Original Article

Bone health status of the elderly in Taiwan by quantitative ultrasound

Yi-Chin Lin PhD,[1] Jeng-Fen Chiu MS,[2] Meng-Chiao Lin MD,[3] Su-Hao Tu PhD[4] and Wen-Harn Pan PhD[5]

[1]Institute of Nutritional Science, Chung Shan Medical University, Taichung, Taiwan; [2]Fooyin Institute of Technology, Kaohsiung, Taiwan; [3]Department of Health, Kaohsiung City, Kaohsiung, Taiwan; [4]Center for Survey Research, Academia Sinica, Taipei, Taiwan; [5]Institute of Biomedical Sciences, Academia Sinica, Taipei, Taiwan

Bone density of the elderly in Taiwan was assessed by quantitative ultrasound bone densitometry of the heel in the Elderly Nutrition and Health Survey in Taiwan (1999-2000). Broadband ultrasound attenuation (BUA) was measured, and the corresponding Z-score was calculated. Physical examination data of 1123 males and 1034 females were included in the current analysis, and data of 752 males and 721 females who also had complete questionnaire information were used for analysis of relationships between several risk factors and BUA status. The results show that in elderly Taiwanese males, higher BMI and intake of dietary calcium is positively associated with a higher BUA Z-score. Advancing age and living in the second stratum in the southern areas appeared to be negatively associated with BUA Z-score in elderly females. BMI, height, years of education, and intake of dietary calcium were positive predictors of BUA Z-score. Further analysis was performed by grouping subjects according to the gender-specific medians of intake levels of dietary calcium, protein, and sodium. The results revealed that for both genders, those in the "high calcium/high protein" group had a higher mean BUA Z-score. The results of the current analysis show that in Taiwan, BMI and dietary calcium intake are positive predictors of BUA Z-score in elderly males, whereas BMI, height, years of education, and dietary calcium intake are positively associated with BUA Z-score in elderly females. The effects of dietary calcium intake may be influenced by the intake of other nutrients such as sodium and protein.

Key Words: **QUS, bone, elderly, survey, Taiwan, Elderly Nutrition and Health Survey in Taiwan (1999-2000)**

Introduction

In recent decades, osteoporosis, characterized by systematic loss of bone mass, has become a growing public health problem in Taiwan as the elderly population expands rapidly. Low bone mineral density (BMD) due to osteoporosis subsequently increases the risk of fracture. It has been reported in 1996 that the prevalence rates of vertebral fractures in urban Taiwanese elderly were 12% for males and 18% for females, respectively.[1] In the year 2000, a total of 5281 elderly males and 8107 elderly females suffered from hip fractures according to applications for health insurance claims (unpublished data). The 5 year age-adjusted incidence rates of hip fracture from 1996 to 2000 estimated from the National Health Insurance Research Database, was 225 per 100,000 in men and 505 per 100,000 in women.[2] The severe outcomes resulting from osteoporotic fractures not only affect the lives of elderly individuals, but also create tremendous social and economic burdens for the country. Understanding factors influencing bone health in the elderly may lead to the development of strategies for better prevention of the occurrence of osteoporotic fractures.

Several risk factors associated with decreased BMD have been identified in a few previous studies, including aging and menopause in females,[3,4] and body weight.[3,5] Height is also positively associated with BMD in females.[3,5] Although the effects of certain dietary factors such as calcium and phosphorus on BMD have been widely studied in western countries,[6-9] the influence of nutrient intake on bone health in the Taiwanese population has not been well studied.

Although BMD assessed by central dual-energy x-ray absorptiometry (DXA) is recognized as the gold standard for diagnosis of osteoporosis, its use in the screening of osteoporotic patients is limited due to the problems of radiation, cost, and portability. In the Elderly Nutrition and Health Survey in Taiwan (1999-2000) (Elderly NAHSIT), a portable quantitative ultrasound (QUS) device was employed to assess the bone health status of the elderly in Taiwan. The results of broadband ultrasound attenuation (BUA) measured by QUS have been approved for the prediction of osteoporotic fracture risk in the U.S.[10] The objectives of the current study were to examine bone health status measured by BUA, and to explore the factors that

Correspondence address: Dr. Wen-Harn Pan, N141 Institute of Biomedical Sciences, Academia Sinica, #128 Academy Road, Sec. 2, Taipei, 11529, TAIWAN
Tel: +886-2-2789-9121
Fax: +886-2-2782-3047
E-mail: pan@ibms.sinica.edu.tw
Accepted 30 June 2005

may have influenced BUA values in the Taiwanese elderly.

