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Nutritional Status and Bone Mineral Density of Elderly Women in Asan*

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ABSTRACT

Nutrition factors play an important role in the pathogenesis of osteoporosis. The purpose of this study is to investigate the relationship between nutritional status and bone mineral density of elderly women. Three hundred thirty five elderly women (over 65 years) in Asan were divided into three age groups (group 1, less than 70 y ; group 2, from 70 to 75 y ; group 3, 75 y or more). Total alkaline phosphatase and serum calcium (Ca) were analyzed using spectrophotometric procedure. Data for food and nutrient intakes were obtained by a 24-hour recall method. Bone density was measured by broadband ultrasound attenuation (BUA) using QUS-2. Age differences were tested with the χ^2 test for categorical variables and with ANOVA and Tukey's test for continuous variables. Correlation was conducted to test the association between bone density and nutrient intake. The subjects in age groups 1, 2 and 3 were 36.7%, 32.8% and 30.4%, respectively. Height and body weight of the subjects were significantly decreased with age. Average bone density of the subjects in group 3 was lower than the other age groups. Osteoporosis determined by t-score is 17.9% for group 1, 24.5% for group 2 and 55.9% for group 3 ($p < 0.001$). The serum Ca level of the subjects in group 2 was significantly lower than that of group 1 although mean values in all age groups are within the normal range. Dietary Ca intake, nutrient adequacy ratio (NAR) and index of nutrient quality (INQ) were decreased with age. Bone density was negatively correlated with age ($p < 0.001$), while body mass index ($p < 0.01$) was positively related with bone density. Although partial correlation did not reveal the significant correlation of BMD and dietary calcium after controlling for age, since calcium intake was very poor compared to sodium and phosphorous intakes, recommendation of more calcium intake for elderly women especially those over 75 years must be continuously emphasized. (*J Community Nutrition* 7(1) : 49~57, 2005)

KEY WORDS : bone mineral density · broadband ultrasound attenuation · dietary intake · elderly women · quantitative ultrasound.

Introduction

Osteoporosis is a skeletal disease characterized by low bone mass and micro-architectural deterioration of bone tissue with a consequent increase in bone fragility and susceptibility to fracture (Prentice et al. 2003). The rapid increase in the elderly population and less opportunities to become beneficiaries of better quality of life among rural elderly will lead to a corresponding increase in the prevalence of this population suffering from osteoporosis. Osteoporosis is a major health problem through its relationship with the fractures of hip, wrist and spine. Fractures in the elderly population are especially important since they are associated with considerable morbidity, necessitating hospitalization in most cases and enormous cost to the health service budget (Prentice et al. 2003). The ultimate determinants of fragility fracture are bone strength and trauma. Bone strength is related to the quality of bone, its architecture and its mass (Walker-Bone et al. 2001). These characteristics cannot easily be assessed in vivo, but in the elderly, they correlate closely with bone mineral density (BMD), measured by quantitative bone ultrasound (QUS), a modern and noninvasive assessment of skeletal status (Gluter 1997). For this reason, the World Health Or-

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ganization (WHO 1994) has a working definition of osteoporosis in terms of BMD relative to the young adults mean, and BMD assessment of elderly population permits the stratification of individuals into diagnostic categories. The diagnostic categories and definition by the BMD are as follows : Normal, a value for BMD that is not more than 1 standard deviation (SD) below the young adult mean value ; Osteopenia, a value for BMD that lies between 1 and 2.5 SD below the young adult mean value ; Osteoporosis, a value for BMD that is more than 2.5 SD below the young adult mean value. BMD reaching a peak during young adulthood, decreases slowly as aging in both sexes but decline in BMD is accelerated in women following menopause. The rate of postmenopausal bone mineral loss reaches up to 2 – 3% per annum in cancellous bone (Wasnich 1991) and this rate is influenced by a complex interplay of genetic, cellular, hormonal and environmental factors including diet and physical activity.

