Original Article

Bone mass status of school-aged children in Taiwan assessed by quantitative ultrasound: the Nutrition and Health Survey in Taiwan Elementary School Children (NAHSIT Children 2001-2002)

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Bone health status in childhood and adolescence may be important factors influencing the attainment of peak bone mass. The Nutrition and Health Survey in Taiwan Elementary School Children 2000-2001 was carried out to evaluate the overall nutrition and health status of school children aged between 6 and 13 years. The survey was conducted using a multi-stage complex sampling scheme. Townships and city districts in Taiwan were classified into 13 strata. Bone mass measured as broadband ultrasound attenuation was taken at heel by quantitative ultrasound bone densitometry. A total of 1164 boys and 1016 girls who had complete physical examination data with ultrasound bone scan were included in the current analysis. There were no apparent differences in BUA across all strata for both genders. In both boys and girls, age, height, body weight, BMI, and intake frequencies of vegetables and fruits/juices were significantly related to BUA. Results of multivariate regression showed that age (β=1.36, p=0.0002) and body weight (β=0.40, p<0.0001) were significant predictors for BUA in boys, whereas in girls body weight (β =0.47, p<0.0001), height, (β =0.20, p=0.01), dietary phosphorus intake (β =-0.002, p=0.038), and frequency of fruit/juice intake (β =0.15, p=0.029) remained statistically significant. The differential effects dietary intake variables on BUA in boys and girls may be in part due to the development of puberty. It would be necessary to include levels of physical activity in future analyses for better understanding factors influencing the development of peak bone mass in Taiwanese children.

Key Words: bone, Taiwan, children, QUS, survey

INTRODUCTION

Osteoporosis has become a growing public health problem as the elderly population expands rapidly in Taiwan in recent decades. The risk of developing osteoporotic fractures due to low bone mass may be reduced by maximizing peak bone mass (PBM) in earlier life and/or by minimizing the rate of bone loss in later life.[1] It is estimated that as high as 40% of the fracture risk may be reduced by an increase in bone mass of 5%.[2-3] The attainment of optimal PBM in early life thus appears to be an effective way to prevent osteoporosis.

It has been shown that inadequate bone gain during childhood and adolescence may increase the risk of low bone mass or developing osteoporosis in adulthood.[4-6] There are several known environmental factors that affect the accrual of bone mass in early life. In general, children with heavier weight, higher calcium or dairy intake, and adequate weight-bearing exercise tend to have higher bone mass.[7-9] In addition, it has been suggested bone health status is also under the influence of genetic factors, or the heritability of bone mass.[10-11] The daughters of osteoporotic women appear to have lower bone mass than the controls.[12-14] The relationship between birthweight and bone mass in adolescence and/or adulthood has also been demonstrated.[15] Through the examination of the risk factors, it may be possible to identify the children and/or adolescents at risk for low bone mass, and providing opportunities to prevent the occurrence of fractures in later stage of life.

Although bone mass assessed by central dual-energy x-ray absorptiometry (DXA) is recognized as gold standard in the diagnosis of osteoporosis, its use in the screening for osteoporotic patients is limited due to the problems of radiation, cost, and portability. In the second Nutrition and Health Survey in Taiwan (NAHSIT), a portable quantitative ultrasound (QUS) device was employed to assess the bone health status of the elderly and the school children in Taiwan.[16]

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The objectives of the current study were to examine the bone health status reflected by BUA measurement, and to explore the influences of demographic, anthropometric, and dietary factors on the BUA measurement in the Taiwanese elementary school children.

MATERIALS AND METHODS

Design

The data was collected through the Nutrition and Health Survey in Taiwan's Elementary School Children 2001-2002 (NAHSIT Children 2001-2002), an island-wide survey conducted to investigate the nutrition and health status of the school children in Taiwan. The 359 townships or city districts in Taiwan were classified into 13 strata according to the characteristics of dietary pattern, geographical location, and degree of urbanization. These 13 strata were the Hakka areas, the mountain areas, the eastern areas, the Peng-Hu Islands, Northern areas Class I - III districts/townships (1^{st} - 3^{rd} stratum), Central areas Class I - III districts/townships (1^{st} - 3^{rd} stratum), and Southern areas Class I – III districts/townships (1^{st} - 3^{rd} stratum). Two population density cut-points were used to divide Northern, Central, and Southern areas into three classes, respectively. The stratification principle has been described in details elsewhere.[17] The sampling procedure is briefly described as below: all registered municipal or private elementary schools were ranked within each stratum according to their location and number of registered students. Eight schools were selected from each stratum with selection probability proportional to population sizes (PPS). In each of the six grades four students were randomly selected, and a total of 24 students aged between 6 and 13 years were recruited within each sampled school. Details are described elsewhere.[14] The study was approved by reviewers from the Department of Health in Taiwan, and the informed consent has been signed by one of the parents of all school children. The survey is consisted of questionnaire interview and physical examination. A total of 2419 school children were interviewed, which corresponds to a response rate of 73.6%. In the present study, the bone data of 1164 boys and 1016 girls who had complete physical examination data with ultrasound bone scan were included.

