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Educational Level and Osteoporosis Risk in Postmenopausal Chinese Women

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Many studies have shown that better education is favorable for lowering the risks for a number of chronic diseases, but little information is available on the relation with bone health. The authors examined the association of educational level, classified as levels I–IV, with bone mineral density (BMD) and with the prevalence of osteoporosis among 685 population-based, postmenopausal, Chinese women aged 48–63 years during 1999–2001. They observed a significant dose-response positive relation between educational level and BMDs at the total-body ($p = 0.011$), lumbar spine, and hip sites ($p < 0.001$) after adjusting for age, years since menopause, and body weight. Mean BMDs of educational level IV women were higher by 4.2–11.9% at the various sites compared with level I women (analysis of covariance, $p < 0.05$). Similarly, the authors also observed a significant inverse dose-response relation between educational level and prevalence of osteoporosis. Women of educational level I were 3.5–8.6 times more likely to be osteoporotic compared with those of level IV at the various sites. The proportion of BMD or osteoporosis variations accounted for by educational level was attenuated by about 40% after further controlling for potentially explanatory covariates. In conclusion, a higher level of education is independently associated with better BMDs and lower prevalence of osteoporosis among postmenopausal Chinese women.

Asian continental ancestry group; bone density; education; osteoporosis, postmenopausal; women

Abbreviations: BMD, bone mineral density; SD, standard deviation.

Osteoporosis is an increasing public health problem worldwide (1, 2). It has been estimated that, in 1990, 1.7 million people globally suffered from osteoporotic hip fractures. The number might increase to 6.3 million by 2050 (3). Osteoporotic fractures are a great burden to the individual and the community, and they pose great economic costs to society (3).

Although therapeutic measures are presently available for the prevention of bone loss and/or restoration of bone health, their long-term benefits are inconsistently reported (4, 5). As such, an understanding of the determinants of bone health and the early prevention of bone loss are important to reduce osteoporotic fractures in later life (6, 7).

Many studies have demonstrated that socioeconomic status or educational level is associated with a number of chronic diseases, such as obesity, diabetes, and some cancers (8–10). Woo et al. (10) have reported that a higher level of education is associated with a healthier diet and lower cardiovascular risk. However, inconsistent findings between educational level and osteoporosis have been noted (11), and little is known about how education affects bone health in postmenopausal Chinese women (12). Better-educated individuals might tend to have better health knowledge and behavior (13–17) in developed countries and regions. On the other hand, increasing affluence and education in developing regions might lead to better nutrition but also to a change of

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traditional-but-healthy behaviors toward less healthy lifestyles, such as a reduction of physical activities. As such, a ''double-edged sword'' phenomenon might occur.

We examined the association of the level of education with bone mineral density (BMD) and with the occurrence of osteoporosis to assess if the education-BMD/osteoporosis association could be attributable to education and relevant lifestyle and behavioral factors among 685 Chinese women in Hong Kong within the first 12 years of natural menopause.

MATERIALS AND METHODS

Subjects

We conducted a cross-sectional study of social and lifestyle factors and bone mass among 685 population-based, postmenopausal, Chinese women from October 1999 to January 2001. The study methods have been described in detail in a previous report (18). In brief, the study participants were community-dwelling subjects residing in housing estates in Shatin, Hong Kong Special Administrative Region, People's Republic of China. Stratified-cluster sampling was used to select the housing estates in the Shatin district of Hong Kong. Recruitment included both door-to-door and written invitations placed in mailboxes. Eligibility criteria included Hong Kong residents of Chinese origin who were aged between 48 and 63 years and within 12 years of natural menopause, defined as at least 12 months since the last menstrual cycle. Subjects who had received hormone replacement therapy for 3 months or more or had any medication known to affect bone mass were excluded. Written, informed consent was obtained from all the participants prior to enrollment. A total of 685 volunteers were recruited and met the screening criteria. The ethics committee of the Chinese University of Hong Kong approved the study.

Data collection

Trained interviewers conducted face-to-face interviews based on a structured and previously validated questionnaire. Information collected included sociodemographic data; final grade of formal education attained; years since menopause; and physical activities including average hours spent in sitting, standing, and walking and in mild and vigorous physical activities. Lifestyle factors included smoking, drinking, and dietary intake (19, 20). Dietary intakes of calcium, protein, and other nutrients were based on a quantitative food frequency questionnaire that included 60 food groups/items as described in previous studies (18, 21). Nutrients were calculated from food composition tables (22, 23).