Calcium, phosphorous, magnesium and zinc are the primary bone-forming minerals. Nutritionally, therefore, adequate supplies of these minerals, the amino acid necessary for collagen matrix formation, and other nutrients involved in bone production, skeletal metabolism and mineral homeostasis, are required for maintenance of bone health (Prentice & Bates 1993). Besides these bone formation minerals, various dietary factors have been suggested as risk factors for osteoporosis, including high protein and high salt intakes (Cohen & Roe 2000). Since many nutritional factors contribute to risk for many chronic diseases including osteoporosis, recent changes in diet and life style have been repeatedly suggested to be the important causes for increase of the major chronic diseases among Koreans (National Statistical Office of Korea 2000). Recent data in Korea shows that chronic diseases are 2.4 times more prevalent in older adults than in other age groups (Byun 1999). The primary reason of higher incidences of chronic diseases among elderly would be attributable to physiological changes. However, since most of these chronic conditions and risk factors of chronic disease prevalent in older adults are modulated by behavioral modification, especially by dietary changes (Drewnowski & Evans 2001), the increased number of the elderly population and lack of adequate nutrient intake among elderly would be another cause of increasing proportion of chronic disease cases among Korean older adults. Therefore, an understanding of nutrition and the role it plays in short-term and long-term health and thorough nutritional care can significantly minimize risk for chronic diseases including osteoporosis. This means that regular nutrition monitoring and intervention for older adults is important to prevent the progression of disease or enhance the quality of life for the older adults to keep their health.

Better nutritional care to maintain adequate nutritional status can therefore contribute to an increase in life expectancy and improved health for older adults (Amarantos et al. 2001). Considerable evidence for a strong association between dietary calcium intake and BMD has been provided in various studies (Simth et al. 1989 ; Elder et at. 1991 ; Andon et al. 1991 ; Suleiman et at. 1997) including Korean data (Choi & Lee 1996 ; Son & Chon 1998 ; Hong et al. 1999), but the results are inconsistent since other studies did not find significant association (Sung et al. 2001 ; Oh et al. 2002) The discrepancy of conflicting results was attributed to the very low level of calcium intake (Sung et al. 2001). The nutrient intake levels of Korean elderly are poor compared to the other age groups (Ministry of Health and Welfare 2002), and the poor nutrient intake status became more severe among rural elderly, especially for riboflavin and calcium intakes. According to the 2001 National Health and Nutrition Survey (Ministry of Health and Welfare 2002), mean calcium intake of elderly age over 65 y was 428.5mg which is only 61.3% of RDA and mean riboflavin intake was 0.78mg (65.6% of RDA).

There are, however, only a few previous reports concerning the association between total nutritional status of rural elderly women and bone health or BMD. The objectives of the present study were to assess the nutritional status of rural elderly women living in Asan using 24-hr recall method and to establish relationship between nutritional or biochemical factors and BMD measured by a simple noninvasive broadband ultrasound attenuation (BUA) measurement using QUS-2 (Metra Biosystems Inc., USA). Since BMD decline is dependent on age of postmenopausal women, we divided the subjects into different age groups of less than 70 y, between 70 and 75 y and over 75 y and compared among the age groups.

Subjects and Methods

1. Subjects

Three hundred thirty five elderly women age over 65 years residing in Asan were invited for a community-based health and nutrition examination during January 2003. Participation was voluntary and all participants of the study provided written informed consent before setting the interview schedule.

2. Data collection and analyses

Bone mineral density (BMD) of the subjects was measured using QUS-2 by BUA (dB/MHz) from the left calcaneal bone. Blood samples were collected in 7-ml vacutainers by trained phlebotomists from an antecubital vein of each subject who had fasted for 8 h. Blood samples were brought to the laboratory on ice and analyzed the same day. Serum calcium and total alkaline phosphatase (ALP) levels were measured by spectrophotometric procedures (TBA-40FR biochemical analyzer, Hitachi, Japan). Each subject was interviewed to obtain information about medical history, demographic characteristics, cigarette smoking and alcohol drinking habits. All participants' heights and weights were measured and percent body fat content was also measured by a portable bioelectrical impedance analyzer (TBF-501, Tanita, Japan). Dietary intakes were assessed with a 24-hour recall method by one to one interview with trained interviewers. In order to obtain detailed descriptions of all foods and beverages consumed and to estimate food portion sizes, food models, standard household measures and natural-sized colored photographs were used as memory aids. Food records were converted to nutrients intakes by using the computerized nutrient