Materials and methods

Design

The data was collected through the Elderly Nutrition and Health Survey in Taiwan (1999-2000) (Elderly NAHSIT), a nationwide survey conducted to investigate the nutrition and health status of elderly people in Taiwan. The 359 townships or city districts in Taiwan were classified into 13 strata according to the characteristics of dietary patterns, geographical location, and degree of urbanization. These 13 strata were: Hakka areas, mountain areas, eastern areas, the PengHu islands, and three strata in each of the northern, central and southern areas. Two population density cut-points were used to divide the northern, cenral, and southern areas into three strata each, respectively. The stratification principle and sampling procedure have been described in detail elsewhere.[11] Briefly, three townhips or districts were selected from each stratum based on the probability proportional to population sizes method. Two villages or city blocks (the smallest administrative level) were selected from each of the 39 townships/ districts. Twenty-six individuals aged 65 years or above were recruited within each village/city block. A pseudo-Latin square design was used to control for the effects of season and year. The survey consisted of two independent components: a questionnaire based interview and a physical examination. A total of 2028 elderly individuals were interviewed, which corresponds to a response rate of 55.2%. There were 2437 participants who completed the physical examination, corresponding to a response rate of 52.8%. In the present study, the bone density data of 2395 participants was used to evaluate the bone health status of the elderly. Out of this number, a total of 752 males and 721 females who also had complete questionnaire and other physical examination data ere included in the regression analyses of the risk fac-tors for low BUA.

Measurements

QUS measurements were performed using the portable CUBA Clinical (McCue Ultrasonics, UK), which measures both broadband ultrasound attenuation (BUA, in dB/MHz) and velocity of sound (VOS, in m/sec). The corresponding Z- and T-scores were generated by the software provided by the manufacturer. Height without shoes and body weight were measured. The weight of clothes was then estimated and subtracted from the weight before calculating Body Mass Index (BMI). Information on other variables in this analysis was obtained through the questionnaires. Education level was expressed as the approximate years of education. Dietary intake of calcium and other related nutrients was assessed by 24-hour dietary recall. Physical activity was assessed

Table 1. Characteristics of subjects by stratum, males

Strata	*N*	BUA[1] (dB/MHz)	Physical Activity (MET)	Education (years)	Calcium/Calories (mg/kcal)	Ca/P ratio (mg/mg)	Ca/Na ratio (mg/mg)	Ca/Protein ratio (mg/g)
		Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Hakka areas	58	68.5 ± 3.7	6.0 ± 1.7	6.8 ± 0.9	0.34 ± 0.02	0.51 ± 0.02*	0.21 ± 0.08	7.53 ± 0.83
Eastern areas	62	76.8 ± 3.6*	3.4 ± 0.9*	5.6 ± 0.5*	0.36 ± 0.10	0.55 ± 0.06	0.13 ± 0.02*	8.50 ± 1.40
Mountain areas	60	74.3 ± 3.2	2.8 ± 1.1*	4.9 ± 0.9*	0.36 ± 0.06	0.56 ± 0.08	0.17 ± 0.03	8.36 ± 1.40
PengHu islands	47	69.2 ± 3.4	4.7 ± 1.5*	6.9 ± 1.0	0.41 ± 0.05	0.62 ± 0.05	0.14 ± 0.02	9.80 ± 0.93
Northern areas: 1st stratum	55	65.3 ± 3.4	9.0 ± 1.1	9.8 ± 1.5	0.36 ± 0.02	0.57 ± 0.02	0.19 ± 0.01	8.27 ± 0.30
Northern areas: 2nd stratum	59	71.6 ± 2.2	5.9 ± 0.7*	8.4 ± 1.1	0.39 ± 0.05	0.60 ± 0.05	0.19 ± 0.02	8.43 ± 1.12
Northern areas: 3rd stratum	56	67.9 ± 2.0	7.0 ± 0.7	7.4 ± 1.9	0.33 ± 0.03	0.56 ± 0.04	0.18 ± 0.02	7.86 ± 0.56
Central areas: 1st stratum	49	69.4 ± 1.2	4.9 ± 0.7*	6.5 ± 0.6*	0.39 ± 0.04	0.61 ± 0.03	0.19 ± 0.03	9.56 ± 0.45*
Central areas: 2nd stratum	61	67.7 ± 1.5	4.3 ± 1.6*	6.2 ± 0.7*	0.32 ± 0.05	0.57 ± 0.05	0.16 ± 0.03	8.30 ± 1.07
Central areas: 3rd stratum	62	64.1 ± 4.1	1.8 ± 0.5**	4.5 ± 0.5*	0.45 ± 0.13	0.60 ± 0.09	0.22 ± 0.10	9.69 ± 2.16
Southern areas: 1st stratum	59	72.4 ± 4.1	7.4 ± 0.7	7.3 ± 1.8	0.34 ± 0.01	0.58 ± 0.03	0.20 ± 0.02	8.95 ± 0.69
Southern areas: 2nd stratum	56	70.9 ± 1.6	5.1 ± 1.3*	8.1 ± 0.9	0.41 ± 0.04	0.58 ± 0.03	0.19 ± 0.01	8.30 ± 0.63
Southern areas: 3rd stratum	70	70.4 ± 2.6	4.6 ± 1.3*	3.2 ± 0.5*	0.38 ± 0.05	0.58 ± 0.04	0.14 ± 0.03	8.85 ± 0.78
Total	752	69.1 ± 0.9	5.7 ± 0.4	6.8 ± 0.4	0.37 ± 0.01	0.58 ± 0.01	0.18 ± 0.01	8.51 ± 0.28

