking, alcohol intake, moderate physical activity, supplement use, and oral contraceptive use.

Chapter 4. Association between dietary patterns and bone mineral density in adults: The Healthy Twin Study

Abstract

As the world's population continues to age, osteoporosis is considered a major public health problem that imposes a significant burden on both individuals and society. The aim of this study was to examine the effects of dietary pattern on bone mineral density (BMD) in Korean adults. The subjects were 716 men and 1102 women from the Healthy Twin study. General information was obtained through a questionnaire, and dietary intake was assessed with 3-day food records. BMD was measured with dual-energy X-ray absorptiometry. The 'low BMD group' was defined as subjects with a T-score of -1.0 or less. Linear mixed models considering familial correlations were used for analysis. Four dietary patterns were identified using factor analysis (Rice and kimchi; Egg, meat, and flour; Fruit, milk, and whole grain; Fast food and soda), and account for 31.1% of the variance in total food intake. The 'Fruit, milk, and whole grain' pattern was associated with a reduced risk of having low BMD in men (OR: 0.37; 95% CI: 0.21, 0.65) and women (OR: 0.45; 95% CI: 0.28, 0.72). The 'Fruit, milk, and whole grain' pattern was positively associated with the BMD of most measured sites, and the 'Rice and kimchi' pattern had a positive association with whole-arm BMD in both men and women when adjusting for confounding effects of genetic factors using a mixed linear model. Our results suggest that a good-quality diet with high intakes of dairy products, fruits, vegetables, mushrooms, whole grain, and nuts may contribute to improved bone health in the Korean population and provide evidence that will contribute to potential dietary pattern-based strategies for bone health.

4-1. Introduction

Osteoporosis is a systemic skeletal disease characterized by reduced bone mass and disruption of bone architecture, resulting in increased bone fragility and increased fracture risk [1]. Recent reports on osteoporosis indicated that approximately 1.66 million hip fractures occur each year worldwide and that the incidence is expected to increase fourfold by 2050 due to the aging population [165]. It is estimated that one in three women and one in five men over the age of fifty will sustain an osteoporotic fractures. Thus, osteoporosis is increasingly considered a major public health problem that imposes a significant burden on both individuals and society [166].

Low bone mineral density (BMD) is considered to be the determinant risk factor of osteoporosis [167]. The accumulation and loss of bone mass are influenced by a variety of factors, such as age, sex, ethnicity, heredity, lifestyle (physical activity, smoking, and alcohol intake), and nutrition (calcium, protein, and vitamin D) [11,12,16].

The results of many studies support the idea that diet plays a critical role in modulating BMD in the acquisition of peak bone mass in early adults [168] and in changing the rate of bone loss in elderly women and men [169]. With regard to nutrients or diet, most studies have focused on a single nutrient or food and have examined the association between nutrient intake and the status of bone health [60,66,68,69]. However, these common approaches may not adequately explain the complicated interaction and synergistic effects of nutrients and foods on bone health outcome because people consume a diet consisting of a variety of food with complex combinations of many nutrients rather than a single nutrient. Recently, the identification of dietary patterns using factor analysis has been widely applied to verify the relationship between diet and health outcome [142]. Furthermore, dietary pattern approach allows the development of appropriate recommendations for overall dietary behaviours [142].

Langsetmo and colleagues reported that a dietary pattern with a high consumption of fruits, vegetables, and whole grains has been shown to have a protective effect on fractures in postmenopausal women and men aged ≥ 50 y [86]. A study of Greek women found that a dietary pattern characterised by fish, olive oil, and a low intake of red meat was associated with higher lumbar spine BMD [113]. Although several studies have shown that specific dietary patterns are associated with bone health, most studies have been conducted on Western populations. The Korean diet consists mainly of steamed rice, vegetables, fermented foods with salt, and soybean products, with only small amounts of dairy products and meat.

Furthermore, previous studies of the relationship between dietary pattern and bone health had a limitation, which could not take account into genetic factors. Dietary behaviour may be confounded by other behavioural, environmental, or genetic factors that are common to members of the same family. Twin and same family member serve as a powerful model with which to identify effects of complex association and to control for unmeasured and unknown potential confounders, including genetic, socioeconomic, and lifestyle shared by same family. To date, few twin and/or family studies have attempted to assess the relationship between dietary pattern and BMD independent of genetic influences.

The aim of the current study was to examine the effects of dietary pattern on BMD using the data from the Korean twin and family study, controlling for the effects of shared family and genetic influences.

4-2. Subjects and methods

Subjects and study design

The participants of this study were part of the Healthy Twin Study, a large longitudinal study that has been conducted as a part of the Korean Genomic Epidemiologic Study since 2005 [(170)]. The Healthy Twin Study is an investigation of risk factors for complex diseases and involves Korean adult twins aged ≥ 30 years and their first-degree adult family members who volunteered from the general population. Details about the design and methodology of the Healthy Twin Study have been published elsewhere [(171)]. Our subjects were those who visited study centres located in Seoul or Pusan, Korea, to undergo a baseline questionnaire and a health examination that included clinical tests, biochemical tests, radiologic examinations, anthropometric measurements, a nutrition survey, and BMD measurements from July 1, 2007, to January 31, 2012. We excluded those who reported implausibly low or high daily energy intake (<500 or 5,000 kcal/d) and those without BMD measurements. Thus, 1,818 subjects (716 men and 1,102 women) were ultimately eligible for analysis.

All participants provided written informed consent when they visited one of the study centres. This study was conducted according to the Declaration of Helsinki guidelines, and all procedures involving human subjects were approved by the Korea Center for Disease Control and the institutional review board of the three participating centres (Samsung Medical Center, Pusan Paik Hospital, and Dankook University Hospital).

Dietary patterns

Information on dietary intake was assessed using data from 3-day (2 weekdays and 1 weekend day) food records. When subjects visited the centre, a trained staff member provided detailed instructions to the subjects on keeping a food diary. A trained dietician reviewed and confirmed the completed 3-day food records using three-dimensional food models and supplemental instruments such as measuring cups, spoons, and a ruler during a face-to-face interview to increase accuracy. Nutrient intake data was derived using the food composition database of the Korean Nutrition Society (Canpro 3.0; Korean Nutrition Society, Korea, 2002).

For factor analysis, the food items consumed by subjects were grouped into 22 food groups based on nutrient profiles or culinary use according to the common food groups classified in the Korean Nutrient database (172). Grains and grain products were divided into four subgroups to address the following types of staple foods (146): white rice, whole grains, noodles and dumplings, and flour and bread. Kimchi, a Korean traditional fermented cabbage commonly eaten as a side dish, was placed in a discrete food group. The food groups and food items used in factor analysis are shown in Table 4-1.

Dietary patterns were identified using factor analysis based on the percentage of total daily energy intake from each food group. The average daily intake of 22 foods or food groups was computed for each subject, and the percentage of energy obtained from each food or food groups was calculated. Principle component factor analysis was used to extract the dietary pattern that explained the maximum proportion of variance in the correlation matrix of the 22 food groups. An orthogonal transformation (Varimax rotation function in SAS) was used to rotate the factor correlation matrix to obtain a simpler structure with greater interpretability. The number of factors to be retained in the model was determined based on eigenvalues (> 1.2), Scree plots, and interpretability of the factors derived (Figure 4-1). Factor scores were calculated for each subject and were determined by summing the intake of each food group, weighed by the factor loading. Thus, subjects with high scores for a dietary pattern have a greater tendency to adhere to the pattern than those with a low score. Each subject was assigned a factor score for each identified factor and was divided by each factor score into groups by using quartiles. Factor names were given that reflected the food group with high positive loadings on that factor.

Health examination and BMD measurements

BMDs (g/cm^2) of the whole arm, whole leg, the whole pelvis, the thorax and spine, and the total body were obtained using dual-energy X-ray absorptiometry (DEXA; Lunar Radiation, Madison, WI, USA; and Delphi W; Hologic, Boston, MA, USA). These devices were maintained using the standardised quality control procedures as recommended by the manufacturer to assure that the BMD calibration remained constant [(173)]. The coefficient of variation for the BMD measurements, based on reproducibility scans, was ≤ 1.0% [(174)]. The 'low BMD group' was defined as subjects with a T-score of -1.0 or less when the maximum BMD value for Asian (Japanese) populations aged ≥ 20 years was applied as a reference [(153)].

Body weight (kg) was measured with a digital scale to the nearest 0.1 kg with the participant in light clothing and wearing no shoes. Height (cm) was measured to the nearest 0.1 cm using a stadiometer, while the subject stood with heels together, legs straight, shoulders relaxed, and head positioned so that the gaze was straight ahead. Body mass index (BMI) was calculated as the weight divided by the height squared (kg/m^2).

A self-reported questionnaire was administered to acquire information regarding health behaviours (smoking, alcohol consumption, and physical activity), reproductive history for women, and medical history. Physical activity was assessed by questions about the frequency of exercise per week. To clarify incomplete or ambiguous responses, face-to-face interviews were performed.

Statistical analyses

Continuous data are expressed as the mean values and standard deviations, and categorical data are expressed as percentages. We tested the mean differences in selected characteristics between males and females using the General linear model, adjusting for age. The distribution differences of general variables were assessed using the chi-square test. Correlations between dietary patterns and BMD and nutrient intakes were calculated by partial Pearson correlations, including age, BMI, and energy intake as covariates.