Measurements

QUS measurements were performed using a portable CUBA Clinical device (McCue Ultrasonics, UK), which measures the broadband ultrasound attenuation (BUA, in dB/MHz). All subjects were examined by the same one device during the survey. Other anthropometric measurements were taken in physical examination sessions. Height without shoes and body weight was measured, and the weight of clothes has been estimated and reduced. Body mass index (BMI, body weight in kg by height in m^2) was calculated. Dietary intake of nutrients was

Table 1. Characteristics by gender and stratum[†]

Gender/ Stratum	N	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)	BUA (dB/MHz)	Dietary Ca (mg/d)	Dietary P (mg/day)
Boys								
Hakka	90	9.5±0.2	33.9±1.2	136±1.2	17.9±0.5	48.4±0.8	542±21	1083±49
Mountainous	87	9.4±0.1	30.2±0.5[**]	131±1.0[**]	17.3±0.2[**]	49.3±1.4	346±28[***]	964±55[*]
Eastern	91	9.4±0.1	32.5±0.7[**]	134±0.8	17.6±0.3[*]	46.3±1.6	490±67	1032±67
PengHu Is.	103	9.5±0.1	32.5±0.9[*]	135±1.0	17.5±0.3[**]	49.9±0.9	551±44	1112±57
Northern 1st	72	9.5±0.2	35.7±1.3	137±1.3	18.7±0.5	48.6±1.5	519±32	1097±41
Northern 2nd	85	9.5±0.2	35.7±1.0	137±1.3	18.7±0.4	49.2±1.2	525±20[*]	1010±40
Northern 3rd	91	9.4±0.2	33.9±0.7	136±1.3	18.0±0.2	49.0±1.4	500±54	1060±81
Central 1st	90	9.5±0.2	35.8±1.6	136±1.8	18.7±0.4	49.4±1.4	685±43[**]	1318±49[**]
Central 2nd	109	9.5±0.1	35.3±1.1	136±1.3	18.6±0.3	47.8±1.3	500±53	1095±81
Central 3rd	95	9.6±0.1	36.1±1.3	137±1.0	18.7±0.4	51.2±1.8	493±37	1166±69
Southern 1st	81	9.5±0.1	37.7±1.2	138±0.9	19.4±0.5	48.2±2.0	608±34[†]	1255±48
Southern 2nd	83	9.4±0.1	35.7±1.1	136±0.9	18.8±0.5	47.4±1.5	598±71	1345±124[*]
Southern 3rd	87	9.4±0.1	35.4±0.8	136±1.1	18.7±0.1	49.6±1.6	520±70	1103±104
Total	1164	9.5±0.1	35.3±0.4	136±0.4	18.6±0.1	48.8±0.9	543±14	1130±22
Girls								
Hakka	72	9.4±0.1	31.4±0.7[**]	134±1.0	17.1±0.3[*]	47.4±1.8	440±36	955±63
Mountainous	99	9.3±0.2	31.4±0.8[**]	132±0.9[**]	17.6±0.3	47.6±1.6	353±37[**]	817±31[**]
Eastern	98	9.4±0.2	33.1±1.1	135±1.3	17.6±0.3	47.1±1.5	540±78	950±69
PengHu Is.	83	9.5±0.1	31.6±1.2[*]	135±1.4	16.8±0.3[**]	48.7±1.6	458±64	936±80
Northern 1st	69	9.5±0.2	34.2±1.0	137±1.4	17.9±0.3	48.7±1.2	539±55	1102±100
Northern 2nd	68	9.5±0.2	35.7±1.0	136±1.2	17.0±0.3[*]	48.7±1.3	483±34	914±60
Northern 3rd	73	9.3±0.2	32.2±0.9	136±1.3	17.4±0.3	46.3±1.8	448±56	895±64[*]
Central 1st	85	9.5±0.2	32.0±1.1	137±1.5	17.4±0.3	48.4±2.3	547±46	1057±41
Central 2nd	87	9.6±0.2	33.3±1.1	136±1.5	18.0±0.4	47.8±1.8	478±29	960±51
Central 3rd	66	9.5±0.1	34.0±0.8	136±0.6	17.6±0.4	47.2±3.1	523±88	1090±76
Southern 1st	61	9.5±0.2	33.3±0.8[*]	137±1.1	16.8±0.2[**]	45.1±1.9	593±34[**]	1089±52
Southern 2nd	81	9.5±0.2	32.1±0.9	136±1.5	17.5±0.4	45.2±1.4[*]	479±45	1122±98
Southern 3rd	74	9.4±0.2	34.1±1.3	135±1.3	18.2±0.4	49.1±3.6	464±43	1014±77
Total	1016	9.5±0.1	33.0±0.3	136±0.4	17.5±0.1	47.7±1.9	497±14	1010±23

[†]Mean±SE. Significantly different from the reference level (Northern areas 1st stratum): [*] $0.05<p<0.1$; [**]$p<0.05$; [***] $p<0.0001$

assessed by 24-hour dietary recall during household questionnaire interview.[17-18] A food frequency questionnaire was also administered during the questionnaire interview session to obtain the frequency of consumption of various food items.[15] The frequency of intake was defined by the number of times per week the food group was consumed, and the questionnaire was jointly answered by parents and child based on the child's actual eating patterns in the month prior to the survey.[19]

Statistical Analysis

All variables were weighted to represent the school-aged population in Taiwan. The northern areas 1st stratum was used as the reference level for the comparison between strata. Regression analyses were performed to evaluate the association between the BUA measurement and the possible related factors. All descriptive statistics and regression analyses were performed using SAS-Callable SUDAAN version 9.0.