Table 1. General characteristics of the subjects by age groups

	Group 1 (65 – 69 y)	Group 2 (70 – 74 y)	Group 3 (75 y or over)	Total	χ^2
N (%)	123 (36.7)	110 (32.8)	102 (30.4)	335 (100.0)	
Family type					0.915
Alone	26 (21.1)	28 (25.5)	25 (24.5)	79 (23.6)	
With spouse	54 (43.9)	44 (40.0)	40 (39.2)	138 (41.2)	
With family	43 (35.0)	38 (34.5)	37 (36.3)	118 (35.2)	
Education level					8.348
Illiterate	54 (43.9)	53 (48.2)	59 (57.8)	166 (49.6)	
Elementary school	61 (49.6)	54 (49.1)	42 (41.2)	157 (46.9)	
Middle school above	8 (6.5)	3 (2.7)	1 (1.0)	12 (3.6)	
Monthly income					2.142
Below 500K[1] Won	82 (66.7)	71 (64.5)	59 (57.8)	212 (63.3)	
500K – 1,000K Won	29 (23.6)	26 (23.6)	30 (29.4)	85 (25.4)	
1,000K Won or above	12 (9.8)	13 (11.8)	13 (12.7)	38 (11.3)	
Smoking habit					13.672**
Smoking	3 (2.4)	2 (1.8)	12 (11.8)	17 (5.1)	
Non-Smoking	120 (97.6)	108 (98.2)	90 (88.2)	318 (94.9)	
Alcohol drinking habit					0.590
Drinking	16 (13.0)	11 (10.0)	13 (12.7)	40 (11.9)	
Non-Drinking	107 (87.0)	99 (90.0)	89 (87.3)	295 (88.1)	
Self-rated health status					10.264*
Good	22 (17.9)	19 (17.3)	34 (33.3)	75 (22.4)	
Fair	16 (13.0)	16 (14.5)	12 (11.8)	44 (13.1)	
Bad	85 (69.1)	75 (68.2)	56 (54.9)	216 (64.5)	
Chronic disease					1.718
Yes	52 (42.3)	50 (45.5)	52 (51.0)	154 (46.0)	
No	71 (57.7)	60 (54.5)	50 (49.0)	181 (54.0)	
Liver disease	4 (3.3)	2 (1.8)	1 (1.0)	7 (2.1)	
Hypertension	38 (30.9)	40 (36.4)	42 (41.2)	120 (35.8)	
CVA[2]	4 (3.3)	4 (3.6)	1 (1.0)	9 (2.7)	
Heart disease	7 (5.7)	4 (3.6)	9 (8.8)	20 (6.0)	
Diabetes	15 (12.2)	7 (6.4)	12 (11.8)	34 (10.1)	
Cancer	0 (0.0)	1 (0.9)	0 (0.0)	1 (0.3)	

1) 1,000
2) Cerebro Vascular Accident
* : p<0.05, ** : p<0.01

analysis program (CAN-pro, Korean Nutrition Society, Korea). Evaluation of nutrient intake was made in reference to the recommended daily allowances (RDA) for elderly population (The Korean Nutrition Society 2000). Nutrient adequacy ratio (NAR) of each subject was estimated by the formulation below and mean nutrient adequacy ratio (MAR) is a mean of NAR and calculated by dividing sum of NAR by number of nutrients.

$$NAR = \frac{\text{Daily nutrient intake}}{\text{Recommended nutrient allowance of the nutrient}}$$

The nutrient intakes were also evaluated by the index of nutritional quality (INQ). INQ is calculated by dividing the percent RDA of each nutrient intake by the percent RDA of individual energy. The formula for INQ is shown below.

$$INQ = \frac{\text{Percent of each nutrient intake per RDA of each nutrient}}{\text{Percent of energy intake per RDA of energy}}$$

3. Statistical analyses

Data was entered and analyzed by SPSSWIN 10.0 program. Cross-tabulations and χ^2 test were conducted on categorical variables. Statistical significance was defined at the $p < 0.05$ level. ANOVA and Tukey's post hoc test were used for general characteristics, nutrients intakes, BMD and serum calcium and ALP concentrations by age groups. Pearson's and partial correlations of BMD with anthropometric, bio-

Table 2. Anthropometric and biochemical measurements of the subjects by age groups[1)]