A multi-variable adjusted logistic regression analysis was conducted to assess the odds ratios (ORs) and 95% confidence intervals (CIs) for the likelihood of having a low BMD across the quartile categories of each dietary pattern score, adjusting for covariates known to be associated with bone health. Trends of association were assessed by a logistic regression model by assigning scores to the levels of the independent variable.

The association between BMD and dietary pattern was evaluated using a mixed linear model in which each family unit and each twin unit were adjusted as random effects. Multi-variable adjusted associations were assessed with the inclusion of BMI, smoking, alcohol consumption, physical activity, and energy intake in the model as fixed effects. For women, the menopausal status was additionally included in the model as a fixed effect. All statistical analyses were performed using SAS software (version 9.3; SAS Institute Inc., Cary, NC, USA).

4-3. Results

The general characteristics and bone health status of study participants are summarised in Table 4-2. The mean ages were 47.2 and 45.9 years for men and women, respectively. Compared to women, men had a higher height, weight, waist circumference, BMI, and BMDs of all measured sites (all $p < .0001$). Men were more likely than women to smoke, drink alcohol, and do physical activity. The proportion of subjects with a low BMD was 30.2% in men and 30.7% in women. Among women, 34.8% were postmenopausal. Intake of energy, carbohydrates, and most vitamins and minerals in men were significantly higher than those in women (Table 4-3).

The factor loading scores, which reflect correlation coefficients between dietary pattern and food groups, are presented in Table 4-4. Four dietary patterns were identified by factor analysis and named according to the food groups that had high positive loadings: ‘Rice and kimchi’, ‘Egg, meat, and flour’, ‘Fruit, milk, and whole grain’, and ‘Fast food and soda’. The ‘Rice and kimchi’ dietary pattern was derived from a high consumption of white rice, kimchi, garlic and onion, fish and shellfish, legumes, and vegetables and mushrooms but a low consumption of bread and snacks. The ‘Egg, meat, and flour’ pattern was loaded heavily with oil and seasoning, eggs, processed meat, meat and poultry, noodles and dumplings, and bread and snacks. The ‘Fruit, milk, and whole grain’ pattern featured high positive loadings for fruits, potatoes, whole grain, dairy food, vegetables and mushrooms, and nuts but negative loadings for meat and poultry and noodles and dumplings. The ‘Fast food and soda’ pattern was characterised by high positive loadings for pizza and hamburgers, french fries, soda and coffee, and sweet fruit juice. These dietary patterns explained 31.1% of the total variance in food intake. The percentages of variation explained 10.0%, 8.4%, 7.1%, and 5.6% for the ‘Rice and kimchi’, ‘Egg, meat, and flour’, ‘Fruit, milk, and whole grain’, and ‘Fast food and soda’ dietary patterns, respectively.

Table 4-5 and table 4-6 present Pearson’s correlation coefficients between dietary pattern scores and measured BMD and nutrient intake with age, sex, and energy intake as covariates. The ‘Rice and kimchi’ pattern was significantly positively associated with the BMD of the whole arm and whole leg, and the ‘Egg, meat, and flour’ pattern was negatively associated with the BMD of the whole arm. The ‘Fruit, milk, and whole grain’ pattern showed a positive association with the BMDs of all measured sites. The ‘Rice and kimchi’ dietary pattern was positively associated with most nutrients except thiamine and riboflavin but negatively associated with fat. The ‘Egg, meat, and flour’ pattern was positively associated with energy, protein, fat, vitamin A, thiamine, riboflavin, vitamin B6, niacin, and vitamin E but negatively associated with carbohydrate, calcium, iron, fibre, potassium, vitamin C, and folate. The factor score for the ‘Fruit, milk, and whole grain’ pattern was positively associated with protein, calcium, iron, fibre, phosphorus, potassium, vitamin A, thiamine, riboflavin, vitamin B6, vitamin C, folate, and vitamin E, whereas it was negatively associated with fat and sodium. The ‘Fast food and soda’ dietary pattern was positively associated with energy, protein, fat, calcium, vitamin A, niacin, and vitamin E but negatively associated with carbohydrate and sodium.

Multivariate-adjusted ORs and CIs for having low BMD of the whole body across the four dietary patterns are presented in Table 4-7. The ‘Fruit, milk, and whole grain’ dietary pattern was inversely associated with the likelihood of having a low BMD. After adjustment for age, BMI, and energy intake, the risk of having a low BMD of the whole body was reduced by 64% in subjects in the highest quartile compared with those in the lowest quartile (OR: 0.36, 95% CI: 0.22-0.60, P for trend=0.0005) in men. This association persisted in model 2, which including terms for several additional confounders (smoking status, alcohol consumption, and physical activity) (OR: 0.37, 95% CI: 0.21-0.65, P for trend=0.0014). In women, compared with the lowest quartile of the ‘Fruit, milk, and whole grain’ dietary pattern, the highest quartile of this pattern was significantly associated with a decreased risk of having low BMD after adjustment for age, BMI, and energy intake (OR: 0.50, 95% CI: 0.33-0.77, P for trend=0.0022). This association remained significant after adjustment for possible confounding factors such as smoking status, alcohol consumption, physical activity, and menopausal status (OR: 0.45, 95% CI: 0.28-0.72, P for trend=0.0028). The other patterns (‘Rice and kimchi’, ‘Egg, meat, and flour’, and ‘Fast food and soda’) were not significantly associated with the risk of low BMD in men and women.

Table 4-8 shows the multivariable-adjusted associations between dietary pattern and BMD using a mixed linear model in which each family unit and each twin unit were adjusted as random effects. In men, the ‘Rice and kimchi’ pattern had a positive association with whole-arm BMD (β=0.008, 95% CI: 0.002-0.013), and the ‘Fruit, milk, and whole grain’ pattern had a positive association with the BMD of the whole leg (β=0.015, 95% CI: 0.008-0.022), whole pelvis (β=0.017, 95% CI: 0.008-0.022), lumbar spine (β=0.017, 95% CI: 0.006-0.028), and whole body (β=0.018, 95% CI: 0.008-0.027). In women, the BMD of the whole arm was positively associated with scores of the 'Rice and kimchi' dietary pattern (β=0.005, 95% CI: 0.001-0.009). Moreover, the BMDs of the whole arm (β=0.008, 95% CI: 0.004-0.012), whole leg (β=0.013, 95% CI: 0.006-0.019), and lumbar spine (β=0.008, 95% CI: 0.002-0.013) were shown to have a significantly positive association with scores of the 'Fruit, milk, and whole grain' dietary pattern.

Associations of BMD percentage at each site with dietary pattern score are presented in Table 4-9. The increment of 1 unit the 'Fruit, milk, and whole grain' dietary pattern score significantly increased percentage of whole arms by 1.84%, whole legs by 3.57%, pelvis by 3.57%, spine by 2.97%, and whole body by 4.63% in men, and of whole arms by 2.39%, whole legs by 3.18%, pelvis by 1.95%, spine by 1.51%, and whole body by 2.72% in women. The 'Rice and kimchi' dietary pattern score significantly increased BMD percentage of whole arms by 2.24% in men. The 'Fast food and soda' dietary pattern score significantly decrease BMD percentage of whole arms by -1.31%, pelvis by -1.53% and spine by -1.64% in women.

Associations of BMD at each site with the 5 selected dietary variables concerned with our dietary pattern are shown in Table 4-10. Intake of vegetable, fruits, whole grain, and dairy food in men and consumption of fish and shellfish, vegetable, fruits, whole grain, and dairy food in women were positively associated with BMD adjusting environmental confounders and potential genetic factors.

4-4. Discussion

We identified four distinct dietary patterns (Rice and kimchi; Egg, meat, and flour; Fruit, milk, and whole grain; Fast food and soda) among Korean adults using data from the Korean twin and family study and found that these dietary patterns were associated with BMD. An increased intake of the ‘Fruit, milk, and whole grain’ dietary pattern was associated with a decreased risk of having a low BMD. This association were similar in men and women and were sustained after adjusting for potentially confounding factors. The men and women with high scores on the ‘fruit, milk, and whole grain’ dietary pattern had 73% and 50% lower risk of having low BMD in whole body, respectively.

In our study, the four dietary patterns accounted for 31.1% of the total variance in food intake. Factor analysis is a common method of defining dietary patterns, and different dietary patterns have been found in various ethnic population groups. Despite the fact that the dietary pattern in the current study cannot be directly compared with those of other studies because of differences in the process of deriving them from factors, the dietary patterns in this study are similar to those reported previously (89,95,155,156). The ‘Fruit, milk, and whole grain’ pattern identified in this study is similar to dietary patterns derived from previous dietary pattern studies. In Scottish postmenopausal women (85) and Japanese premenopausal women (87), a ‘health diet’ pattern showing a high loading of fruit, vegetables, rice or pasta, fish, and dairy foods had a beneficial effect on bone health. In addition, our ‘Fruit, milk, and whole grain’ dietary pattern was similar to the Dietary Approaches to Stop Hypertension (DASH) diet characterised by a calcium-rich and low sodium diet that emphasises fruits, vegetables, nuts, and dairy products. Lin *et al*., reported that subjects who consumed the DASH diet showed significantly reduced bone turnover [175].