RESULTS

The characteristics of subjects by gender and stratum are shown in Table 1. There appeared to be some differences in weight and BMI exist between other strata and Northern areas 1st stratum for both genders. Comparing with boys and girls living in the northern first stratum, those living in the mountainous areas appeared to be significantly lighter in body weight, shorter in height, and had lower intakes in dietary calcium and phosphorus. The values of BUA measurement for boys and girls in each stratum, however, did not markedly differ from those living in the northern 1st stratum. Boys living in the 3rd stratum in the central region and girls of Southern areas 3rd stratum had the highest mean BUA, but the values did not significantly higher than that of their counterparts in Northern areas 1st stratum.

Table 2 shows the characteristics of the children by gender and age group. For both boys and girls, weight, height, BMI, and BUA all increase with advancing age, whereas dietary intakes of calcium and phosphorus did not appear to differ by age groups. The age trend of BUA is also illustrated in Figure 1. The trends of increase in BUA with age in boys and in girls were similar. The mean dietary calcium intakes, assessed by 24-hour diet recall method, were lower than 600 mg/day in all gender-age groups of children, with the highest intakes were observed in boys of 6-6.99 years and girls of 12-12.99 years. The ratio of calcium to phosphorus ranged from 0.44 to 0.51 in boys and from 0.47 to 0.53 in girls.

Figure 2 depicts the mean dietary calcium intake by age group with comparison to the levels of dietary refenence intake (DRI) in Taiwan. The mean dietary calcium intake of boys 6-6.99 year-old is the only age-gender group that met the level of DRI. In fact, 84.6% of boys and 98.4% of girls aged 6-9, and 98.4% of boys and 100.0% of girls aged 10-12 had dietary intakes of Ca below the recommended levels for their age.[18]

Figure 3 illustrates the mean energy intake by age group with comparison to the levels of dietary refenence intake (DRI) in Taiwan. In general, the mean energy intake of children in all age groups is higher than recommended levels.

In Table 3, the results of correlation analyses for the intake frequency of selected foods and BUA were listed. No significant correlations were observed for the children between the intake frequency of milk, counting individually or together with yogurt, and BUA measurement. There was, however, a significantly positive correlation between intake frequency of yogurt and BUA found in girls (p=0.036). In both genders, frequencies of consuming vegetables (r=0.112 for boys and r=0.140 for girls, respectively; p<0.0001) or fruits (including fresh juices) (r=0.059, p=0.047 for boys and r=0.140, p<0.0001 for girls, respectively) were found to be positively related to

Table 2. Characteristics by gender and age group†

Gender/ Age Group	N	Weight (kg)	Height (cm)	BMI (kg/m^2)	BUA (dB/MHz)	Dietary Ca (mg/d)	Dietary Ca Density (mg/kcal)	Dietary P (mg/d)	Dietary P Density (mg/kcal)	Ca/P Ratio
Boys										
6-6.99	89	25.2±0.8	120.3±0.6	17.2±0.4	39.4±1.6	598±64	0.33±0.05	1111±58	0.59±0.03	0.51±0.03
7-7.99	214	26.8±0.4	124.9±0.4	17.0±0.2	41.0±0.6	561±33	0.30±0.02	1115±43	0.57±0.01	0.50±0.02
8-8.99	201	30.1±0.6	130.3±0.4	17.6±0.3	44.7±0.8	497±32	0.26±0.01	1030±40	0.53±0.01	0.47±0.02
9-9.99	186	34.8±0.8	135.8±0.6	18.6±0.3	48.7±0.9	513±29	0.25±0.01	1106±36	0.53±0.01	0.46±0.01
10-10.99	195	38.9±.0.8	141.4±0.5	19.3±0.3	53.2±0.8	535±36	0.25±0.01	1165±47	0.54±0.01	0.45±0.02
11-11.99	200	44.3.±0.9	147.9±0.6	20.1±0.3	55.6±0.9	556±32	0.25±0.01	1186±48	0.53±0.01	0.46±0.02
12-12.99	79	50.0±1.7	155.7±1.0	20.4±0.5	60.1±1.8	587±66	0.23±0.02	1244±92	0.52±0.02	0.44±0.03
Total	1164	35.3±0.4	136.3±0.4	18.6±0.1	48.8±0.9	543±14	0.27±0.01	1130±22	0.54±0.01	0.48±0.01
Girls										
6-6.99	82	22.8±0.7	118.6±0.6	16.1±0.4	38.5±1.2	524±42	0.29±0.02	1028±71	0.57±0.03	0.49±0.03
7-7.99	160	25.3±0.5	123.8±0.5	16.4±0.2	40.8±0.9	449±36	0.27±0.02	888±42	0.54±0.01	0.50±0.02
8-8.99	175	28.7±0.5	130.2±0.5	16.8±0.2	44.1±0.7	440±24	0.26±0.02	951±34	0.55±0.02	0.47±0.02
9-9.99	163	33.1±0.8	135.8±0.6	17.8±0.4	47.8±1.1	492±25	0.27±0.01	995±43	0.54±0.01	0.50±0.02
10-10.99	177	35.5±0.7	141.8±0.5	17.5±0.3	50.0±1.0	551±34	0.29±0.02	1069±43	0.56±0.02	0.51±0.02
11-11.99	165	41.0±0.8	147.4±0.6	18.7±0.3	53.3±1.1	496±30	0.25±0.01	1081±40	0.54±0.02	0.48±0.02
12-12.99	94	47.0±1.6	153.4±0.9	19.8±0.6	61.0±2.0	585±45	0.31±0.03	1119±65	0.56±0.02	0.53±0.03
Total	1016	33.0±0.3	135.7±0.4	17.5±0.1	47.7±1.9	497±14	0.27±0.01	1009±23	0.55±0.01	0.49±0.01