[1] BUA = broadband ultrasound attenuation; Significantly different from the reference level (Northern areas: 1st stratum); *$P<0.05$; *$P<0.0001$.

Table 2. Characteristics of subjects by stratum, females

Strata	*N*	BUA[1] (dB/MHz)	Physical Activity (MET)	Education (years)	Calcium/Calories (mg/kcal)	Ca/P ratio (mg/mg)	Ca/Na ratio (mg/mg)	Ca/Protein ratio (mg/g)
		Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Hakka areas	55	49.6 ± 0.8	4.9 ± 1.1	3.8 ± 1.5	0.40 ± 0.08	0.66 ± 0.07	0.23 ± 0.08	9.78 ± 0.99
Eastern areas	63	50.9 ± 3.8	2.9 ± 0.7*	2.0 ± 0.7*	0.32 ± 0.04	0.59 ± 0.09	0.14 ± 0.04*	8.98 ± 2.04
Mountain areas	68	48.8 ± 5.2	3.1 ± 0.9*	3.7 ± 1.0	0.40 ± 0.09*	0.56 ± 0.03	0.22 ± 0.05	8.21 ± 0.87*
PengHu islands	40	51.3 ± 1.6	3.8 ± 0.5*	1.7 ± 0.4*	0.65 ± 0.13	0.82 ± 0.08	0.35 ± 0.10	15.99 ± 2.33*
Northern areas: 1st stratum	47	53.5 ± 1.8	6.9 ± 0.9	5.9 ± 1.7	0.46 ± 0.06	0.67 ± 0.05	0.27 ± 0.04	10.79 ± 0.85
Northern areas: 2nd stratum	59	45.4 ± 2.5*	5.3 ± 0.6	3.6 ± 0.7	0.46 ± 0.06	0.70 ± 0.06	0.24 ± 0.04	10.90 ± 1.46
Northern areas: 3rd stratum	51	49.1 ± 3.3	5.4 ± 0.4	2.5 ± 0.8	0.43 ± 0.04	0.67 ± 0.02	0.20 ± 0.02	10.62 ± 1.03
Central areas: 1st stratum	44	45.4 ± 4.2	4.7 ± 1.0	3.4 ± 0.8	0.44 ± 0.04	0.65 ± 0.06	0.28 ± 0.04	10.43 ± 1.05
Central areas: 2nd stratum	57	45.6 ± 0.8*	4.1 ± 1.0*	2.0 ± 0.6*	0.40 ± 0.09	0.62 ± 0.10	0.18 ± 0.08	9.18 ± 2.18
Central areas: 3rd stratum	68	45.3 ± 4.1	3.0 ± 0.7*	1.4 ± 0.2*	0.48 ± 0.05	0.72 ± 0.09	0.22 ± 0.01	11.02 ± 1.01
Southern areas: 1st stratum	50	49.1 ± 1.1*	7.0 ± 0.6	2.9 ± 1.4	0.49 ± 0.02	0.63 ± 0.03	0.29 ± 0.04	10.30 ± 0.62
Southern areas: 2nd stratum	50	45.5 ± 1.3*	6.7 ± 0.9	4.5 ± 1.2	0.52 ± 0.08	0.66 ± 0.06	0.21 ± 0.02	11.56 ± 1.32
Southern areas: 3rd stratum	69	47.5 ± 5.1	4.3 ± 0.9	0.8 ± 0.1*	0.55 ± 0.05	0.73 ± 0.07	0.23 ± 0.06	11.80 ± 0.94
Total	721	48.0 ± 1.2	5.1 ± 0.3	3.0 ± 0.3	0.47 ± 0.02	0.68 ± 0.02	0.23 ± 0.02	10.72 ± 0.38