	Group 1 (65 – 69 y)	Group 2 (70 – 74 y)	Group 3 (75 y or over)	Total	
Height (cm)	151 ± 5.13[a)]	149 ± 5.62[b)]	147 ± 6.04[c)]	149 ± 5.83	
Weight (kg)	58.4 ± 8.68[a)]	54.8 ± 8.45[b)]	51.5 ± 8.49[c)]	55.1 ± 8.99	
BUA[2)] (dB/MHz)	68.9 ± 16.3	62.5 ± 12.5	51.9 ± 15.9	61.6 ± 16.5	
T-Score	−1.37 ± 1.24	−1.83 ± 1.00	−2.45 ± 1.14	−1.85 ± 1.22	
Serum Ca (mg/dl)	8.94 ± 0.47[a)]	8.77 ± 0.42[b)]	8.81 ± 0.52[ab)]	8.85 ± 0.48	
ALP[3)] (IU/L)	221 ± 55.5	211 ± 54.8	226 ± 56.3	219 ± 55.7	
Osteoporosis[4)] N (%)	22 (17.9)	27 (24.5)	57 (55.9)	106 (31.6)***	χ^2
Body mass index (kg/m²)					7.616
< 18.5	2 (1.6)	6 (5.5)	5 (4.9)	13 (3.9)	
18.5 – 24.9	58 (47.2)	59 (53.6)	60 (58.8)	177 (52.8)	
25.0 – 29.9	52 (42.3)	39 (35.5)	32 (31.4)	123 (36.7)	
≥ 30.0	11 (8.9)	6 (5.5)	5 (4.9)	22 (6.6)	
Mean ± SD	25.7 ± 3.61[a)]	24.7 ± 3.42[ab)]	23.9 ± 3.29[b)]	24.8 ± 3.52	
Body fat (%)					9.447
< 20.0	4 (3.3)	1 (0.9)	1 (1.0)	6 (1.8)	
20.0 – 24.9	0 (0.0)	4 (3.6)	2 (2.0)	6 (1.8)	
25.0 – 29.9	33 (26.8)	26 (23.6)	18 (17.6)	77 (23.0)	
≥ 30.0	86 (69.9)	79 (71.8)	81 (79.4)	246 (73.4)	
Mean ± SD	33.4 ± 7.08	33.1 ± 5.59	34.3 ± 5.77	33.6 ± 6.23	
Diastolic blood pressure (mmHg)					7.679
< 90.0	105 (85.4)	103 (93.6)	88 (86.3)	296 (88.4)	
90.0 – 94.9	7 (5.7)	6 (5.5)	6 (5.9)	19 (5.7)	
≥ 95.0	11 (8.9)	1 (0.9)	8 (7.8)	20 (6.0)	
Mean ± SD	77.9 ± 14.1	74.4 ± 11.9	75.5 ± 16.1	76.0 ± 14.1	
Systolic blood pressure (mmHg)					3.685
< 140	73 (59.3)	64 (58.2)	55 (53.9)	192 (57.3)	
140.0 – 159.9	36 (29.3)	29 (26.4)	26 (25.5)	91 (27.2)	
≥ 160.0	14 (11.4)	17 (15.5)	21 (20.6)	52 (15.5)	
Mean ± SD	136 ± 20.5	135 ± 22.5	140 ± 20.9	137 ± 21.4	

1) Means not sharing a common letter differ ($p<0.05$) by ANOVA and Tukey's test
2) BUA : Broadband Ultrasound Attenuation
3) ALP : Alkaline Phosphatase
4) Osteoporosis : −2.5 ≥ T-score
*** : $p<0.001$ by χ^2

chemical and nutritional factors were also conducted. Age was controlled for the partial correlation analysis.

Results

1. Demographic characteristics of the subjects

The demographic characteristics of the 335 participants are shown in Table 1. The ages of the subjects ranged from 65 to 94 years (average 72.4 ± 5.7 years). The subjects belong to group 1 (age between 65 and 69 y) were 36.7%, group 2 (age between 70 and 74 y) were 32.8% and those belong to group 3 (age over 75 y) were 30.4%. About fifty percent of the subjects were illiterate and only 3.6% were educated higher than middle school, which ends up to 96.6 % of women over 65 years living in rural Asan area were educated to only elementary level or less. This illiterate level is unusually high compared to the modern Korean population with younger age groups. More than sixty percent of the participants earned less than 500,000 won per month, which is less than half the Korean average wage. Most (95% of total) of the subjects were non-smokers, but the ratio of smokers becomes significantly higher ($p < 0.01$) with higher age groups. No difference among age groups in alcohol drinking was observed. With respect to perceived health status, 45.1% of the subjects in group 3 (age over 75 y) considered their present health to be considerably better or as good as other people of the same age group, which is significantly higher percentage compared to other age groups ($p < 0.05$). Forty six percent of the total participants (42 – 51%) reported that they had one or more chronic diseases such as liver disease, hypertension, cerebro vascular accident, heart disease, diabetes or cancer. Anthropometric characteristics and biochemical factors related to BMD of each age group are as in Table 2. Height and weight significantly decrease with higher age ($p < 0.05$). However, body mass index (BMI), percentage of body fat and blood pressure did not show any differences among age groups. Osteoporosis rate of the subjects in age group 3 (75 y and over) was significantly higher (55.6%) than other age groups ($p < 0.001$). Osteoporosis rate and serum calcium concentration decreased in higher age groups. BMD measured as