†Mean±SE

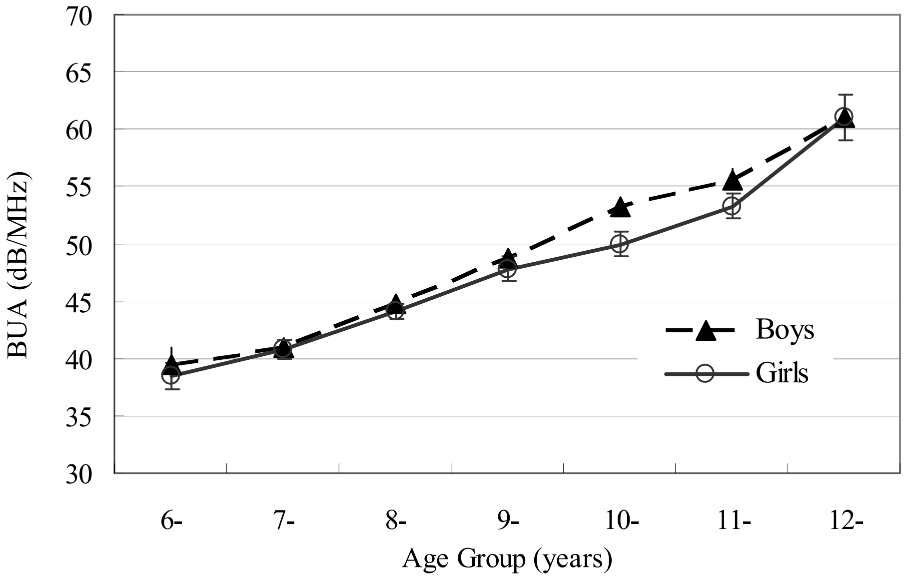

Figure 1. Age trend of BUA in the children in Taiwan

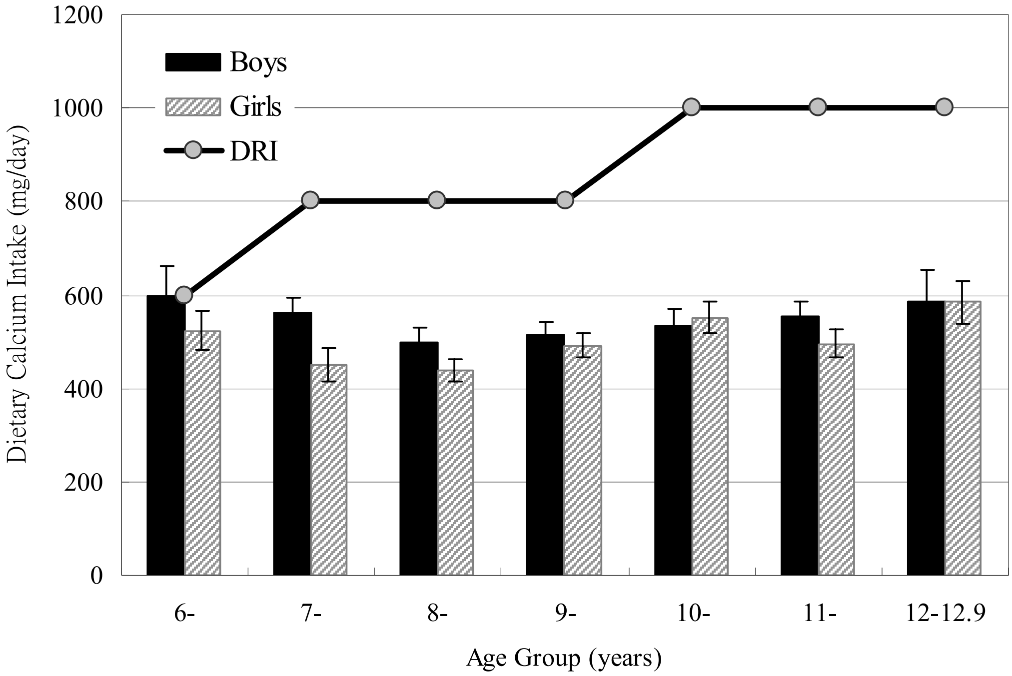

Figure 2. Mean dietary calcium intake and SE of boys and girls in Taiwan. † DRI, dietary reference intake for calcium in Taiwan. For 6-6.9 years of age, 600 mg/d; for 7-9.9 years of age, 800 mg/d; for 10-12.9 years of age, 1000 mg/d

BUA.