In this study, the 'Fruit, milk, and whole grain' dietary pattern score was significantly positively associated with calcium and dairy products such as milk, yogurt, and cheese. Calcium is a fundamental architectural component of bone and is important for the maintenance of bone health [3]. The positive effect of calcium supplementation on bone health has been well established [176,177]. Calcium supplementation of approximately 1,000 mg daily had a significant preventive effect on bone loss in postmenopausal women for at least 4 years [176]. A meta-analysis by Tang *et al*. supported the use of calcium, or calcium in combination with vitamin D supplementation, in the preventive treatment of osteoporosis in people aged 50 years or older [177]. In the NHANES III survey, a low recalled milk intake during childhood and adolescence was associated with significantly lower hip BMD and with a doubling of fracture risk among women 50 years of age and older [79]. In an intervention study, three servings per day of yogurt added to the diet of older women led to a significant reduction in the urinary excretion of N-telopeptide, reflecting reduced bone turnover compared with control subjects [178].

In addition, the 'Fruit, milk, and whole grain' dietary pattern included a variety of food types such as fruit, vegetables, mushrooms, potatoes, whole grains, and nuts. These foods contain nutrients that have a beneficial effect on bone health. The 'Fruit, milk, and whole grain' dietary pattern was significantly related with protein, iron, fibre, potassium, and various vitamins. A number of previous studies have demonstrated the positive effect of fruit and vegetables on bone health [179-181]. According to the acid-ash hypothesis, food components such as dietary protein produce acid loads that use the buffering capacity of bone through the release of alkaline salts to neutralise the acid load [182]. Fruit and vegetables may act on bone by providing base buffering of excess dietary metabolic acids, increasing osteoclast activity[183], and dropping the body pH to the physiological range in which bone resorption can increase[184]. In the Women's Health Initiative study, a low-fat and increased fruit, vegetable, and grain diet intervention modestly reduced the risk of multiple falls and slightly lowered hip BMD in postmenopausal women aged 50-79 years old [185]. Taken together, the 'Fruit, milk, and whole grain' dietary pattern of this study may have reduced the risk of having low BMD in our subjects. It is likely that the interactions and synergetic effects of various foods including fruit, vegetables, whole grains, and nuts are more effective and that the calcium in dairy food such as milk, yogurt, and cheese has a beneficial effect on BMD.

In addition, the 'Rice and kimchi' dietary pattern score significantly increased the BMD of the whole arm in men (0.008 g/cm^2/unit) and women (0.005 g/cm^2/unit). The increased BMD according to the 'Rice and kimchi' dietary pattern score may be explained by eating foods such as vegetables, soy products, and fish and shellfish that provide adequate protein, vitamins, and minerals.

The current study has several strengths. This is the first Asian twin and family study identifying an association between dietary pattern and whole-body BMD. We also controlled for potential covariates in our multivariate model. One of the strengths of the current study is the dietary assessment method used. Whereas most population studies of dietary patterns have used an FFQ, we assessed the patterns using 3-day food records, which provide detailed and accurate information regarding the types of foods and beverages consumed. This technique is often regarded as the 'gold standard' against which other dietary assessment methods are validated [186]. Additionally, we used factor analysis to assess overall dietary patterns, and these methods can contribute to identifying the features of complex diets and the large variety of dietary components that may affect bone health.

In summary, we identified four dietary patterns in participants of the Korean twin and family study. The 'Fruit, milk, and whole grain' dietary pattern characterised by a high consumption of fruit, vegetables, dairy products, whole grains, and nuts and a low consumption of meat and flour-based foods was positively associated with a reduced risk of having a low BMD and of having an increased BMD at most measured bone sites. This study provides evidence that will contribute to potential dietary pattern-based strategies for improving bone health. A good-quality diet with high intakes of dairy products, fruits, vegetables, mushrooms, whole grains, and nuts may contribute to improved bone health.

Table 4-1. Food groups and items from the 3-day food records of subjects

Food or food group	Food items
White rice	White rice
Kimchi	Kimchi (cabbage, mustard leaves, young leafy radish, small radish, cubed radish roots), salted radish in rice bran, cucumber pickle
Garlic and onion	Onion, garlic, scallion
Fish and shellfish	Squid, octopus, anchovy, shrimp, crab, scallop, oyster, granulated ark shell, hard clam, little-neck clam, abalone, pen shell, ark shell, mussel, flatfish, hair tail, mackerel, pacific saury, bastard halibut, common sea bass, pacific cod, tuna, sea bream, Alaska pollack, harvest fish, Spanish mackerel, common mullet, angler, salmon, eel, yellow croaker
Soy product	Kidney beans, soybeans, green peas, red beans, soybean curd, soybean milk, Soybean sauce, soybean paste
Vegetable and mushroom	bracken, mung bean sprouts, lotus root, burdock, soybean sprouts, red pepper, carrot, garlic, radish, water dropwort, cabbage, Chinese chives, broccoli, lettuce, celery, spinach, cucumber, tomato, paprika, pumpkin, mushrooms
Oils and seasonings	Oils, butter, margarine, cream, mustard, mayonnaise, ketchup, salt, vinegar, condiment, dressing, pepper, hot sauce, curry sauce
Eggs	Egg, quail's egg, duck egg
Processed meat	Pork cutlet, meatball, luncheon meat, ham, bacon, sausage
Meat and poultry	Pork, beef, chicken, duck, turkey
Flour-based food	Noodle, ramen, dumpling
Bread and snacks	Rolls, doughnuts, muffins, waffles, castella, croissants, croquettes, pastries, loaf bread, pie, biscuits, nachos, snacks, cookies, crackers
Fruits	Lychee, persimmon, tangerine, strawberry, lemon, mango, apricot, melon, fig, banana, pear, cherry, peach, blueberry, apple, raspberry, pomegranate, water melon, avocado, mulberry, orange, olive, citron, plum, grape, kiwi, pineapple
Potatoes	Potato, sweet potato, taro
Whole grain	Oats, millet, buckwheat, wheat, barley, sorghum, maize, brown rice
Milk, yogurt, and cheese	Milk, yogurt, cheese
Nuts	Peanut, chestnut, almond, pine nut, ginkgo nut, walnut, sesame, perilla seeds, sunflower seeds, pumpkin seeds
Alcohol	Rice wine, beer, soju(Korean distilled spirits), whiskey, wine
Pizza and hamburger	Pizza, hamburger, sandwich
French fries	Mashed potatoes, hash browns, french fries
Soda and coffee	Soda, coffee, cocoa
Sweet fruit juice	Sweet fruit juices

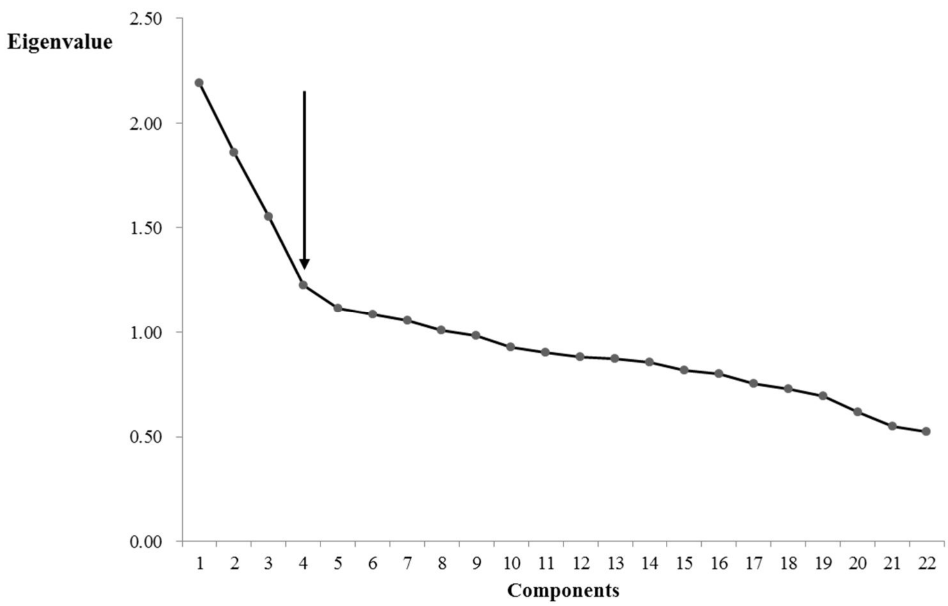

Figure 4-1. Scree plot showing eigenvalue explained by each component. ↓, indicates the cut-off point for dietary patterns.

Table 4-2. General characteristics of the study subjects.

	Men (n=716)		Women (n=1102)		All (n=1818)		*P-value*
Age (years)	47.2	12.8	45.9	11.9	46.4	12.3	0.0232
Height (cm)	169.0	6.1	156.8	5.8	161.6	8.4	<.0001
Weight (kg)	70.5	10.1	57.6	8.8	62.7	11.2	<.0001
Waist circumference (cm)	85.5	7.8	78.6	8.9	81.3	9.1	<.0001
BMI (kg/m^2)	24.6	2.9	23.4	3.4	23.9	3.2	<.0001
BMD (g/cm2)							
Whole arm	1.011	4.454	0.804	3.535	0.885	3.923	<.0001
Whole leg	1.255	0.119	1.081	0.121	1.149	0.147	<.0001
Whole pelvis	1.139	0.148	1.076	0.142	1.101	0.148	<.0001
Lumbar spine	0.991	0.161	0.941	0.164	0.960	0.164	<.0001
Whole body	1.167	0.160	1.079	0.153	1.113	0.161	<.0001
Prevalence of low BMD at whole body (%)	30.2		30.7		30.1		0.8196
Postmenopausal women (%)	-		34.8				
Smoking habit							
Never (%)	28.3		91.6		68.1		<.0001
Ex-smoker (%)	36.3		3.7		15.8		
Current smoker (%)	35.4		4.7		16.1		
Drinking habit (%)							
Never	13.0		39.8		29.3		<.0001
< 4 times per month	8.8		9.4		9.1		
≥ 3times per week	78.2		50.8		61.6		
Physical exercise (%)							
≤ 2/week	57.4		66.4		62.9		0.0001
≥ 3/week	42.6		33.6		37.1		
Education level (%)							
≤ Junior high school	19.3		27.1		24.0		<.0001
≤ High school	29.7		35.0		32.9		
≥ College	51.0		37.9		43.1		

Values are expressed as the mean SD. All other values are presented as %.