[1]BUA = broadband ultrasound attenuation; Significantly different from the reference level (Northern areas: 1st stratum); *P<0.05; P<0.0001.

by the frequency and average time spent on activities in the preceding month, including cycling, ball games, gymnastics, boxing, swimming, aerobics, country dancing, mountain climbing, jogging, walking, gardening, housework and occupation-related physical activities such as moving/loading objects or mechanical assembly. The amount of physical activity was expressed by the metabolic equivalent (MET) score system. One MET is approximately equal to 3.5 ml of oxygen per kilogram body weight per minute. METs are used to compare the energy expenditures of different activities. The average MET intensity of each physical activity was assigned according to the recently published compendium.[12]

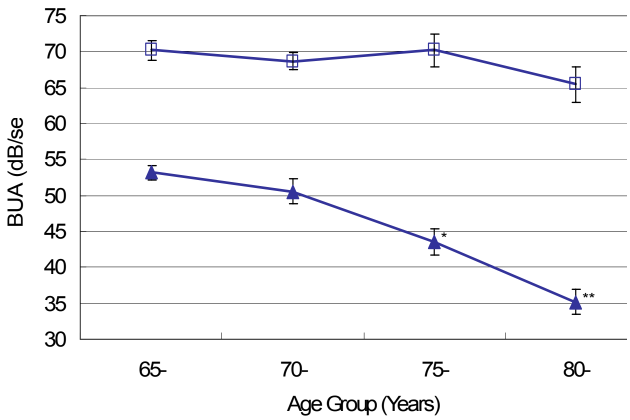

Figure 1. Age trend of BUA in the elderly in Taiwan (males ; females) . Significantly different from the 65-69 year age group, * P<0.05; **P<0.0001.

Statistical analysis

All variables were weighted to represent the elderly population in Taiwan. The first stratum in the northern areas was used as the reference stratum for comparison between strata. At present there are no available values of mean peak BUA and age-matched mean BUA in Taiwan, so the T- and Z-scores of BUA were estimated from the Caucasian data provided by the manufacturer of the QUS device. Univariate regression analyses were performed to evaluate the association between the BUA Z-score and possible related factors. The factors with significant

Elderly males in the mountain areas also had a significantly lower intake of phosphorus, but their sodium intake was significantly higher than males in the first stratum in the northern areas. Dietary calcium density (mg/kcal), however, did not differ across strata (Table 1). In elderly females, those living in the first stratum in the northern areas had higher mean BUA values, a higher

MET, and more years of education (Table 2). In terms of dietary intake, there were no significant differences in the intake of phosphorus or sodium across all strata. Elderly females in the mountain areas had significantly lower mean calcium density than those in the first stratum in the northern areas (Table 2).

Table 3 shows the characteristics of elderly subjects by gender and age group. Compared to the 65-69 year group, elderly males in the age group of 80 and above had a significantly lower mean BUA. However, there were no significant differences in dietary calcium density, ratios of calcium/phosphorus, calcium/sodium, calcium/protein, MET score, or years of education across the four age groups. In females, those in the age groups of 75-79 years and 80 years and above also had significantly lower mean BUA compared to those in the 65-69 year age group. The oldest females also had significantly lower MET scores and the least years of education.

The age-trends of BUA distribution are illustrated in Figure 1. In elderly males the mean BUA did not change significantly with age. In females, however, mean BUA was significantly lower in age groups older than 75 years compared to the reference 65-69 year age group. The distribution of BUA T-scores by age group is shown in Figure 2. In general, most elderly persons in all age groups (> 60%) and for both genders, had a BUA T-score below –2. The proportion of males with a BUA T- scores below –2 ranged from 62-69% across the 4 age groups, and the distribution did not change significantly with age. In females, the proportion having a BUA T-score below –2 increased with age. Only 1% of elderly females aged 80 years and older had a BUA T-score above –1, and 96% of women in this age group had a BUA T-score below –2. The influence of several factors on BUA Z-scores are listed in Table 4. Living in the eastern areas, body weight, BMI, dietary calcium intake (in density format), and the ratio of dietary calcium to dietary sodium were all significant predictors of BUA Z-score in elderly males.