Table 3. Comparisons of mean daily energy and nutrient intake[1)]

	Group 1 (65 – 69 y)	Group 2 (70 – 74 y)	Group 3 (75 y or over)	Total
Energy (kcal)	1362 ± 511	1311 ± 539	1222 ± 598	1303 ± 499
Protein (g)	53.3 ± 25.6	50.9 ± 18.8	46.4 ± 27.7	50.4 ± 24.4
Plant protein (g)	34.1 ± 13.6	32.4 ± 10.2	30.4 ± 16.2	32.4 ± 13.5
Animal protein (g)	19.4 ± 19.0	18.5 ± 14.4	16.0 ± 16.9	18.0 ± 17.0
Fat (g)	19.5 ± 17.4	20.1 ± 12.9	17.2 ± 13.8	19.0 ± 15.0
Plant fat (g)	11.2 ± 7.53	10.8 ± 6.68	9.85 ± 7.97	10.7 ± 7.40
Animal fat (g)	8.64 ± 13.1	9.29 ± 9.87	7.31 ± 9.52	8.45 ± 11.1
Carbohydrate (g)	253 ± 131	238 ± 63.7	231 ± 132	241 ± 114
Ca (mg)	468 ± 199	433 ± 213	407 ± 212	438 ± 208
Plant Ca (mg)	282 ± 122	267 ± 131	249 ± 141	267 ± 131
Animal Ca (mg)	186 ± 136	165 ± 140	157 ± 112	170 ± 131
Phosphorous (mg)	726 ± 346[a)]	671 ± 260[ab)]	582 ± 313[b)]	664 ± 315
Iron (mg)	12.4 ± 7.13[a)]	11.4 ± 4.59[ab)]	10.4 ± 6.01[b)]	11.5 ± 6.08
Plant Iron (mg)	8.93 ± 3.50	8.82 ± 3.92	7.89 ± 4.17	8.58 ± 3.87
Animal Iron (mg)	3.45 ± 5.68	2.62 ± 1.90	2.56 ± 2.51	2.91 ± 3.88
Sodium (g)	3.71 ± 1.60[a)]	3.62 ± 1.52[ab)]	3.12 ± 1.55[b)]	3.50 ± 1.57
Potassium (g)	2.17 ± 1.07[a)]	2.00 ± 0.85[ab)]	1.79 ± 1.03[b)]	2.00 ± 1.00
Vitamin A (μgRE)	364 ± 408[a)]	345 ± 519[ab)]	235 ± 198[b)]	318 ± 405
Vitamin B_1 (mg)	0.84 ± 0.56[a)]	0.80 ± 0.32[ab)]	0.69 ± 0.38[b)]	0.78 ± 0.44
Vitamin B_2 (mg)	0.63 ± 0.42	0.60 ± 0.33	0.53 ± 0.59	0.59 ± 0.45
Vitamin B_6 (mg)	1.45 ± 0.75	1.42 ± 0.75	1.22 ± 0.83	1.37 ± 0.78
Niacin (mg)	10.7 ± 5.98[a)]	9.85 ± 3.58[ab)]	9.01 ± 6.00[b)]	9.90 ± 5.35
Vitamin C (mg)	96.5 ± 92.6	95.6 ± 84.4	83.1 ± 72.9	92.1 ± 84.2
Vitamin E (mg α-TE)	4.99 ± 6.24	4.70 ± 5.03	4.34 ± 4.71	4.70 ± 5.41

1) Means not sharing a common letter differ ($p < 0.05$) by ANOVA and Tukey's test

Table 4. Nutrient adequacy ratio (NAR) and mean nutrient adequacy ratio (MAR) of the subjects[1)]