Table 4-3. Nutrients intake of the study subjects.

	Men (n=716)		Women (n=1102)		All (n=1818)		*P-value*
	mean	SD	mean	SD	mean	SD	
Energy (kcal)	1771.9	495.9	1501.1	472.9	1607.8	499.8	<.0001
Carbohydrate (g)	257.9	72.5	233.6	76.7	243.2	76.0	<.0001
Protein (g)	68.6	23.4	58.1	22.7	62.2	23.5	0.5206
Fat (g)	43.7	20.5	36.8	17.7	39.5	19.1	0.478
Calcium (mg)	476.2	202.2	440.4	208.4	454.5	206.7	0.0003
Iron (mg)	13.2	5.5	11.8	5.6	12.4	5.6	0.0067
Fiber (g)	18.9	6.8	18.2	8.0	18.4	7.5	<.0001
Phosphorus (mg)	962.6	311.2	847.2	314.1	892.6	317.9	0.001
Sodium (mg)	4178.4	1459.4	3382.8	1242.7	3696.1	1387.4	<.0001
Potassium (mg)	2453.2	799.6	2327.1	879.5	2376.7	851.0	<.0001
Zinc (mg)	8.6	4.6	7.2	3.3	7.7	3.9	0.0988
Vitamin A (μg RE)	625.0	375.0	562.7	389.3	587.2	384.8	0.1103
Thiamin (mg)	1.2	0.5	1.0	0.5	1.1	0.5	0.0047
Riboflavin (mg)	1.1	0.6	1.0	0.8	1.0	0.7	0.0356
Vitamin B6 (mg)	1.9	0.7	1.8	0.8	1.8	0.8	<.0001
Niacin (mg)	15.7	5.8	13.1	5.0	14.1	5.5	0.0412
Vitamin C (mg)	86.1	60.1	96.4	79.0	92.3	72.3	<.0001
Folate (μgDFE)	218.3	88.0	208.6	93.1	212.4	91.2	<.0001
Vitamin E (mg α-TE)	11.7	6.2	10.8	5.4	11.1	5.7	<.0001
Cholesterol (mg)	268.4	165.2	222.3	135.5	240.5	149.6	0.2259

Values are expressed as the means SD

Table 4-4. Factor loading* matrix of food groups for major factors in subjects of the twin and family study

	Dietary patterns			
	Factor 1	Factor 2	Factor 3	Factor 4
Food or food groups	Rice and kimchi	Egg, meat, and flour	Fruit, milk, and whole grain	Fast food and soda
White rice	0.35			
Kimchi	0.32			
Garlic and onion	0.24			
Fish and shellfish	0.26			
Soy product	0.22			
Vegetable and mushroom	0.20		0.24	
Oils and seasonings		0.31		
Eggs		0.34		
Processed meat		0.29		
Meat & poultry		0.20	-0.20	
Flour-based food		0.25	-0.20	
Bread and snacks	-0.20	0.25		
Fruits			0.31	
Potatoes			0.28	
Whole grains			0.27	
Milk, yogurt, and cheese			0.26	
Nuts			0.22	
Alcohol			-0.25	
Pizza and hamburger				0.48
French fries				0.48
Soda and coffee				0.34
Sweet fruit juice				0.22
Variance of intake explained (%)	10.0	8.4	7.1	5.6

* Factor loading scores of -0.20 and +0.20 are not shown.

Table 4-5. Correlation coefficients† among four dietary pattern scores and BMD.

	Rice and kimchi	Egg, meat, and flour	Fruit, milk, and whole grain	Fast food and soda
Men				
Whole arm	0.140***	0.024	0.098***	-0.055
Whole leg	0.098***	0.047	0.175***	0.014
Whole pelvis	0.065	-0.010	0.151***	-0.020
Lumbar spine	0.082*	-0.009	0.135***	0.020
Whole body	0.033	0.069	0.167***	-0.015
Women				
Whole arm	0.045	-0.063*	0.109***	-0.017
Whole leg	0.033	-0.021	0.127***	0.034
Whole pelvis	0.014	0.012	0.067*	-0.020
Lumbar spine	-0.007	-0.020	0.068*	-0.020
Whole body	0.000	0.025	0.065*	0.070*

† Partial Pearson's correlation, including age, BMI, and energy intake as covariates.

* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Table 4-6. Correlation coefficients† among four dietary pattern scores and nutrients

	Rice and kimchi	Egg, meat, and flours	Fruit, milk, and whole grain	Fast food and soda
Energy (kcal)	0.231***	0.519***	-0.014	0.148***
Carbohydrate (g)	0.181***	-0.313***	0.011	-0.120***
Protein (g)	0.257***	0.074**	0.403***	0.255***
Fat (g)	-0.173***	0.404***	-0.108***	0.190***
Calcium (mg)	0.130***	-0.055**	0.422***	0.068***
Iron (mg)	0.175***	-0.056**	0.196***	0.030
Fiber (g)	0.260***	-0.159***	0.523***	-0.045
Phosphorus (mg)	0.244***	0.037	0.365***	0.031
Sodium (mg)	0.446***	0.026	-0.170***	-0.117***
Potassium (mg)	0.297***	-0.110***	0.607***	0.038
Zinc (mg)	0.160***	-0.003	0.028	0.024
Vitamin A (μgRE)	0.253***	0.068**	0.193***	0.051*
Thiamin (mg)	-0.018	0.048*	0.153***	0.039
Riboflavin (mg)	-0.030	0.103***	0.149***	0.011
Vitamin B6 (mg)	0.157***	0.083***	0.350***	0.005
Niacin (mg)	0.333***	0.058**	-0.005	0.082**
Vitamin C (mg)	0.141***	-0.130***	0.444***	0.089***
Folate (μgDFE)	0.183***	-0.063**	0.449***	0.034
Vitamin E (mg α-TE)	0.092***	0.273***	0.269***	0.029

† Partial Pearson's correlation, including age, sex, BMI, and energy intake (excluding energy variables) as covariates.

* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Table 4-7. Multivariate ORs and 95% CIs for likelihood of having low BMD across quintile categories of dietary pattern scores in subjects of the twin and family study

	Q1	Q2		Q3		Q4		p for trend
		OR	(95%CI)	OR	(95%CI)	OR	(95%CI)	
Men								
Factor1: Rice and kimchi								
model1*	1(ref)	0.97	(0.60, 1.58)	1.30	(0.81, 2.10)	0.75	(0.46, 1.24)	0.4008
model2†	1	1.07	(0.62, 1.85)	1.30	(0.76, 2.22)	0.65	(0.37, 1.15)	0.2167
Factor2: Egg, meat, and flour								
model1*	1	0.69	(0.42, 1.11)	0.90	(0.56, 1.46)	0.60	(0.35, 1.01)	0.9647
model2†	1	0.78	(0.45, 1.34)	0.91	(0.53, 1.58)	0.63	(0.35, 1.13)	0.7542
Factor3: Fruit, milk, and whole grain								
model1*	1	0.91	(0.58, 1.45)	0.69	(0.43, 1.11)	0.36	(0.22, 0.60)	0.0005
model2†	1	0.83	(0.49, 1.40)	0.73	(0.43, 1.24)	0.37	(0.21, 0.65)	0.0014
Factor4: Fast food and soda								
model1*	1	0.86	(0.52, 1.40)	1.22	(0.75, 1.99)	1.50	(0.92, 2.44)	0.7422
model2†	1	0.94	(0.54, 1.64)	1.29	(0.74, 2.26)	1.57	(0.91, 2.71)	0.4793
Women								
Factor1: Rice and kimchi								
model1*	1	0.98	(0.64, 1.48)	1.09	(0.73, 1.63)	0.98	(0.65, 1.49)	0.7424
model2†	1	0.88	(0.56, 1.37)	1.09	(0.70, 1.69)	1.09	(0.70, 1.72)	0.7736
Factor2: Egg, meat, and flour								
model1*	1	1.12	(0.75, 1.67)	0.83	(0.54, 1.28)	0.98	(0.62, 1.52)	0.7437
model2†	1	1.12	(0.73, 1.73)	0.84	(0.53, 1.34)	0.99	(0.61, 1.60)	0.8559
Factor3: Fruit, milk, and whole grain								
model1*	1	0.75	(0.50, 1.12)	0.92	(0.62, 1.37)	0.50	(0.33, 0.77)	0.0022
model2†	1	0.62	(0.40, 0.95)	0.83	(0.54, 1.27)	0.45	(0.28, 0.72)	0.0028
Factor4: Fast food and soda								
model1*	1	0.80	(0.54, 1.20)	0.75	(0.49, 1.14)	0.79	(0.51, 1.22)	0.3735
model2†	1	0.75	(0.49, 1.16)	0.79	(0.50, 1.23)	0.79	(0.49, 1.25)	0.4300

* Model 1 adjusted for age, BMI, and energy intake.

† Model 2 adjusted as Model 1 + age, BMI, energy intake, smoking, alcohol consumption, and physical activity. For women, the menopausal status was also adjusted.