Anthropometric and bone mass measurements

Height was measured to the nearest 0.5 cm, and weight was measured to the nearest 0.1 kg in light clothing and without shoes. Body mass index was calculated as weight (kg)/height $(m)^2$. The BMD of the whole body and subsites, the lumbar spine (L1–L4) and the left hip sites, was measured by dual-energy x-ray absorptiometry using a Hologic QDR-4500 densitometer (Hologic, Inc., Waltham, Massachusetts) (18, 21). The BMD was calculated as bone mineral content (g)/bone area (cm^2) at the relevant sites. Whole-body BMD represents bone mineral content per unit (cm^2) of total bone area of the whole body. All subjects were measured with the same densitometer and by the same operator. The coefficient of variation of measurements with the spine phantom was 0.4 percent. The in vivo coefficients of variation for BMD measurements were 1.53 percent, 1.72 percent, 1.15 percent, 4.86 percent, and 1.2 percent for the spine, femoral neck, trochanter, intertrochanter, and whole body, respectively. Osteoporosis of the whole body, spine, and hips was defined as *T* scores of BMDs at the relevant sites equal to or less than −2.5 standard deviations using the Oriental population referent values established by Hologic, Inc. The BMD peak mean referent values in the Oriental population for the calculation of *T* scores were 1.102 (standard deviation (SD): 0.087) (whole body), 1.047 (SD: 0.110) (lumbar spine), 0.975 (SD: 0.120) (total hip), 0.895 (SD: 0.100) (neck), 0.722 (SD: 0.090) (trochanter), 1.148 (SD: 0.141) (intertrochanter), and 0.796 (SD: 0.110) (Ward's triangle) g/cm^2.

Statistical analysis

The independent variable (educational level) was classified into four groups including no formal education (I), primary school education (II), secondary school education (III), and college education or above (IV). The dependent variable included bone mineral density of the whole body, lumbar spine (L1–L4), and left hip. Means and covariate-adjusted means of the BMDs at the various bone sites among the education groups were compared by post hoc multiple comparison tests (method: least significant difference) of one-way analysis of variance and analysis of covariance. The linear dose-response relations between educational level and BMDs were also calculated using analysis of variance and analysis of covariance models. In the multivariate analyses, age, body weight, and years since menopause were first adjusted for to examine the independent association between educational level and BMDs. Potentially explanatory covariates, including height, age at menarche, duration of pregnancy and lactation, physical activities, dietary intakes, and current job, were further controlled for to evaluate whether the education-BMD association could be explained by these covariates. Only the covariates that remained significant at borderline significance ($p < 0.10$) were retained in the final model. A manual forward stepwise method was used in adding the potential covariates, with educational level forced into the models. *F*-to-entry and -remove criteria were 0.05 and 0.10. Partial η^2 was used to assess the percentage of the BMD variations accounted for by educational level in the final models.

Logistic regression analyses were used to test the independent association of levels of education with the occurrence of osteoporosis as defined by *T* scores of less than 2.5 standard deviations from the respective bone sites after controlling for the covariates. Forward stepwise and enter procedures were used, respectively, for adding the covariates and educational level. *F*-to-entry and -remove criteria were 0.05 and 0.10 in the stepwise procedure. The proportion of variations in the prevalence of osteoporosis accounted for by educational level was estimated by the change of Nagelkerke R^2 statistics produced by adding the independent variable. SPSS for Windows, release 11, software (SPSS, Inc., Chicago, Illinois) was used for the analysis.

RESULTS

The study subjects had a mean age of 55 (SD: 3.5) years, ranging from 48 to 63 years. The mean years since menopause were 4.6 (SD: 2.8) years, with a range from 1 to 12.5 years. Better-educated subjects tended to be taller and to have a lower body mass index and higher intakes of dietary energy, calcium, phosphorus, plant protein, soy protein, and fresh fruits. Higher education is also associated with a younger age at menarche and a shorter duration of pregnancy and lactation (table 1). The primary and secondary education groups were younger and had fewer years since menopause. There were few differences in physical activities among the four education groups. Better-educated individuals tended to spend less time in walking and in weight-bearing physical activities. Only a few individuals drank alcohol more than once per week (3.7–4.8 percent) or were smokers ($\geq$1 cigarette/week for 3 months) (<2 percent) (table 1).

The mean BMDs were significantly higher among groups with a higher level of education. We observed dose-response linear relations between educational level and mean BMDs at the lumbar spine (L1–L4) ($p = 0.008$), total hip ($p = 0.001$), and subhip ($p < 0.003$) sites. The mean BMDs of education group IV were 4.0 percent (whole body), 7.8 percent (lumbar spine), and 8.0–18.1 percent higher at the hip sites compared with those of group I ($p < 0.05$) (data not shown).

After adjustments for age, years since menopause, and body weight in analysis of covariance models (table 2), the differences in covariate-adjusted means and the linear trends between education and BMDs were much more pronounced than those in the univariate models. We also observed very significant linear trends of increasing BMDs and educational level ($p < 0.008$) at all study sites except for the arms. The proportion of BMD variations explained by educational level ranged between 1.1 percent for the whole body and 3.5 percent for the total hip.