	Group 1 (65 – 69 y)	Group 2 (70 – 74 y)	Group 3 (75 y or over)	Total
Energy	0.80 ± 0.30	0.77 ± 0.21	0.76 ± 0.37	0.78 ± 0.30
Protein	0.97 ± 0.47	0.93 ± 0.34	0.84 ± 0.50	0.92 ± 0.44
Ca	0.67 ± 0.28	0.62 ± 0.30	0.58 ± 0.30	0.63 ± 0.30
Phosphorous	1.04 ± 0.49[a)]	0.96 ± 0.37[ab)]	0.83 ± 0.45[b)]	0.95 ± 0.45
Iron	1.03 ± 0.59[a)]	0.95 ± 0.38[ab)]	0.87 ± 0.50[b)]	0.96 ± 0.51
Vitamin A	0.52 ± 0.58[a)]	0.49 ± 0.74[ab)]	0.34 ± 0.28[b)]	0.45 ± 0.58
Vitamin B_1	0.84 ± 0.56[a)]	0.80 ± 0.32[ab)]	0.69 ± 0.38[b)]	0.78 ± 0.44
Vitamin B_2	0.52 ± 0.35	0.50 ± 0.28	0.45 ± 0.49	0.49 ± 0.38
Vitamin B_6	1.04 ± 0.54	1.01 ± 0.54	0.87 ± 0.59	0.98 ± 0.56
Niacin	0.82 ± 0.46[a)]	0.76 ± 0.28[ab)]	0.69 ± 0.46[b)]	0.76 ± 0.41
Vitamin C	1.38 ± 1.32	1.37 ± 1.21	1.19 ± 1.04	1.32 ± 1.20
Vitamin E	0.50 ± 0.62	0.47 ± 0.50	0.43 ± 0.47	0.47 ± 0.54
MAR	0.84 ± 0.40[a)]	0.80 ± 0.31[ab)]	0.72 ± 0.37[b)]	0.79 ± 0.36

1) Means not sharing a common letter differ ($p<0.05$) by ANOVA and Tukey's test

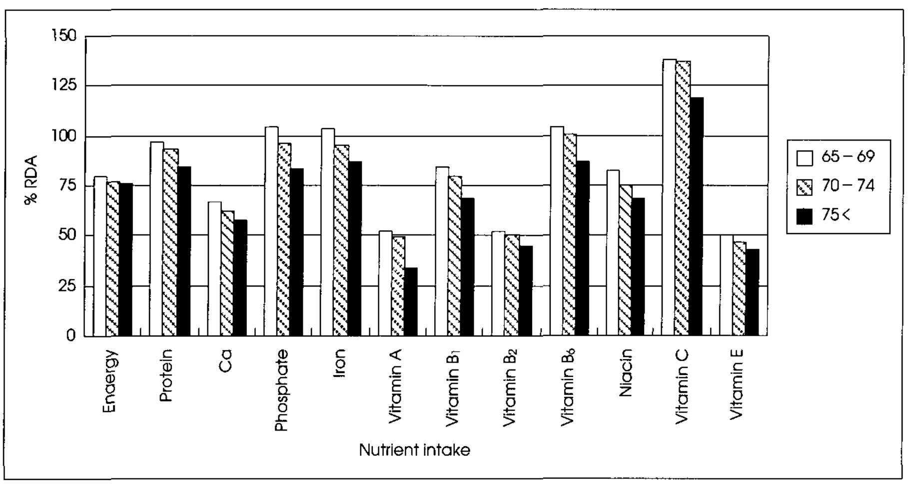

Fig. 1. Nutrient intake status expressed as percentages of recommended dietary allowance (RDA) of the subjects by age groups.

BUA and t-score also decrease as higher age group, but the differences were not statistically different due to high SD values.

2. Dietary nutrient intakes

Table 3 shows the average daily nutrient intake of the subjects. The energy intake was approximately 78% of RDA. No significant age-related differences were observed in the intakes of dietary energy, protein, fat and carbohydrate. However, some nutrient-intake patterns exhibit age differences : intakes of phosphorous, iron, sodium, potassium, vitamin A, B_1 and niacin significantly decreased with higher age ($p<0.05$). The nutrients which showed significant decreases in intake levels with higher age also showed significant differences in NAR values (Table 4). Intakes of calcium, vitamins A, B_2 and E were less than 75% of RDA values (less than 0.75 of NAR). The intakes of vitamins A, B_2 and E were particularly low for most subjects in the present study, with NAR values less than 0.5 (50% of RDA, Fig. 1).