Table 4-8. Multivariable-adjusted associations between dietary patterns and BMD.

	Rice and kimchi		Egg, meat, and flour		Fruit, milk, and whole grain		Fast food and soda	
	β*	(95%CI for β)	β	(95%CI for β)	β	(95%CI for β)	β	(95%CI for β)
Men								
Whole arm	0.008	(0.002, 0.013)	0.002	(-0.004, 0.008)	0.006	(0.000, 0.012)	-0.003	(-0.009, 0.002)
Whole leg	0.005	(-0.002, 0.012)	0.004	(-0.003, 0.012)	0.015	(0.008, 0.022)	-0.001	(-0.008, 0.006)
Whole pelvis	0.006	(-0.003, 0.015)	0.001	(-0.008, 0.011)	0.017	(0.008, 0.026)	-0.004	(-0.013, 0.005)
Lumbar spine	0.009	(-0.002, 0.019)	0.001	(-0.010, 0.012)	0.017	(0.006, 0.028)	0.001	(-0.009, 0.012)
Whole body	0.003	(-0.006, 0.013)	0.006	(-0.004, 0.016)	0.018	(0.008, 0.027)	-0.003	(-0.012, 0.007)
Women								
Whole arm	0.005	(0.001, 0.009)	-0.003	(-0.007, 0.002)	0.008	(0.004, 0.012)	-0.002	(-0.006, 0.002)
Whole leg	0.004	(-0.002, 0.011)	-0.002	(-0.009, 0.005)	0.013	(0.006, 0.019)	0.001	(-0.005, 0.008)
Whole pelvis	0.003	(-0.004, 0.010)	0.001	(-0.007, 0.008)	0.006	(-0.001, 0.013)	-0.006	(-0.013, 0.001)
Lumbar spine	-0.002	(-0.011, 0.007)	-0.005	(-0.014, 0.005)	0.008	(0.000, 0.017)	-0.008	(-0.017, 0.001)
Whole body	0.001	(-0.007, 0.009)	0.003	(-0.005, 0.012)	0.007	(0.000, 0.015)	0.005	(-0.003, 0.012)

* β (95% CI) was estimated by using a linear mixed model in which random effects (family structure) and fixed effects (age, BMI, energy intake, smoking, alcohol consumption, and physical activity) were adjusted for. For women, the menopausal status was adjusted as a fixed effect.

Table 4-9. Multivariable-adjusted associations between dietary patterns' score and percentage of BMD.

	Rice and kimchi		Egg, meat, and flour		Fruit, milk, and whole grain		Fast food and soda	
	β*	(95%CI for β)	β	(95%CI for β)	β	(95%CI for β)	β	(95%CI for β)
Men								
Whole arm	2.24	(0.42, 4.06)	0.16	(-1.73, 2.04)	1.84	(0.01, 3.67)	-1.54	(-3.33, 0.25)
Whole leg	0.80	(-0.98, 2.58)	0.98	(-0.86, 2.82)	3.57	(1.78, 5.35)	-0.02	(-1.77, 1.73)
Whole pelvis	1.45	(-0.32, 3.23)	0.42	(-1.42, 2.26)	3.57	(1.76, 5.38)	-0.52	(-2.28, 1.24)
Lumbar spine	1.39	(-0.47, 3.26)	0.01	(-1.92, 1.94)	2.97	(1.10, 4.84)	-0.53	(-2.36, 1.31)
Whole body	0.53	(-1.25, 2.32)	0.81	(-1.04, 2.66)	4.63	(2.83, 6.43)	-0.05	(-1.81, 1.71)
Women								
Whole arm	1.16	(-0.20, 2.53)	-1.41	(-2.85, 0.04)	2.39	(1.12, 3.67)	-1.31	(-2.62, -0.01)
Whole leg	0.56	(-0.87, 2.00)	-0.70	(-2.21, 0.81)	3.18	(1.84, 4.51)	-0.14	(-1.50, 1.23)
Whole pelvis	0.24	(-1.26, 1.75)	0.00	(-1.56, 1.56)	1.95	(0.55, 3.34)	-1.53	(-2.96, -0.10)
Lumbar spine	-0.16	(-1.66, 1.34)	-0.65	(-2.22, 0.92)	1.51	(0.11, 2.91)	-1.64	(-3.07, -0.21)
Whole body	0.33	(-1.09, 1.74)	0.24	(-1.25, 1.74)	2.72	(1.40, 4.04)	-0.27	(-1.62, 1.09)

* β (95% CI) was estimated by using a linear mixed model in which random effects (family structure) and fixed effects (age, BMI, energy intake, smoking, alcohol consumption, and physical activity) were adjusted for. For women, the menopausal status was adjusted as a fixed effect.

Table 4-10. Multivariable-adjusted associations between food groups and BMD.

	Fish and shellfish(35g)		Vegetables(35g)		Fruits(50g)		Whole grain(20g)		Dairy food(100g)	
	β*	95%CI for β	β	95%CI for β	β	95%CI for β	β	95%CI for β	β	95%CI for β
Men										
Whole arm	0.0007	(-0.0004, 0.0018)	0.0013	(-0.0004, 0.0030)	-0.0003	(-0.0008, 0.0002)	0.0001	(-0.0021, 0.0022)	0.0022	(-0.0005, 0.0049)
Whole leg	-0.0006	(-0.0020, 0.0009)	0.0020	(-0.0002, 0.0042)	0.0002	(-0.0004, 0.0008)	-0.0001	(-0.0029, 0.0027)	0.0055	(0.0020, 0.0090)
Whole pelvis	-0.0001	(-0.0019, 0.0017)	0.0010	(-0.0017, 0.0038)	0.0023	(0.0015, 0.0030)	-0.0010	(-0.0044, 0.0024)	0.0029	(-0.0014, 0.0073)
Lumbar spine	0.0010	(-0.0011, 0.0031)	0.0039	(0.0007, 0.0071)	0.0013	(0.0004, 0.0022)	-0.0012	(-0.0052, 0.0029)	0.0043	(0.0002, 0.0105)
Whole body	-0.0012	(-0.0031, 0.0007)	0.0009	(-0.0020, 0.0038)	0.0021	(0.0013, 0.0029)	0.0028	(0.0007, 0.0064)	0.0033	(0.0007, 0.0078)
Women										
Whole arm	0.0011	(0.0001, 0.0021)	0.0004	(-0.0004, 0.0011)	0.0001	(-0.0002, 0.0003)	0.0003	(-0.0006, 0.0012)	0.0037	(0.0021, 0.0053)
Whole leg	0.0009	(-0.0007, 0.0024)	0.0009	(-0.0002, 0.0021)	0.0021	(0.0017, 0.0025)	0.0009	(-0.0005, 0.0022)	0.0029	(0.0005, 0.0054)
Whole pelvis	0.0020	(0.0003, 0.0037)	0.0006	(-0.0007, 0.0018)	0.0000	(-0.0004, 0.0005)	0.0008	(-0.0007, 0.0023)	0.0035	(0.0008, 0.0062)
Lumbar spine	0.0025	(0.0004, 0.0047)	-0.0001	(-0.0017, 0.0015)	0.0017	(0.0012, 0.0023)	-0.0009	(-0.0028, 0.0010)	0.0032	(-0.0002, 0.0066)
Whole body	0.0005	(-0.0014, 0.0023)	0.0033	(0.0019, 0.0047)	0.0020	(0.0015, 0.0025)	0.0019	(0.0005, 0.0038)	0.0062	(0.0032, 0.0091)

*β (95% CI) was estimated by using a linear mixed model in which random effects (family structure) and fixed effects (age, BMI, energy intake, smoking, alcohol consumption, and physical activity) were adjusted for. For women, the menopausal status was adjusted as a fixed effect

Chapter 5. Overall discussion and conclusion

This study was conducted to identify prevalent dietary pattern using factor analysis in Korean population and to examine whether these dietary pattern were associated with bone health. We ascertained distinct dietary pattern in three different age groups. In Korean adolescent aged 12-15 years, four distinct dietary patterns - traditional Korean, fast food, milk and cereal, and snacks – were identified and accounted for 28.4% of the total variance in total food intake. Four dietary patterns – 'Meat, alcohol, and sugar', 'Vegetables and soy sauce', 'White rice, kimchi, and seaweed', and 'Dairy and fruit' - were identified and accounted for 30.9% of the variance in total food intake in Korean menopausal women from the KNHANES. 'Rice and kimchi', 'Egg, meat, and flours', 'Fruit, milk, and whole grain', and 'Fast food and soda' were identified among Korean adults of the Healthy Twin Study, and these patterns were account for 31.1% of the variance in total food intake.

Whereas dietary patterns from three studies have similar characteristics, dietary patterns deriving from each population have own distinct characteristics. Traditional Korean in adolescent, 'White rice, kimchi, and seaweed' in postmenopausal women, and 'Rice and kimchi' in adults were characterized by high positive white rice, kimchi, and fish and shellfish, and these patterns shows nature of a typical Korean diet. 'Milk and cereal', 'Dairy and fruit', and 'Fruit, milk, and whole grain' dietary pattern have something in common with high consumption of dairy products, and have positive coefficients with calcium.

In this study, 'Milk and cereal', 'Dairy and fruit', and 'Fruit, milk, and whole grain' dietary pattern were positively associated with bone health. Adolescents with high scores of the ‘Milk and cereal’ dietary pattern had a 64% reduction in the likelihood of having low BMD at the lumbar spine and postmenopausal women with high scores on the ‘Dairy and fruit’ pattern had a 53% lower risk of osteoporosis in the lumbar spine after adjusting for potentially confounding factors. In addition, after adjusting for potentially confounding factors the men and women with high score on ‘Fruit, milk, and whole grain’ dietary pattern had 73% and 50% lower risk of having low BMD in whole body, respectively.