The influences of selected factors on BUA are listed in Table 4. In both genders, there were significant positive relationships between age and BUA (β=3.76 for boys and β=3.45 for girls, $p<0.0001$), and body weight appeared to be the most significant predictor (β=0.65, r^2=0.357 for boys and β=0.72, r^2=0.373 for girls, respectively; $p<0.0001$). Height (β=0.60, r^2=0.355 for boys and β=0.58, r^2=0.348 for girls, respectively; $p<0.0001$) and BMI (β=1.46, r^2=0.185 for boys and β=1.71, r^2=0.194 for girls, respectively; $p<0.0001$) were also positively related to BUA. In both boys and girls, residing location was not significantly related to BUA. The relationships between dietary intakes of calcium, calcium density (mg/kcal), phosphorus, or phosphorus density (mg/kcal) and BUA were also not significant in boys, whereas a trend toward significance was observed in the negative relationship between dietary phosphorus intake and BUA in girls (β=-0.001, r^2=0.265; p=0.057). The positive correlations between BUA and the frequency of vegetable intake in boys (β=0.15, p=0.039) and the frequency of fruit/juice consumption in girls ((β=0.17, p=0.029) remained significant in the bivariate models when age was also included. When factors with significance in the univariate/bivariate analyses (age, body weight, and height, intake frequency of vegetables for boys; age, body weight, height, dietary phosphorus intake, and frequency of fruit/juice consumption for girls) were taken into account simultaneously in the multivariate models, the effect of height did not reach a statistically significant level (p=0.063) for boys, and the

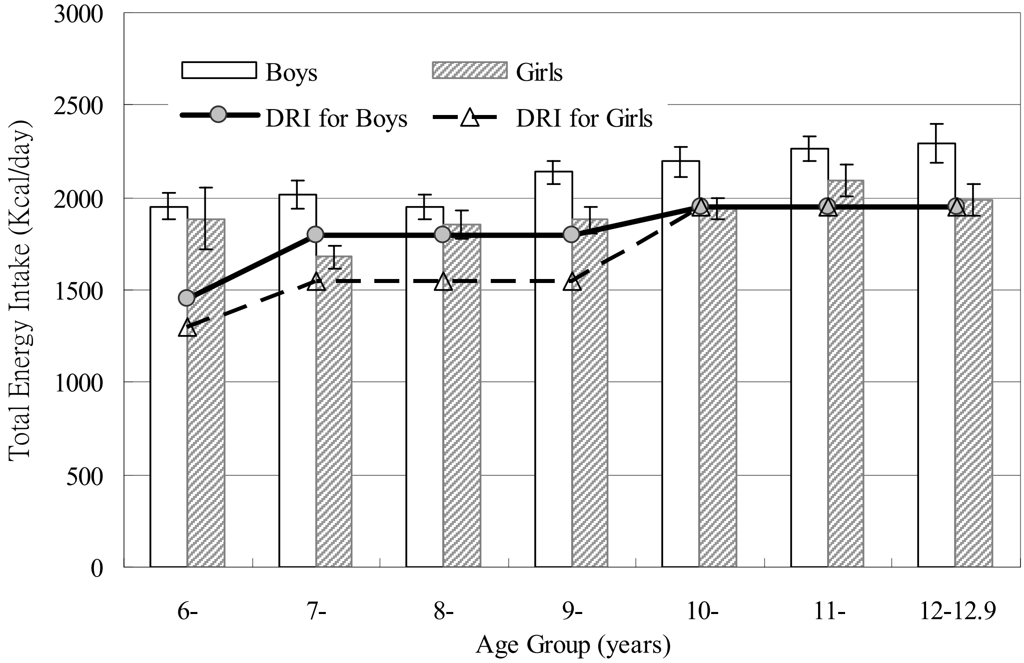

Figure 3. Mean energy intake and SE of boys and girls in Taiwan. † DRI, dietary reference intake for total energy in Taiwan. For 6-6.9 years of age, 1450 kcal/d for boys and 1300 kcal/d for girls; for 7-9.9 years of age, 1800 kcal/d for boys and 1550 kcal/d for girls; for 10-12.9 years of age, 1950 kcal/d for both genders

Table 3. Correlation between intake frequency of selected foods and BUA by gender

Gender/ Food Item or Food Group	Sample Size for Analysis	Range of Intake Frequency	Correlation Coefficient with BUA
Boys			
Milk (cups/week)	954	0.25-24.5	-0.055
Yogurt (cups/week)	519	0.25-17.5	-0.037
Dairy† (cups/week)	477	0.50-42.0	-0.018
Vegetables (dishes/week)	1154	0.25-24.5	0.112**
Fruits/Juices (times/week)	1146	0.25-24.5	0.059*
Girls			
Milk (cups/week)	827	0.25-24.5	-0.006
Yogurt (cups/week)	484	0.25-17.5	0.095*
Dairy (cups/week)	427	0.50-42.0	0.051
Vegetables (dishes/week)	1006	0.25-24.5	0.140**
Fruits/Juices (times/week)	998	0.25-24.5	0.140**

† Dairy food group include intake frequencies of milk and yogurt. Statistically significant correlation coefficient * $p<0.05$; ** $p<0.0001$

effect of intake frequency of vegetables also became insignificant ($p=0.363$). In the multivariate model for girls, body weight, height, dietary phosphorus intake, and the frequency of fruit/juice intake remained significant predictors, whereas age was no longer a significant predictor. The proportions of total variance in BUA explained by the multivariate models were 40.1% for boys and 41.2% for girls, respectively.