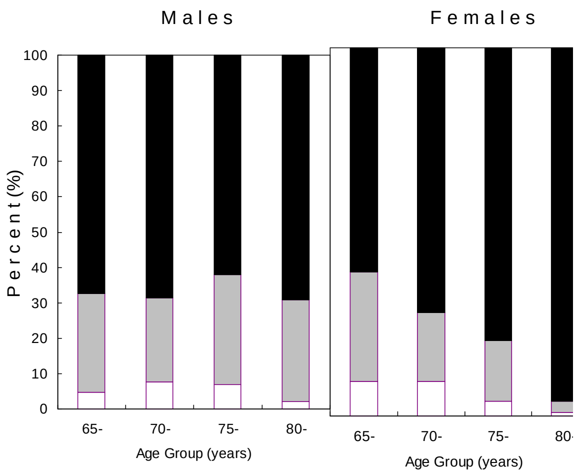

Figure 2. Distribution of BUA T-Scores by age group
□ T-score> -1; ■ T-score from –1 to –2; ■ T-score < -2

In contrast, age and living in the second strata in the northern, central and southern areas were all negatively associated with BUA Z-scores in elderly females. Body weight, height, BMI, years of education, physical activity level (MET score), dietary calcium density, and the ratio of dietary calcium to dietary protein were all positive predictors of BUA Z-scores in elderly females. The above significant factors were then entered into the multivariate model. For dietary calcium-related factors, only one variable was entered into the model. The results showed that BMI and dietary calcium intake were the only two significant predictors of BUA Z-score for elderly males. Living in the second stratum in the southern areas was negatively associated with BUA Z-score in elderly females whereas height, BMI, years of education, and dietary calcium intake had a positive association. The negative effect of age and the positive effect of physical

Table 3. Descriptive statistics of subjects by age group

Age Group (years)	*N*	BUA[1] (dB/MHz)	Physical Activity	Education (years)	Dietary Ca Density[2] (mg/kcal)	Ca/P ratio (mg/mg)	Ca/Na ratio (mg/mg)	Ca/Protein ratio (mg/g)
		Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Male								
65-69	276	69.7 ± 0.9	5.3 ± 0.4	6.7 ± 0.3	0.35 ± 0.02	0.58 ± 0.03	0.19 ± 0.03	8.66 ± 0.58
70-74	266	68.8 ± 1.1	6.0 ± 0.6	6.6 ± 0.4	0.38 ± 0.02	0.57 ± 0.02	0.18 ± 0.01	8.69 ± 0.36
75-79	142	67.9 ± 1.5	5.6 ± 0.6	6.7 ± 0.7	0.39 ± 0.03	0.58 ± 0.03	0.19 ± 0.02	8.88 ± 0.70
≥80	68	64.8 ± 1.9*	4.8 ± 0.7	5.7 ± 1.0	0.33 ± 0.02	0.53 ± 0.03	0.16 ± 0.02	7.69 ± 0.57
Total	752	68.4 ± 0.8	5.5 ± 0.4	6.7 ± 0.4	0.36 ± 0.01	0.57 ± 0.01	0.18 ± 0.01	8.58 ± 0.28
Female								
65-69	302	51.9 ± 0.7	5.4 ± 0.3	3.4 ± 0.4	0.47 ± 0.03	0.68 ± 0.02	0.24 ± 0.02	10.55 ± 0.41
70-74	228	50.3 ± 1.3	4.8 ± 0.4	3.0 ± 0.4	0.50 ± 0.02	0.70 ± 0.03	0.24 ± 0.02	11.30 ± 0.46
75-79	115	43.8 ± 1.2**	4.2 ± 0.6	2.4 ± 0.5	0.43 ± 0.03	0.66 ± 0.02	0.22 ± 0.02	10.61 ± 0.72
≥80	76	34.6 ± 1.2**	2.6 ± 0.5*	1.0 ± 0.4**	0.42 ± 0.04	0.63 ± 0.05	0.03 ± 0.04	9.97 ± 0.75
Total	721	47.1 ± 0.9	4.5 ± 0.3	2.7 ± 0.3	0.47 ± 0.02	0.67 ± 0.02	0.24 ± 0.01	10.68 ± 0.29

[1]BUA = broadband ultrasound attenuation; [2] Dietary calcium intake by total calories, estimated from 24-hour dietary recall; Significantly different from the reference group (age 65-69 years); **P*<0.05; ***P*<0.0001.

activity became less significant in the multivariate model. To verify the effect of dietary calcium intake on BUA Z-score and the influence of other nutrients on dietary calcium, we performed some more in-depth analyses by grouping the subjects according to their nutrient intake status. Figure 3 demonstrates that elderly males with a dietary calcium density in the 2nd, 3rd and highest quartiles all had significantly higher BUA Z-scores than those with a dietary calcium density in the lowest quartile. Elderly females with a dietary calcium density in the highest quartile had significantly higher BUA Z-scores than those in the 3rd, 2nd and lowest quartiles.