For exploring dietary pattern, two different approaches, namely *a posteriori* and *a priori*, have been used [(93)]. *A posteriori* method, such as factor analysis and cluster analysis, is statistical exploratory post hoc techniques that use information from dietary records to aggregate variables into factors representing common underlying patterns of food consumption within a population [(187)]. *A priori* methods such as the healthy eating index and Mediterranean diet score explores data using pre-defined diet quality scores, generally based on existing knowledge about what constitutes a healthy diet [(188)]. Factor analysis used in current study is the most common method to derive dietary patterns and has the advantage of resulting in the creation of a continuous variable, which can result in increased power to detect diet-disease relationship. This approach describes the patterns of eating that actually exist in the population rather than depending on our a priori conceptions of diet-disease relationships. It can provide useful insights into existing eating behaviours and targets for dietary intervention.

Although the principle components method used current study itself has limitations that stem from several subjective or arbitrary decisions that investigators must make, this study attempted to replicate dietary patterns reported in other previous studies by using similar steps in the subjective decision making process. The dietary patterns in the first study were similar to patterns in previous studies. Li *et al.,* [112] identified four dietary patterns in Korean adolescents: 'Rice and kimchi' (white rice, kimchi, vegetables, and garlic), 'Shellfish and processed meat' (shellfish, processed meat, and bread), 'Pizza and drinks' (carbohydrate-rich drinks, hamburgers, fruit, and cookies), and 'Milk and cereal' (milk and dairy products, cereal, and fish). Other studies carried out in Korean adolescents reported a 'Traditional' pattern, with high consumption of rice, kimchi, and vegetables, and a 'Western' pattern, with high intake of pizza, hamburgers, meat, and soft drinks [94,124], which are similar to dietary patterns (Korean traditional and fast food, respectively) identified in our study.

The 'Dairy and fruit' dietary pattern identified in second study is similar to the 'Healthy' dietary pattern obtained from elderly adults 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 [85,92]. Additionally, both the 'Dairy and fruit' dietary pattern in this study and 'Healthy diet' pattern in previous studies had high loadings of milk and dairy foods, which are calcium-rich [85,92]. The 'White rice, kimchi, and seaweed' and 'Vegetables and soy sauce' dietary patterns identified in second study were similar to the traditional rice-based Korean dietary pattern that has been reported previously. The 'Fruit, milk, and whole grain' pattern in third study was similar to dietary patterns derived from previous dietary pattern studies. In Scottish postmenopausal women[85] and Japanese premenopausal women [87], ‘Health diet’ pattern, showed high loading fruit, vegetables, rice or pasta, fish, and dairy foods, had beneficial effect on bone health. In addition, ‘Fruit, milk, and whole grain’ dietary pattern was similar to the Dietary Approaches to Stop Hypertension (DASH) diet characterized by a calcium-rich and low sodium diet that emphasizes fruits, vegetables, nuts and dairy products. Even though we observed similar dietary pattern in previous studies, it should be noted that the results of dietary pattern analysis depend on the population and may differ according to the geographic area, race, and culture of the population [87]. Therefore, the results should be interpreted with caution. Food guide for Korean recommends how many food guide servings people should eat from each of the six food group (‘Grains’, ‘Meat, Fish, Eggs, and Beans’, ‘Vegetables’, ‘Fruits’, ‘Milk and Dairy products’, and ‘Oils, Fat, and Sugar’). The recommended number of food guide servings is different for people at different stages of life and is different for males and females. The adults in the highest group of ‘Dairy and fruit’ and postmenopausal women in the highest group of ‘Fruit, milk, and whole grain’ tended to have adequate intake of vegetables, fruits, and milk and dairy products food group. Although the intake of milk and dairy products of adolescents in highest tertile of ‘Milk and dairy’ pattern was below the level of recommended servings, higher than those of adolescents in other tertiles.

Calcium is a fundamental architectural component of bone and important factor for maintenance of bone health. In addition, because at least 90% of the peak bone mass (PBM) is attained by the age of 18 years, sufficient calcium intake during adolescence is essential to attain the maximal PBM, which protects against osteoporosis and fragility fracture in later life. The positive effect of calcium supplementation on bone health has been well established [176,177]. Calcium supplementation of about 1,000 mg daily had a significant preventive effect on bone loss in postmenopausal women for at least 4 years [176]. A meta-analysis by Tang *et al.*, supported that the use of calcium, or calcium in combination with vitamin D supplementation, in the preventive treatment of osteoporosis in people aged 50 years or older [177]. Calcium-rich foods such as milk, yogurt, and cheese are essential to bone health, and calcium is important factor for the normal development of the skeleton during growth and the maintenance of bone mass in later life [189]. Calcium intake recommendation in Korea currently rage from 500 mg/d for children through 1 years of age, to 1000 mg/d for adolescents 12-14 years of age, with 700 to 900 mg/d for most adults. The dietary reference intake of calcium for Korean are established by considering the characteristics of age and gender and applying the results from balance studies and factorial methods. The EAR for adults is established considering the reference weight and absorption rate from the balance between calcium loss and calcium intake reported in 2007. For children and adolescents in the growth spurt phase, the EAR is calculated by factorial method with an emphasis on calcium reserve in the body to reach the average skeletal growth of the population, while for elderly people the requirement is calculated for the purpose of preventing decrease in bone mass and osteoporosis [190]. However, calcium intake among Korean is typically low because dairy foods are not popular and are rarely consumed in Korea. The KNHANES survey reported a mean calcium intake of 528.4

mg/d among 13-19 years adolescents (55.4% of the Recommended Intake, RI) and 506.8 mg/d among 50-64 years women (72.4% of RI). Thus, increased intake of calcium-rich foods may enhance the accumulation of bone mass in Korean adolescents and decrease the loss of bone in Korean adult.

In addition, 'Dairy and fruit' and 'Fruit, milk, and whole grain' dietary pattern included a variety of food type such as fruit, vegetable, mushroom, potatoes, whole grain, and nuts. These foods contain nutrients that are beneficial effect on bone health. The 'Dairy and fruit' and 'Fruit, milk, and whole grain' dietary pattern were significantly related with protein, iron, fiber, potassium, and various vitamins as well as calcium. A number of previous studies have demonstrated positive effect of fruit and vegetables on bone health [(179-181)]. Fruit and vegetables are good sources of vitamin C, vitamin K, fibre, flavonoid, and phytoestrogens [(85)]. In the Women's Health Initiative study, a low-fat and increased fruit, vegetables, and grain diet intervention modestly reduced the risk of multiple falls and slightly lowered hip BMD in postmenopausal women aged 50-79 years old [(185)]. Macdonald *et al.* [(81)] found that calcium and several nutrients found in fruit and vegetables (potassium, vitamin C, magnesium) 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 magnesium and potassium were positively associated with the BMD of elderly men and women in the Framingham Osteoporosis Study [(66)].

We conducted additional analysis to identify the sole effect of single nutrient and food intake on bone health. In adolescents of first study, the ORs for low BMD according to tertiles of the milk (P for trend = 0.0692 at lumbar spine and 0.0715 at femur) and calcium intake (P for trend = 0.0765 at lumbar spine and 0.0975 at femur) were not significantly decreased. In postmenopausal women of second study, we analysed the effect of nine selected dietary components (calcium, potassium, sodium, white rice, kimchi, fish and shellfish, vegetables, milk, and fruit) on the risk of osteoporosis. Milk intakes had significant association with bone health; higher milk intake (more than one serving size, 200g per day) were associated with decreased likelihood of osteoporosis of the lumbar spine (OR 0.59, 95% CI 0.43-0.81, p for trend = 0.0028). Also, subjects in the highest quintile of calcium intake showed a decrease risk of osteoporosis of the lumbar spine (OR 0.71, 95% CI 0.51-0.98, p for trend = 0.0590). On the other hand, the ORs for the risk of osteoporosis according to quintile of white risk consumption were significantly increased in lumbar spine (p for trend = 0.0066). In third study, the sole effect of single nutrient and food group concerned with dietary patterns were not significantly associated with the risk of having likelihood of low BMD in both of men and women except sodium. The reason why dietary patterns had a significant effect on bone health, while single nutrient and food intake was not associated with bone health, may be complex and potentially involves a synergic effect from the mixture of foods that contain other beneficial nutrients as well as calcium for bone health. Additionally, the effects of these combinations on the bone health reflect whole diet patterns, which may be driven by a mixture of social, cultural, environmental, health, economic and lifestyle factors.