DISCUSSION

In the current study with data collected in school-aged children in the NAHSIT Children 2001-2002, we found that the results of BUA did not significantly differ between strata, and that BUA basically increased with advancing age. Age, body weight, and height were positively related to BUA for both boys and girls, and dietary intake of phosphorus appeared to have negatively relationship with BUA in girls. Dietary intakes of calcium, whether in absolute amount or as a nutrient density, were not significant factors in predicting BUA in these elementary school children. The effect of intake frequency of vegetables became insignificant in the multivariate regression model for boys, whereas intake frequency of fruits/juices remained positively and dietary phosphorus intake remained negatively related to BUA for girls when other factors were also included in the model.

It has been suggested that maximization of bone mass acquired in childhood and adolescence to attain an optimal peak bone mass may be the best protection against osteoporosis, and dietary intake of calcium and/or dairy products as well as adequate physical activity have been found to play important roles in enhancing bone health.[1, 4-6, 20] Two studies in Japan and China also demonstrated the importance of calcium nutrition and exercise in children bone health.[21-22] In this survey of the school-aged children in Taiwan, we did not observe any positive

Table 4. Regression of selected factors on BUA by gender

Variable	Boys (n=1164)				Girls (n=1016)			
	β (*p*-value)†	r^2	β (*p*-value)‡	r^2	β (*p*-value)†	r^2	β (*p*-value)‡	r^2
Age (Years)	3.76 (<0.0001)	0.293	1.36 (0.0002)	0.401	3.45 (<0.0001)	0.258	0.48 (0.231)	0.412
Strata		0.006				0.011		
Hakka	-0.21 (0.905)				-1.39 (0.525)			
Mountainous	0.70 (0.739)				-1.11 (0.584)			
Eastern	-2.30 (0.298)				-1.49 (0.442)			
PengHu Is.	1.51 (0.393)				0.02 (0.992)			
Northern 1st§	ref				ref			
Northern 2nd	0.63 (0.742)				0.03 (0.988)			
Northern 3rd	0.37 (0.857)				-2.36 (0.289)			
Central 1st	0.82 (0.678)				-0.23 (0.928)			
Central 2nd	-0.77 (0.744)				-0.85 (0.704)			
Central 3rd	2.66 (0.0.295)				-1.43 (0.666)			
Southern 1st	-0.40 (0.0.850)				-3.67 (0.106)			
Southern 2nd	-1.24 (0.571)				-3.50 (0.062)			
Southern 3rd	0.98 (0.582)				0.46 (0.838)			
Body Weight (kg)	0.65 (<0.0001)	0.357	0.40 (<0.0001)		0.72 (<0.0001)	0.373	0.47 (<0.0001)	
Height (cm)	0.60 (<0.0001)	0.355	0.12 (0.107)		0.58 (<0.0001)	0.348	0.20 (0.01)	
BMI (kg/m²)	1.46 (<0.0001)	0.185			1.71 (<0.0001)	0.194		
Dietary Ca (mg)	0.002 (0.175)	0.295			-0.001 (0.235)	0.263		
Dietary Ca Density (mg/kcal)	1.72 (0.561)	0.293			-1.18 (0.560)	0.261		
Dietary P (mg)	0.0009 (0.212)	0.294			-0.001 (0.057)	0.265	-0.002 (0.038)	
Dietary P Density (mg/kcal)	0.52 (0.816)	0.293			-1.49 (0.373)	0.262		
Intake Frequency of Vegetables (dishes/week)	0.15 (0.039)	0.299	0.06 (0.363)		0.11 (0.331)	0.263		
Intake Frequency of Fruits/Juices (dishes/week)	0.03 (0.656)	0.297			0.17 (0.029)	0.271	0.15 (0.029)	
Intake Frequency of Yogurt (times/week)					0.21 (0.279)	0.280		

† Results of univariate analysis for age as independent variable, or of bivariate analysis with age and other selected variables as independent variables. ‡ Results of multivariate analysis. § Reference group

relationships between dietary calcium intake and BUA in the regression analyses. When the relationships between intake frequency of dairy products, including milk and yogurt, and BUA were examined, the only positive correlation was observed between the frequency of yogurt consumption and girl's BUA (Table 3). The significance of the intake frequency of yogurt, however, was lost when age was adjusted (bivariate analysis, Table 4). It has been revealed that prospective studies with calcium intervention may be more effective than cross-sectional observation in finding the influences of calcium intake on bone mass.[23] In this nation-wide survey, the mean dietary calcium intake in the children were only 543±14 mg/day for boys and 497±14 mg/day for girls (Table 2). Except for boys of 6-6.99 year-old, the mean dietary calcium intake for each age-gender group was well below the recommended levels for their ages. Thus the effect of calcium intake on BUA measurements, if there is any, may not be detectable.

In addition to dietary calcium, consumption of fruit and vegetables has also been linked positively to bone health in adults.[24-25] The results of correlation analyses showed that the intake frequencies of fruits or vegetables positively related to BUA measurement in these children (Table 3). Nevertheless, the effects of intake frequencies of vegetables and/or fruits/juices were no longer significant for boys when age and/or other variables were regressed simultaneously on BUA (Table 4), suggesting that in these boys the intake frequency of fruits/juices may be age-dependent, and the influence of body weight on bone mass may be more profound than dietary intake factors in boys of this age range. On the other hand, the intake frequency of fruits/juices and dietary intake of phosphorus appeared to have an age-independent effect for girls, as the statistical significance still remained after adjusting for age and/or the anthropometric measurements. In fact, the relation of age to BUA was insignificant in the multivariate model for girls (Table 4). A study by Tylavsky *et al.* found that consuming 3 or more servings of fruit/vegetables per day is positively associated with larger bone size in early pubertal girls.[26] In general, fruits and vegetables are considered bases-rich food that may regulate the acid-base balance in our body and thus reducing urinary calcium excretion and decreasing the requirement of release of calcium from bone to buffer the acid-load.[25] On the other hand, fruits and vegetables are abundant in other vitamins and minerals that also appear to be important for building up bone, such as vitamin C, magnesium, and potassium.[25] More in-depth analyses would be necessary to investigate if the dietary patterns differ in boys and girls, and whether the differential effects of dietary variables on bone mass in boys and girls are related to the onset and/or development of puberty.