When subjects were grouped by their calcium and sodium or protein intake status based on the median level in density form, it appeared that elderly males with lower calcium density but higher sodium density had signiicantly lower BUA Z-scores than those with higher calium density regardless of sodium density status (Fig. 4). Similar results were also observed in elderly females with a less significant difference in BUA Z-score (Fig. 4). Elderly males with lower calcium density and lower protein intake had a significantly lower BUA Z-score than those with higher protein intake regardless of calcium density status (Fig. 5).

Discussion

In the Elderly Nutrition and Health Survey in Taiwan, we attempted to assess the bone health status of the elderly

Table 4. Regression of risk factors on BUA Z-Score

Variables	Males (N = 752)		Females (N = 721)	
	β (P value)[1]	β (P value)[2]	β (P value)[1]	β (P value)[2]
Age (Years)	-0.0024 (0.761)		-0.0347 (0.0001)	-0.0120 (0.082)
Strata				
Hakka areas	0.1087 (0.735)	0.1554 (0.605)	-0.2252 (0.197)	-0.0853 (0.343)
Mountain areas	0.4984 (0.067)	0.4450 (0.155)	-0.3296 (0.303)	0.0889 (0.799)
Eastern areas	0.6306 (0.029)	0.5858 (0.071)	-0.2353 (0.418)	0.0996 (0.669)
PengHu islands	0.2518 (0.356)	0.2203 (0.458)	-0.1737 (0.427)	-0.1211 (0.363)
Northern areas: 1st stratum[3]	-	-	-	-
Northern areas: 2nd stratum	0.3438 (0.144)	0.3044 (0.231)	-0.5097 (0.030)	-0.3099 (0.065)
Northern areas: 3rd stratum	0.1394 (0.546)	0.1214 (0.638)	-0.2326 (0.088)	0.0452 (0.838)
Central areas: 1st stratum	0.2395 (0.248)	0.2504 (0.294)	-0.4838 (0.376)	-0.2677 (0.190)
Central areas: 2nd stratum	0.1179 (0.568)	0.1586 (0.508)	-0.5024 (0.004)	-0.0940 (0.369)
Central areas: 3rd stratum	-0.0674 (0.817)	-0.0313 (0.913)	-0.4015 (0.162)	-0.1176 (0.697)
Southern areas: 1st stratum	0.3788 (0.210)	0.2741 (0.410)	-0.2587 (0.137)	-0.0660 (0.573)
Southern areas: 2nd stratum	0.3094 (0.155)	0.2707 (0.284)	-0.4447 (0.020)	-0.2872 (0.034)
Southern areas: 3rd stratum	0.2380 (0.323)	0.2902 (0.281)	-0.3522 (0.259)	-0.0827 (0.610)
Body Weight (kg)	0.0235 (<0.0001)		0.0365 (<0.0001)	
Height (cm)	0.0132 (0.148)		0.0368 (0.002)	0.0255 (0.025)
BMI (kg/m^2)	0.0698 (<0.0001)	0.0668 (<0.0001)	0.0765 (<0.0001)	0.0687 (<0.0001)
Education (years)	0.0028 (0.829)		0.0340 (0.004)	0.0174 (0.044)
MET Score	0.0037 (0.633)		0.0373 (0.001)	0.0190 (0.092)
Total Calories[4]	-0.00003 (0.372)		0.00006 (0.211)	
Dietary Ca Density (mg/kcal)[4]	0.2692 (0.027)	0.2391 (0.026)	0.3623 (0.007)	0.2653 (0.019)
Dietary Ca/P ratio	0.1648 (0.089)		0.2355 (0.065)	
Dietary Ca/Na ratio	0.3232 (0.018)		0.3628 (0.069)	
Dietary Ca/Protein ratio	0.0067 (0.269)		0.0168 (0.017)	
Model R^2		0.079		0.2136

[1]Results of age-adjusted univariate analysis; [2]Results of multivariate analysis; [3]Reference group; [4]Dietary intake estimated from 24-hour recall methods

by using a portable QUS device. The results showed that in elderly males in Taiwan, higher BMI and intake of dietary calcium was positively associated with a higher BUA Z-score. In contrast, age, residing location, height, physical activity, or years of education did not significantly predict BUA Z-score (Table 4). In elderly women, age and living in the second strata in the northern or southern areas appeared to be negatively associated with BUA Z-scores, BMI, height, years of education, and intake of dietary calcium were positive predictors of BUA Z-score. Although living in strata other than the first stratum in the northern areas appeared to be negatively associated with BUA Z-score in the univariate analysis, the effect remained significant only for living in the second stratum in the southern areas in the multivariate analysis.