The quality of diet determined by INQ presented in Table 5 shows similar patterns from the results observed in Table 4. The nutrients with very low NAR values such as vitamins A, B_2 and E also show very poor INQ values of 0.58, 0.59 and 0.61, respectively. INQ of vitamin A was not different among different age groups unlike their NAR values probably due to decreased intake of energy in age group 3. INQ of calcium, vitamins B_1 and niacin was lower than 1.0, which also means poor nutritional quality. These INQ values decrease with older age except for calcium. Nutrients with INQ values higher than 1.0 (protein, phosphorous, iron and vitamins B_6) showed significant difference among age groups ($p<0.05$) except for vitamin C.

Table 5. Index of nutritional quality (INQ) of the subjects[1)]

	Group 1 (65 − 69 y)	Group 2 (70 − 74 y)	Group 3 (75 y or over)	Total
Protein	1.21 ± 0.31[a)]	1.19 ± 0.27[a)]	1.09 ± 0.28[b)]	1.17 ± 0.29
Ca	0.87 ± 0.31	0.81 ± 0.34	0.78 ± 0.30	0.82 ± 0.32
Phosphorous	1.29 ± 0.32[a)]	1.24 ± 0.32[a)]	1.08 ± 0.27[b)]	1.21 ± 0.32
Iron	1.32 ± 0.58[a)]	1.26 ± 0.50[ab)]	1.14 ± 0.42[b)]	1.24 ± 0.51
Vitamin A	0.62 ± 0.59	0.67 ± 1.24	0.44 ± 0.35	0.58 ± 0.82
Vitamin B_1	1.01 ± 0.36[a)]	1.02 ± 0.31[a)]	0.89 ± 0.28[b)]	0.98 ± 0.32
Vitamin B_2	0.63 ± 0.42	0.60 ± 0.33	0.53 ± 0.59	0.59 ± 0.45
Vitamin B_6	1.30 ± 0.51[a)]	1.31 ± 0.58[a)]	1.11 ± 0.46[b)]	1.24 ± 0.52
Niacin	1.01 ± 0.30[a)]	0.98 ± 0.24[a)]	0.87 ± 0.24[b)]	0.96 ± 0.27
Vitamin C	1.67 ± 1.36	1.75 ± 1.43	1.56 ± 1.30	1.66 ± 1.36
Vitamin E	0.59 ± 0.64	0.60 ± 0.57	0.63 ± 1.00	0.61 ± 0.75

1) *Means not sharing a common letter differ ($p < 0.05$) by ANOVA and Tukey's test*

Table 6. Correlation between bone density measured by broadband ultrasound attenuation (BUA) and anthropometric, biochemical and dietary variables

Variables	Pearson's correlation BUA	Partial correlation controlled for age BUA
Age	−0.451***	−
Body mass index	0.273**	0.196***
Serum calcium	0.066	0.017
Alkaline phosphatase	−0.052	−0.039
Dietary energy intake	0.137*	0.074
Dietary protein intake	0.087	0.025
Dietary calcium intake	0.117*	0.035

*: $p < 0.05$, ** : $p < 0.01$, *** : $p < 0.001$

3. Correlation between BMD and nutritional or biochemical indices

Table 6 shows the correlation between BMD and the anthropometric, biochemical or nutritional indices. The negative correlation between BMD and age was most significant with $r = -0.451$ ($p < 0.001$). BMI, dietary energy and calcium intakes positively correlated with BMD. However, correlation coefficient was not very high with dietary intake values and when partial correlation was conducted with controlling for age, the significance disappeared with dietary factors. Other factors as serum calcium and ALP concentrations or other dietary intake values did not show significant correlation.

Discussion

Osteoporosis raises growing public health concerns especially in elderly women due to its close relationship with the fractures and consequently with the considerable morbidity. Thanks to the modern technology of portable BMD measuring equipment as QUS, a larger community study with rural elderly women who have relatively less chances to access a conventional and expensive BMD measuring equipment as dual energy x-ray absorptiometry (DEXA) becomes possible (McLean et al. 2000). This population-based study with rural elderly women living in Asan was conducted to evaluate the prevalence of osteoporosis with portable BMD measuring equipment using the manufacturer's young adult population mean and to investigate the association of BMD with nutritional status.