The mechanical loading on bone produced by adequate physical activity has been thought to stimulate bone growth in size and mass in childhood.[27-28] The physical activity level of the children was not included in the current analysis. Nevertheless, it is still necessary to include the estimate of daily physical activity level in order to understanding the influences of exercise on BUA measurements in the Taiwanese children, and whether the effects may differ in genders, or vary by different types of physical activity.

This is the first island-wide survey with the attempt of using QUS bone densitometry to investigate the bone health status of the children in Taiwan. Although QUS has been considered a convenient tool for population-screening of osteoporotic patients, there has not been much information on its applicability to measurement of bone status in children. A study by Brukx and Waelkens reported that in children aged 7-18 years, the reproducibility of QUS was considered moderate, and so was the correlation between results of QUS and that of dual-energy x-ray absorptiometry (DXA) (r=0.14-0.50 for different sites).[29] They also found that children having low bone mass, as diagnosed by DXA, were not readily recognized by QUS measurements, and the significant differences in bone mineral density across different age and pubertal groups were also not observed in QUS parameters.[29] In this survey, DXA was not available for direct measurement of bone mineral density in our subjects, nor for comparing the measurements between these two devices. However, it is generally agreed that the development of appropriate reference database and diagnosis criteria would be necessary for the use of QUS in bone health evaluation.[29,30]

In summary, the results of our analyses suggested that age and body weight, are important predictors of BUA in boys, and body weight, height, dietary intake of phosphorus, and frequency of fruit/juice consumption are significantly related to BUA for girls (Table 4). Dietary calcium intake was not a significant factor in predicting BUA for both genders. It would be necessary to examine the effect of physical activity in future analyses as well as the influence of pubertal stage on the differential gender effects of dietary factors on BUA.

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AUTHOR DISCLOSURES

Yi-Chin Lin, Su-Hao Tu, and Wen-Harn Pan, no conflicts of interest.

REFERENCES

1. Sambrook PN. Osteoporosis: What's the best prevention…diet, exercise or pharmacological intervention? Med J Aust. 1996;165:332-336.
2. Cummings SR, Nevitt MC, Browner WS, Stone K, Fox KM, Ensrud KE, Cauley J, Black D, Vogt TM. Risk factors for hip fracture in white women. Study of Osteoporotic Fractures Research Group. New Engl J Med. 1995;332: 767-773.
3. Weaver CM. Calcium nutrition: strategies for maximal bone mass. J Women's Health. 1997;6:661-664.
4. Cassidy JT. Osteopenia and osteoporosis in children. Clin Exp Rheumatol. 1999;17:245-250.
5. van der Sluis IM, de Muinck Keizer-Schrama SM. Osteoporosis in childhood: bone density of children in health and disease. J Pediatr Endocrinol Metab. 2001;14:817-832.
6. Saggese G, Baroncelli GI, Bertelloni S. Osteoporosis in children and adolescents: diagnosis, risk factors, and prevention. J Pediatr Endocrinol Metab. 2001;14:833-859.
7. Johnston CC Jr, Miller JZ, Slemenda CW, Reister TK, Hui S, Christian JC, Peacock M. Calcium supplementation and increases in bone mineral density in children. New Eng J Med. 1992;327:82-87.
8. Boot AM, de Ridder MA, Pols HA, Krenning EP, de Muinck Keizer-Schrama SM. Bone mineral density in children and adolescents: relation to puberty, calcium intake, and physical activity. J Clin Endocrinol Metab. 1997; 82:57-62.
9. Illich JZ, Skugor M, Hangartner T, Baoshe A, Matkovic V. Relation of nutrition, body composition and physical activity to skeletal development: a cross-sectional study in preadolescent females. J Am Coll Nutr. 1998;17:136-147.
10. Prentice A, Bonjour J-P, Branca F, Cooper C, Flynn A, Garabedian M, Muller D, Pannemans D, Weber P. PASSCLAIM – Bone health and osteoporosis. Eu J Nutr. 2003; 42(suppl 1):I/28-I/49.
11. Recker RR, Deng HW. Role of genetics in osteoporosis. Endocrine. 2002;17:55-66.
12. Seeman E, Hopper JL, Bach LA, Cooper ME, Parkinson E, McKay J, Jerums G. Reduced bone mass in daughters of women with osteoporosis. New Engl J Med. 1989;320:554-558.
13. Francois S, Benmalek A, Guaydier-Souquieres G, Sabatier JP, Marcelli C. Heritability of bone mineral density. Rev Rhum Engl Ed. 1999;66:146-151.
14. Drozdzowska B, Pluskiewicz W. Quantitative ultrasound at the calcaneus in premenopausal women and their postmenopausal mothers. Bone. 2001;29:79-83.
15. Javaid MK, Cooper C. Prenatal and childhood influences on osteoporosis. Best Prac Res Clin Endocrinol Metab. 2002;16:349-367.
16. Lin YC, Chiu JF, Lin MC, Tu SH, Pan WH. Bone health status of the elderly in Taiwan by quantitative ultrasound. Asia Pac J Clin Nutr. 2005;14(3):270-277.
17. Tu SH, Hung YT, Chang HY, Hang CM, Shaw NS, Lin W, Lin YC, Hu SW, Yang YH, Wu TC, Chang YH, Su SC, Hsu HC, Pan WH. Nutrition and Health Survey in Taiwan Elementary School Children 2001-2002: research design, methods and scope. Asia Pac J Clin Nutr. 2007; 16(S2):507-517.
18. Wu SJ, Pan WH, Yeh NH, Chang HY. Dietary nutrient intakes and major food sources: the Nutrition and Health Survey in Taiwan Elementary School Children 2001-2002. Asia Pac J Clin Nutr. 2007;16(S2):518-533.
19. Fu ML, Cheng L, Tu SH, Pan WH. Association between unhealthy eating patterns and unfavorable overall school performance in children. J Am Diet Assoc. (In Press).