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 [164] and this transition is occurring more rapidly in children and adolescents than in adults. However, most adolescents and adults still consume rice-based diets with low dairy food and calcium contents [94], which may negatively affect bone health. Our study shows that the subjects in the highest group of beneficial dietary patterns ('Milk and cereal', 'Dairy and fruit', 'Fruit, milk, and whole grain') of bone health tended to eat higher dairy food consumption compared subjects in the lowest group. In first study, the milk intake (233.5 ± 265.6 g) of the adolescents in the highest tertile (T3) of the 'Milk and cereal' pattern was significantly higher compared with that (81.0 ± 124.5 g) of subjects in other tertile (T1-2) (P < .0001). In second study, the milk consumption (178.7 ± 184.9 g/d) of the postmenopausal women in the highest quintile (Q5) of the 'Dairy and fruit' dietary pattern was significantly higher than that (23.9± 64.9 g/d) of subjects in the other quintiles (Q1-4) (P< .0001). In third study, the women in the highest quartile (Q4) of 'Fruit, milk, and whole grain' pattern shows higher dairy intake (209.3 ± 292.6 g/d) compared with those (170.9 ± 228.7 g/d) in the other quartile (Q1-3) (P=0.0484), but in men had no significant. Furthermore, in second the subjects in the highest quintile (Q5) of 'Dairy and fruit' had tendency to eat more legume, vegetable, fruits, eggs, fish and shellfish, seaweed, and milk and dairy food than other quintile (Q1-4). In third study, the consumptions of vegetable and mushroom, fruits, whole grain, and dairy food of women in the highest quartile (Q4) of 'Fruit, milk, and whole grain' pattern were higher than those of women in the other quartile (Q1-3).

Among men, intakes of fruits and nuts in the highest quartile (Q4) of 'Fruit, milk, and whole grain' pattern were higher than those in the other quartile (Q1-3) (data not shown).

In this study, dietary patterns only had influence on the lumbar spine, not the femur. 'Milk and cereal' dietary pattern was associated with a decreased likelihood of having low BMD of the lumbar spine in Korean adolescents. 'Dairy and fruit' pattern reduced and 'White rice, kimchi, and seaweed' pattern increased the risk of osteoporosis of the lumbar spine in Korean postmenopausal women. These results may be attributed to the variable proportions of cancellous and cortical bone at the different bone site. Cancellous bone has an accelerated metabolism and therefore a more rapid and earlier loss than cortical bone [(191)]. Lumbar spine consist primarily of cancellous and trabecular bone, while the femur contains more cortical bone, which has a lower metabolic rate than cancellous and trabecular bone [(192)]. Another explanation is that weight-bearing can cause rise in bone density especially in the hip and femur regions [(193)] and lean body mass may protect against bone loss in the femur, which must bear greater mechanical loads and stresses than the axial spine through muscular contraction [(194)]. This may explain why dietary pattern had only effect on the lumbar spine, which is susceptible by external factors such as nutrition, hormone, and medication.

Low bone mineral density is a crucial predisposing factor of osteoporosis and increased the risk of osteoporotic fractures. In addition, the prevalence of osteoporosis has increased in Korea as population aging. To prevent osteoporosis, public health strategies focus on modifiable environmental factors that promote PBM in adolescent and minimize the rate of bine loss in later life [91]. Current research on diet and health tends to focus on more on dietary patterns rather than on single components and nutrients because of the complex relation between diet and diet-related diseases as reflected by food-based dietary guidelines.

Our dietary pattern analysis identified the complex nature of age- and culture-specific dietary behaviours and their associations with bone health in Korean population. This study provides evidence that will contribute to potential dietary patterns-based strategies for improving bone health. Our overall findings that sufficient intake of dairy food such as milk, yogurt, and cheese were beneficial on bone health for all aged Korean population whose diet is composed of mainly grains and vegetables. Additionally, the results of current study suggest that a good quality diet with high intake of dairy products, fruit, vegetables, mushroom, whole grain, and nuts may contribute to improve bone health across whole life and to decrease the risk of osteoporosis in later life.

Our study provides a significant public health message for development of dietary guidelines and information for nutrition policies aimed at the improvement of bone health and reduction of risk of osteoporosis.

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Abstract (In Korean)

한국인의 식사패턴과 골건강에 관한 연구

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서론

골다공증(Osteoporosis)이란 낮은 골량과 골의 미세구조의 변화로 골의 강도가 감소되어 골절에 대한 감수성이 증가하는 전신성 골격질환으로 정의할 수 있다. 전세계적으로 노인인구의 증가와 더불어 골감소증 및 골다공증의 골 관련 질환의 발병률이 증가하고 있어, 보건학적인 문제로 대두되고 있다. 골다공증은 20대 후반에 형성된 최대 골밀도와 이후 감소하는 골 소실량에 따라 위험도가 달라진다. 골밀도는 청소년기에 최대 골밀도의 약 90% 정도 형성이 되어 20대 후반에 최대 골밀도를 이루고 이후 연령이 증가함에 따라 서서히 감소하고, 특히 여성의 경우, 폐경 이후 호르몬 변화로 인해 골밀도가 급격히 감소하여 여성이 남성보다

골다공증에 더 높은 위험도를 가지고 있다. 최대 골밀도 형성에는 연령, 성별, 체중, 인종, 유전, 생활양식 (신체활동, 흡연, 음주 등), 영양소 섭취 상태 등 다양한 요인들이 영향을 미치는 것으로 보고되고 있다. 골다공증에 영향을 주는 요인 중 영양소와 식행동은 청소년기 최대 골밀도 형성뿐만 아니라 성인기 골 대사 조절에도 중요한 요인이고, 많은 영양소들이 골격의 성장과 발달에 필수적이라고 알려져 있다. 따라서 골감소증 및 골다공증과 같은 골건강과 관련하여 식사섭취를 어떻게 평가하느냐가 중요한 문제가 되는데 기존에 수행된 연구들은 대부분 단일 영양소 또는 단일 식품 및 식품군 섭취상태를 평가하는 방법을 많이 사용해왔다. 그렇지만, 최근 보다 전반적이고 통합적인 식사의 영향을 평가하기 위해 다변량 통계기법을 이용한 식사패턴 분석 방법이 영양역학 분야에서 활용되고 시작하였고, 식사패턴과 골건강과의 관련성에 대한 다수의 연구들이 보고되고 있다. 그렇지만 이러한 연구들은 대부분 서양인을 대상으로, 주로 성인이나 노인을 대상으로 실시되었기 때문에, 아시아인과 다양한 연령 집단에서 식사패턴과 골건강과의 관련성에 대해 보고된 연구 결과들은 제한적이다. 현재 한국에서 식사패턴은 전통적인 식사에서 육류, 유제품, 패스트푸드의 섭취량이 증가하는 서양식 패턴으로 변화하고 있고, 이러한 식사패턴의 변화는 성인보다 청소년에서 더 빠르게 진행되고 있지만, 이러한 식사패턴의 변화에도 불구하고, 현재 한국의 식사는 여전히 쌀밥 위주의 식사로 유제품과 칼슘 섭취량이 낮은 것으로 보고되고 있다. 한국인의 식사패턴은 문화적·지리적·환경적 영향으로 서양인들의 식사패턴과 다르고, 연령 집단에 따라 식사패턴이 다르기 때문에, 한국인을 대상으로 다양한 연령 그룹에서 식사패턴과 골건강과의 관련성을 확인할 필요성이 대두되고 있다.

목적

본 연구에서는 한국인의 다양한 연령 그룹에 따라 대상 연령의 식사를 잘 반영하는 식사패턴을 확인할 수 있을 것이고, 특정 식사패턴은 골건강에 영향을 미칠 수 있고, 또한 식사패턴의 효과는 가족 관계에서 유전적 요인을 고려한 이후에도 골건강에 영향을 줄 것이라는 가설을 설정하였다. 따라서 본 연구의 목적은 다양한 한국인의 연령대에서 식사패턴을 확인하고, 식사패턴과 골건강과의 관련성을 확인하는 것이다. 첫 번째 연구는 한국 청소년의 6일간의 식사 조사 자료를 활용하여 주요한 식사패턴을 확인하고, 식사패턴과 골밀도와의 관련성을 확인하는 것이다. 두 번째 연구는 국민건강영양조사 자료를 활용하여, 폐경 후 여성을 대상으로 식사패턴을 확인하고, 식사패턴과 골다공증과의 관련성을 분석하였다. 세 번째 연구는 한국인 쌍둥이-가족 코호트 연구의 30세 이상 성인의 식사패턴을 확인하고, 유전적 요인을 고려한 후에 식사패턴이 골밀도에 미치는 영향을 확인하고자 한다.

연구 방법 및 결과

Study 1.

본 연구는 2006년 서울소재 중학교 학생을 대상으로 실시하였다. 설문조사와 신체계측을 완료한 12~15세 학생 총 595명 중 무작위로 95명의 남학생, 101명의 여학생을 선택하였다. 설문조사를 통해 일반적 정보를 확인하였고, 개방형

식사조사 방법인 식사기록법을 사용하여 총 6일(주중 5일, 주말 1일)간의 식사자료를 수집하였다. 골밀도는 이중에너지 방사선 흡수 계측법(dual-energy X-ray absorptiometry)을 활용하여 lumbar spine과 femur 부위를 측정하였다.

대상자들의 평균 나이는 14.2세이고, 65.5%가 이차 성징이 나타났다. 대상자가 섭취한 식품을 24개의 식품군으로 분류하여 요인분석을 실시한 결과 Eigenvalue 1.3 이상인 4개의 식사패턴이 도출되었다. 4개의 식사패턴은 'Traditional Korean', 'Ffast food', 'Milk and cereal', 'Snacks' 이었고, 요인의 설명력은 28.4%였다. 'Traditional Korean' 패턴은 어패류, 콩류, 간장 및 된장, 해조류, 김치류를 특징으로 하였고, 'Fast food' 패턴은 탄산음료, 후렌치 후라이, 햄버거, 비스킷 및 쿠키, 피자, 치킨 등의 섭취가 높았다. 'Milk and cereal' 패턴은 우유와 요구르트, 시리얼, 빵의 섭취량이 높고, 탄산음료나 육류의 섭취량이 낮은 특징을 가지고 있었고, 'Snack' 패턴은 초콜렛과 아이스크림, 껌, 사탕, 과일 및 채소, 샌드위치, 단순당류의 섭취가 높은 전형적인 간식으로 섭취하는 식품들의 특징을 가지고 있었다. 성별, 연령, 체질량 지수 백분위, 2차 성징 나이, 체중 조절 경험, 규칙적인 운동 실시 여부를 보정한 다중 로지스틱 회귀 모델에서 'Milk and cereal' 패턴점수가 높은 학생(T3)들이 낮은 학생(T1)에 비해 lumbar spine의 낮은 골밀도를 가질 위험도가 유의하게 낮았다 (OR: 0.36, 95% CI: 0.14 – 0.93, P = 0.0461). 나머지 3개의 식사패턴과 lumbar spine의 낮은 골밀도를 가질 위험도는 유의한 결과가 없었고, femur 부위의 낮은 골밀도를 가질 위험도는 4개의 식사패턴 모두 유의한 결과가 없었다.