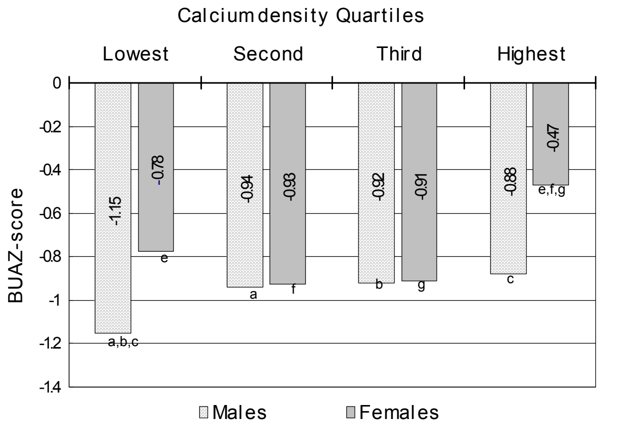

Figure 3. BUA Z-score by dietary calcium intake (as calcium density) quartiles; calcium density quartiles: for males: lowest <0.1467, second 0.1467-0.2712, third 0.2712-0.4954, highest ≥0.4954; for females: lowest <0.1707, second 0.1707-0.3358, third 0.3358-0.6445, highest ≥ 0.6445; bars with the same letter are significantly different, $P<0.05$ *$0.05 \le P<0.1$

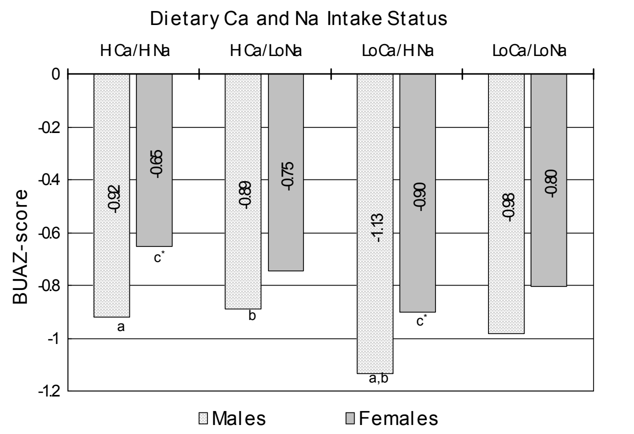

Figure 4. BUA Z-score by dietary calcium and sodium intake status (H=high, Lo=low). Median 24-h dietary Ca intake (density): males = 0.2712 (mg/kcal), females = 0.3358 (mg/kcal); Na intake (density): males = 2.3736 (mg/kcal), females = 2.3608 (mg/kcal); bars with the same letter are significantly different, $P<0.05$ *$0.05 \le P<0.1$.

This suggests that the effect of residing location on BUA may be in part accounted for by other factors (Table 4). In addition, the positive association between physical activity (MET score) and BUA Z-score in elderly females became less significant in the multivariate model (Table 4). It is possible that the effect of physical activity is also partially explained by other factors such as geographical location or education level.

Although the QUS device we employed in the survey has been approved by the US FDA for the prediction of fracture risk, the prevalence of high fracture risk in the elderly population in Taiwan cannot be estimated from the T-score values generated by the device as the default reference for calculating T- or Z- scores are based on Caucasian BUA data. The BUA Z-score value can be considered the result of comparing the BUA measurements of our elderly subjects to that of Caucasian elderly persons of the same age and sex. It appeared that the BUA measurements of Taiwanese elderly males were uniformly 1 standard deviation lower than Caucasian elderly males of the same age group. The BUA measurements of Taiwanese elderly females were about 0.7-0.75 standard deviations below the Caucasian female mean values for the 65-69 and 70-74 year age groups, and the discrepancies increased to 0.88 and 1.22 standard deviations for the two older age groups. It seems that the bone mass and bone structure of the Taiwanese elderly were poorer than Caucasian elderly persons of the same age according to the results of the BUA Z-scores. It has been reported that BMD is similar in the lumbar spine but lower in the hip region in Taiwanese persons compared to European and American Caucasians.[3,13] Whether the reference BUA values would be similar for Taiwanese and Caucasians, and whether the fracture risk for Taiwanese elderly would be the same as for Caucasians at given BUA levels requires future studies to explore.