20. Vatanaparast H, Whiting SJ. Early milk intake, later bone health: results from using the milk history questionnaire. Nutr Rev. 2004;62:256-260.
21. Zhu K, Du X, Greenfield H, Zhang Q, Ma G, Hu X, Fraser DR. Bone mass in Chinese premenarcheal girls: the roles of body composition, calcium intake and physical activity. Br J Nutr. 2004;92:985-993.
22. Hirota T, Kusu T, Hirota K. Improvement of nutrition stimulates bone mineral gain in Japanese school children and adolescents. Osteoporos Int. 2005;16:1057-1064.
23. Lin YC, Lyle RM, Weaver CM, McCabe LD, McCabe GP, Johnston CC, Teegarden D. Peak spine and femoral neck bone mass in young women. Bone. 2003;32:546-553.
24. Tucker K, Hannan M, Kiel D. The acid-base hypothesis: diet and bone in the Framingham osteoporosis study. Eur J Nutr. 2001;40:231-237.
25. New SA. Impact of food clusters on bone. In: Burckhardt P, Dawson-Hughes B, Heaney RP, editors. Nutritional aspects of osteoporosis. San Diego: Academic Press, 2001; p.379-397.
26. Tylavsky FA, Holliday K, Danish R, Womack C, Norwood J, Carbone L. Fruit and vegetable intakes are an independent predictor of bone size in early pubertal children. Am J Clin Nutr. 2004;73:311-317.
27. Iuliano-Burns S, Stone J, Hopper JL, Seeman E. Diet and exercise during growth have site-specific skeletal effects: a co-twin control study. Osteoporos Int. 2005;16:1225-1232.
28. Zhu K, Du X, Greenfield H, Zhang Q, Ma G, Hu X, Fraser DR. Bone mass in Chinese premenarcheal girls: the roles of body composition, calcium intake and physical activity. Br J Nutr. 2004;92:985-993.
29. Brukx LJCE, Waelkens JJJ. Evaluation of the usefulness of a quantitative ultrasound device in screening of bone mineral density in children. Annal Human Biol. 2003;30:304-315.
30. Grampp S, Henk CB, Fuerst TP, Lu Y, Bader TR, Kainberger F, Genant HK, Imhof H. Diagnostic agreement of quantitative sonography of the calcaneus with dual x-ray absorptiometry of the spine and femur. AJR. 1999;173: 329-334.

Original Article

Bone mass status of school-aged children in Taiwan assessed by quantitative ultrasound: the Nutrition and Health Survey in Taiwan Elementary School Children (NAHSIT Children 2001-2002)

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以定量超音波評估臺灣學齡兒童骨質狀況：臺灣地區國小學童營養健康狀況調查(NAHSIT Children 2001-2002)

兒童和青少年時期骨質健康狀況可能影響顛峰骨量(peak bone mass)。臺灣地區國小學童營養健康狀況調查（2001-2002）旨在評估國小學童整體營養攝取與健康情形。骨質狀況評估係以定量超音波測量腳跟骨而得到寬頻超音波衰減率(broadband ultrasound attenuation, BUA)。本研究以具有完整體檢資料及腳跟骨超音波檢測結果之 1164 位男童與 1016 位女童之資料進行分析。不論男童或女童之 BUA 平均值皆無明顯的地區層差異。年齡、身高、體重、身體質量指數、以及蔬菜、水果的攝取頻率皆與男童和女童的 BUA 有關。多變量迴歸分析顯示年齡(β=1.36, p=0.0002)及體重 (β=0.40, p<0.0001) 是預測男童 BUA 的顯著因子，而女童的 BUA 則與體重(β=0.47, p<0.0001)，身高(β=0.20, p=0.01)，磷攝取量(β=-0.002, p=0.038)，及水果/果汁攝取頻率(β=0.15, p=0.029)有顯著關聯。飲食攝取因素對男童與女童的 BUA 具有不同的效應或許與青春期的起始和發展有關。未來仍需探討體能活動量是否與學童骨質健康有關，以便了解影響臺灣地區學童顛峰骨量發展的因素。

關鍵字：骨質、臺灣、學童、定量超音波、調查。