Our data shows as high as 50% of osteoporosis prevalence depends on the subjects' age category (18% for age group 1, 25% for group 2 and 56% for group 3). The rates of postmenopausal bone mineral loss are average 1 − 2% per annum in cortical bone and 2 − 3% per annum in cancellous bone (Prentice et al. 2003). Since QUS-2 used in this study measures the BUA of ultrasound beam as it passes through the heel, this measurement is reported to reflect not only BMD but also microarchitecture of cancellous bone (Prins et al. 1998). The average menopausal age of the subjects is 47.6 ± 5.2 y meaning that about 20 or more years have passed since menopause of most elderly women in this study. Oh et al. (1999) reported that the peak BUA measured with QUS-2, the same type of instrument used in this study, for Korean women aged 30 − 35 was 90.7 ± 17.0 dB/MHz while others (Koh et al. 2004) reported Korean postmenopausal women's (age of 60 − 69 y) calcaneal BUA was 94.8 ± 10.1 dB/MHz using another kind of instrument (the Achilles+ scanner). Compared to the reference value of Oh et al. (1999), our results show the at average about 32% loss of peak BMD (24% for age group 1, 31% for group 2 and 43% loss for group 3), which is a reasonable and predictable loss as a cancellous bone. However, when compared to the value of

Koh et al. (2004), BUA reported in this study was low even if average age of this study is higher (72.4 ± 5.7 y) than that of Koh et al. (64.0 ± 2.8 y). The discrepancy may be attributable to the different equipment used for these two studies ; however, due to limited availability of references since QUS measurement is relatively new, it is difficult to draw a conclusion with available data. When osteoporosis was defined according to WHO criteria (1994) using t-score, the osteoporosis rate of this study (average 32%) is very similar to the rate reported by Sung et al. (2001), where BMD was measured by DEXA at lumbar spine and femoral neck, but the prevalence of osteoporosis of elderly women in Asan was much lower compared to the results of Shin et al. (2002) conducted in Jang-sung Chonnam, where BMD was measured as Sung et al. (2001). The differences in bone mass and prevalence of osteoporosis of elderly women may vary with methods of assessment, target population, measurement sites and regional differences due to the urban and rural discrepancy of Korean society. More intensive studies with a variety of measurements and validation studies with different methods of assessment are required with wide ranges of age groups and regions for the Korean population.

Nutrition plays an important role in multifactorial pathogenesis of osteoporosis, but studies on nutritional aspects on the prevention and treatment of osteoporosis are relatively rare probably because nutrition does not account for the totality of the problems in osteoporosis. Recent reports, however, have supported the importance of many nutrients other than calcium and vitamin D (Cashman 2004). Our study confirmed the importance of dietary energy and calcium intakes, although results of some studies examined the relationship between BMD and nutritional factors among Korean elderly are conflicting. Sung et al. (2001) found significant positive correlation of vitamin B_2 intake and BMD, while Oh et al. (2002) found only carbohydrate intake was significantly correlated with BMD. When study was conducted with younger age groups (college women), Kim (2005) reported significant positive correlation of energy, calcium, carbohydrate and fat intake and negative correlation of protein, iron, sodium, potassium and cholesterol intake with BMD. The nutritional intakes of the young women in Kim's study (2005) was much higher than those of the elderly study of the present, Sung et al. (2001) and Oh et al. (2002). All nutrient intakes except for calcium and iron were higher than RDA of the matching age group in Kim's study (2005). Different nutrient intake and age showed the different results. The mean sodium intake level of the subjects in this study was 3.50 ± 1.57g. As mentioned before, since high sodium intake is the risk factor of osteoporosis (Cohen & Roe 2000), recommendation for more calcium intake in order to compensate for the high sodium intake is crucial for the participants of this study. Especially when we compared calcium intake relative to phosphorous intake, the ratio of Ca/P was 0.68, which is lower than half of the recommended value of 1.7 (Ilich et al. 2003). Therefore, the poor calcium intake of the elderly population of this study could cause a serious problem not only in terms of bone health, but also in many other physiological changes in the process of aging.

However, since bone is a complex living tissue, and it is probable that a wide spectrum of micronutrients contributes to its maintenance, examining nutrients individually may sometimes be misleading. Nutrients tend to be packaged together in foods, and therefore associations seen with a single nutrient may, in fact, be caused by a more complex constellation of other nutrients consumed contemporaneously. If a variety of individual nutrients are in fact important, then overall dietary patterns that maximize those nutrients should be associated with BMD. Future studies, therefore, should consider overall dietary patterns and recommendations for improving BMD. Especially the Korean diet is considered to be a healthy diet except for a lack of rich calcium sources, to relate overall Korean dietary patterns within the elderly population to BMD would be more important than trials with a single individual nutrient.

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