Study 2.

두 번째 연구는 2008-2010년 국민건강영양조사에서 건강설문조사, 영양조사, 골밀도 측정을 포함한 검진조사를 완료한 3,735명의 폐경 후 여성을 대상으로 실시하였다. 표준화된 설문지를 통해 일반적 특성을 확인하였고, 24시간 회상법을 사용하여 대상자들의 식품섭취 실태를 조사하였다. 골밀도 측정은 이중에너지 방사선 흡수 계측법(dual-energy X-ray absorptiometry)을 사용하여 요추부위와 대퇴골의 다섯 부위를 측정하였다. 골다공증은 WHO T-score 기준을 적용하여 정의하였다.

본 연구 대상자들의 평균 나이는 64.1세이고, 체질량지수(BMI)는 24.1kg/m2, 비만 유병률은 37.2%였다. 골다공증 유병률은 femoral neck 부위에서 22.1%, lumbar spine 부위에서 30.3%였다. 대상자들이 섭취한 식품을 20개의 식품군으로 재분류하여 요인분석을 실시하였을 때, 4개의 특징적인 식사패턴이 도출되었다. Factor 1은 기름, 당류, 육류, 알코올의 섭취량이 높아서 'Meat, alcohol, and sugar', Factor 2는 채소, 버섯, 마늘, 양파, 콩류, 백미의 섭취량이 높아서 'Vegetables and soy sauce'로 명명하였다. Factor 3은 백미, 해조류, 김치, 어패류와 상관성이 높아서 'White rice, kimchi, and seaweed', Factor 4는 우유 및 유제품, 밀가루 및 빵류, 과일, 견과류, 콩류의 섭취량이 높아 'Dairy and fruit'으로 명명하였다. 4개의 식사 패턴의 설명력은 30.9% 였다. 'White rice, kimchi, and seaweed' 패턴은 femoral neck의 ward, lumbar spine의 골밀도와 음의 상관관계가 있었고, 'Dairy and fruit' 패턴은 측정한 모든 부위의 골밀도와 양의 상관관계가 있었다. 각 식사패턴 점수의 오분위에 따른 lumbar spine과 femoral neck의 골다공증 위험도는 연령, 체질량지수, 에너지 섭취량, 부갑상선호르몬, 혈액 내 vitamin D 농도, 흡연,

음주, 신체활동, 영양제섭취, 경구피임약 복용을 보정한 모델에서 'White rice, kimchi, and seaweed' 패턴의 섭취량이 가장 높은 집단(Q5)은 섭취량이 가장 낮은 집단(Q1)에 비해 lumbar spine 부위의 골다공증 위험도가 1.4배 증가하였다 (OR: 1.40, 95% CI: 1.03 - 1.90, P = 0.0479). 'Dairy and fruit' 패턴의 섭취량이 가장 높은 집단(Q5)은 섭취량이 가장 낮은 집단(Q1)에 비해 세 개의 모델에서 모두 요추부위의 골다공증 위험도가 유의하게 감소하였다. (Model 3 OR: 0.47, 95% CI: 0.34 – 0.65, P< .0001). Femoral neck 부위의 골다공증 위험도와 4개 식사패턴과의 관련성은 유의하지 않았다.

Study 3.

세 번째 연구는 한국인 쌍둥이-가족 코호트 연구 대상자의 일부로 2007년 7월부터 2012년 1월까지 서울과 부산 센터에 방문한 대상자 중 기초 설문조사, 건강검진, 신체계측, 영양조사, 골밀도 측정을 실시한 30세 이상 성인 1,818명 (남자 716명, 여자 1102명)을 대상으로 실시하였다. 일반적 특성은 설문지를 통해 확인하였고, 식사조사는 주중 2일, 주말 1일을 포함한 총 3일간의 식사내용을 식사기록법을 사용하여 조사하였다. 골밀도는 측정은 이중에너지 방사선 흡수 계측법(dual-energy X-ray absorptiometry)으로 측정하였다. WHO T-score를 적용하여 -1.0 이하인 대상자들을 'low BMD' group으로 정의하였다. 식사패턴과 골밀도와의 관련성을 평가하기 위해 가족내의 유전적 요인을 보정한 mixed linear model을 사용하였다.

대상자의 평균 나이는 남자 47.2세, 여자 45.9세이고, 체질량 지수는 남자 24.6kg/m2, 여자 23.4kg/m2이었다. 대상자들이 섭취한 식품을 22개의 식품군으로

재분류하여 요인분석을 실시하였을 때, 4개의 식사패턴이 도출되었다. 4개의 식사패턴은 요인과 관련성이 높은 대표적인 식품을 반영하여 'Rice and kimchi', 'Egg, meat, and flour', 'Fruit, milk, and whole grain', 'Fast food and soda' 라고 명칭하였다. 각 식사패턴 점수의 사분위에 따른 whole body 부분의 낮은 골밀도를 가질 위험도는 연령, 체질량지수, 에너지 섭취량, 흡연, 음주, 신체활동을 보정하였을 때, 남자에서 'Fruit, milk, and whole grain' 패턴의 섭취량이 가장 높은 집단(Q4)은 섭취량이 가장 높은 집단(Q1)에 비해 낮은 골밀도를 가질 위험도가 0.37배 감소하였다 (OR: 0.37, 95% CI: 0.21 – 0.65, P = 0.0014). 여자의 경우, 폐경 유무를 추가적으로 보정하였을 때, 'Fruit, milk, and whole grain' 패턴의 섭취량이 가장 높은 집단(Q4)은 섭취량이 가장 높은 집단(Q1)에 비해 낮은 골밀도를 가질 위험도가 0.45배 감소하였다 (OR: 0.45, 95% CI: 0.28 – 0.72, P = 0.0028). Mixed linear model을 사용하여 가족내의 유전적 요인과 공유하는 환경적 특성을 보정하였을 때, 남자의 경우, 'Rice and kimchi' 패턴 점수가 한 단위 증가할 때, whole body 골밀도 값이 0.008 증가하였고, 'Fruit, milk, and whole grain' 패턴 점수가 한 단위 증가할 때, whole legs는 0.015, whole pelvis는 0.017, lumbar spine 은 0.017, whole body는 0.018 증가하였다. 여자의 경우, 'Rice and kimchi' 패턴 점수가 한단위 증가할 때, whole body 골밀도 값이 0.005 증가하였고, 'Fruit, milk, and whole grain' 패턴 점수가 한 단위 증가할 때, whole arms는 0.008, whole legs는 0.013증가하였다. 동일한 mixed linear model을 사용하여 관련있는 식품의 1/2 serving size에 따른 골밀도와의 관련성을 분석하였을 때, 남자의 경우, 채소, 과일, 전곡류, 유제품 섭취량이 골밀도 증가에 유의한 영향을 주었고, 여자의 경우, 어패류, 채소, 과일, 전곡류, 유제품 섭취량이 골밀도 증가에 유의한 영향을 주었다.

결론

본 연구에서는 한국인의 다양한 연령 집단에서 특징적인 식사패턴을 확인하였고, 식사패턴과 골건강과의 관련성을 확인하였다. 한국청소년들의 6 일간의 식사자료를 통해서 4 개의 식사패턴을 확인하였고, 이 중 'Milk and cereal' 패턴이 요추 부위의 낮은 골밀도를 가질 위험도를 낮추었다. 따라서 우유와 유제품의 충분한 섭취는 곡류와 채소 위주의 한국 식사를 하는 청소년들의 골밀도에 유익한 영향을 미칠 것이다 쌀밥과 채소 위주의 전통적인 한국 식사의 특성을 가지고 있는 폐경 후 여성에서 우유와 같은 유제품과 과일 섭취의 증가는 골다공증의 위험도를 낮추었고, 반면 백미, 김치, 해조류 위주의 식사는 골다공증 위험도를 높였다. 따라서 폐경 후 여성의 골건강을 위한 식사 가이드는 'Dairy and fruit' 패턴과 같이 다양한 비타민과 미네랄이 풍부한 식사를 할 수 있는 방향으로 전략을 수립하는 것이 필요하다. 30 세 이상 성인의 식사섭취자료로부터 4 개의 식사패턴을 도출하였고, 이 중 유제품, 과일, 채소, 버섯, 전곡, 견과류를 많이 섭취하는 식사패턴이 성인의 골밀도에 유익한 영향을 미쳤다.

본 연구의 결과는 한국인의 골건강 향상을 위해 식사패턴을 기반으로 한 가이드라인 개발에 과학적 근거를 제시할 수 있다.

주요어: 식사패턴, 골밀도, 골다공증, 요인분석

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