In this cross-sectional survey, we assessed dietary intake of nutrients by 24-hour recall. Results of regression analyses revealed that dietary calcium intake, controlled for the effect of total calories, was positively associated with BUA Z-score in both genders, and the effect remained significant in the multivariate models (Table 4). When we performed more detailed analysis by grouping subjects according to the dietary calcium density quartiles (≥0.4954 mg/kcal for males; ≥0.6445 for females), the results showed that both elderly men and women with dietary calcium density in the highest quartile had significantly higher BUA Z-scores (Fig. 3). Taking into account the mean energy intake of 1900 kcal/day for males and 1500 kcal/day for females in our current analysis, the above calcium densities are approximately 941 mg and 967mg of calcium for males and females, respectively, which are quite close to the current recommended level of 1000 mg/day for the elderly in our country.[14] It has been demonstrated in a meta-analysis that consumption of 1000 mg Ca/day can reduce the risk of a hip fracture by 24%.[15] Several other studies also reveal that additional calcium intake by dietary intake or supplementation has positive effects on increasing or maintaining BMD in mid to late postmenopausal women,[6,7,16,17] and the improvement is greatest in those with low base-

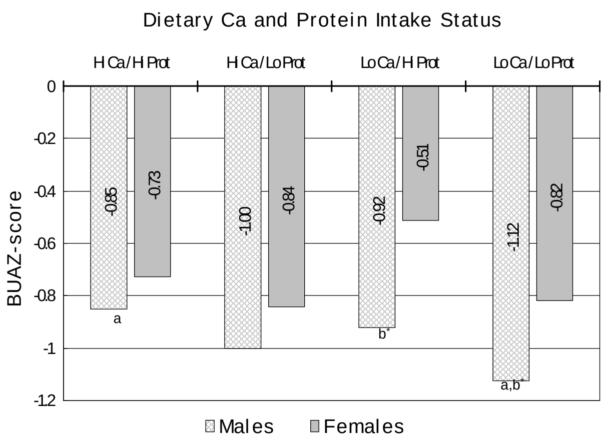

Figure 5. BUA Z-score by dietary calcium and protein intake status (H=high, Lo=low); median 24-h dietary Ca intake (density): males = 0.2712 (mg/kcal), females = 0.3358 (mg/kcal); protein intake (% of total energy intake): males = 16.06%, females = 16.16%; bars with the same letter are significantly different, P <0.05 *0.05 ≤ P <0.1

line calcium intake.[6] Increasing calcium intake in the elderly may provide protection against osteoporotic fractures and thus should be considered an important public health policy.

In our further analyses we also took into consideration some other dietary nutrients that may influence the effects of calcium. When subjects were grouped according to their dietary intake of calcium and sodium and data controlled for the effect of total energy intake, the results showed that for elderly males with lower calcium intake (<0.2712 mg/kcal) and higher sodium intake (≥2.3736 mg/kcal), the BUA Z-score was significantly lower than those with higher calcium intake regardless of the intake level of sodium (Fig. 4). Similar results were also observed in females with less significance. In contrast, if subjects were grouped according to their dietary intake of calcium and protein, it appeared that elderly males with lower calcium intake (<0.2712mg/kcal) and lower protein intake (<16.06% of total energy) had significantly lower BUA Z-scores than those with higher intakes of both calcium and protein, or higher protein intake but lower calcium intake (P = 0.07) (Fig. 5). These results seem to be consistent with the findings from other studies in western countries that high dietary sodium intake is significantly associated with urinary calcium loss and decreased BMD,[18,19] and that higher protein intake has a positive effect on reducing bone loss in elderly persons supplemented with calcium and vitamin D.[20]

Although QUS has been implicated as a convenient tool in screening individuals at high risk of fracture, its application in the diagnosis of osteoporosis is limited. The current WHO definition of osteoporosis is based on BMD measurement at spine, hip, or forearm using DXA,[21] and the results from QUS scans cannot be evaluated using the WHO diagnostic criteria. It has been suggested that the false negative rate may be as high as 10% when patients are tested for osteoporosis using QUS.[22] In addition, the precision of QUS is relatively poor compared to DXA.[23] The inconsistent correlation between QUS measurements and BMD by DXA could result in considerable discordance in the diagnosis of osteoporosis.[24] The appropriate thresholds for fracture risk that are equivalent to those defined for DXA measurements need to be established before QUS can be recommended for extensive use in diagnosing osteoporosis.

In summary, the results of the current analysis show that the elderly population in Taiwan may have a problem of low bone mass based on assessments using QUS. BMI and dietary calcium intake were positive predictors of BUA Z-score in elderly males, whereas BMI, height, years of education, and dietary calcium intake were positively associated with BUA Z-score in elderly females. The effects of dietary calcium intake may be influenced by the intake of other nutrients such as sodium and protein. Understanding whether the effects of nutrient intake on bone mass reflect certain types of dietary patterns, and whether different sources of dietary protein (animal vs. plant) would influence the effects on bone requires further studies.

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