The prevalences of osteoporosis, as defined by a BMD T score of less than -2.5 at the various bone sites, decreased with increases in levels of education (table 3). Logistic regression analyses revealed a significant independent increase in risk of osteoporosis from 3.5- to 8.6-fold among subjects with no formal education (group I) when compared with those with tertiary education (group IV), even after adjustment for age, years since menopause, and body weight. The educational level accounted for 1.9–3.9 percent of the variations in prevalences of osteoporosis. The educational level still remained significant when it was treated as a linear variable (I = no formal, II = primary, III = secondary, IV = tertiary) (data not shown).

To explore whether the education-BMD/osteoporosis association is attributable to the measured covariates, including body height, reproductive factors, habitual dietary intakes, physical activities, and current job, we performed further adjustments for these covariates. Although the associations between educational levels and BMD or prevalences of osteoporosis still remained significant at the lumbar spine and hip sites (table 4), the proportions of BMD variations (partial η^2) were attenuated by 39 (range: 19–48) percent (percent variations in the partial η^2) after further including these covariates in the models compared with the models including only age, years since menopause, and body weight (tables 2 and 4). Similarly, we also observed a significantly increased risk of osteoporosis with a lower level of education after the further adjustments (table 3). Women with no formal education had a significant increased risk of having osteoporosis of from 2.9- to 5.8-fold. The covariates accounted for an average of 43 (range: 35–65) percent (percent variations in the R^2 change) of the association of education with prevalences of osteoporosis.

DISCUSSION

Many studies have demonstrated that increases in educational level are associated with lower risks for many chronic diseases, such as obesity, cardiovascular diseases, and diabetes (8–10). However, it is unclear whether better education is favorable to bone health. del Rio Barquero et al. (24) first reported that Spanish men and women with lower socioeconomic status had significantly lower BMD values than those with higher socioeconomic status, but other studies had found higher BMD values at the lumbar spine and femoral neck among men with lower socioeconomic status (25). Similar inconsistent associations between education and bone mass or risk of fractures have been reported (11, 26–28). Lauderdale et al. (11, 26) found a favorable association between better bone density and higher educational status among premenopausal women from the United States but not among postmenopausal immigrant women from Vietnam, Cambodia, and Laos. Shaw (27) found no significant associations in a cross-sectional study of healthy volunteers in Taiwan. Colon-Emeric et al. (28) observed a positive association between educational levels and risk of hip fracture (odds ratio = 2.0, 95 percent confidence interval: 1.2, 3.2) among ambulatory non-Hispanic White men.

In this population-based, cross-sectional study of postmenopausal Chinese women, we found that a higher level of formal education, in particular tertiary education, was strongly associated with better BMD values at various sites and with lower prevalence of osteoporosis. The associations held, even after adjustments for strong confounders such as age, years since menopause, and body weight. We also observed a linear dose-response relation between BMD values or osteoporosis prevalence and levels of education. We observed quite large BMD differences of 9–12 percent for the spine or femoral neck between women with no formal education and those with tertiary education. A meta-analytical study (29) of the effect of 2-year hormone

TABLE 1. Characteristics of 685 postmenopausal Chinese women aged 48–63 years by educational levels, Hong Kong, 1999–2001

Characteristics	No formal education (*n* = 48)		Primary education (*n* = 269)		Secondary education (*n* = 205)		Tertiary education (*n* = 63)		*p* value from ANOVA*	*p* value from linear trend
	Mean	SD*	Mean	SD	Mean	SD	Mean	SD		
Age (years)	56.7	3.1	54.9	3.3	54.4	3.5	56.0	3.3	0.000	0.207
Time since menopause (years)	6.0	3.2	4.4	2.7	4.4	2.8	5.3	2.9	0.001	0.187
Age at menarche (years)	14.8	1.9	14.3	1.9	14.0	1.8	13.6	1.8	0.002	<0.001
Total pregnant time (months)	38.5	16.2	31.8	13.3	27.3	17.7	21.0	14.5	0.000	<0.001
Total lactating time (months)	20.7	26.3	13.4	21.4	10.0	14.8	9.5	12.9	<0.001	<0.001
Body weight (kg)	59.7	10.1	57.6	9.5	57.1	7.9	57.3	9.4	0.304	0.140
Body height (m)	1.52	0.05	1.53	0.05	1.54	0.05	1.56	0.06	0.002	<0.001
Body mass index (kg/m^2)	25.8	4.0	24.6	3.9	24.2	3.3	23.7	3.5	0.010	0.001
Physical activities										
Standing (hours/day)	2.9	1.7	3.4	1.9	3.5	1.8	3.4	1.8	0.146	0.162
Walking (hours/day)	3.8	1.9	3.6	1.9	3.5	1.9	3.1	1.7	0.123	0.032
Weight bearing (hours/day)	1.03	1.54	0.74	0.86	0.77	0.95	0.57	0.96	0.105	0.017
Mild activities (hours/day)	4.93	3.00	5.84	2.89	5.49	2.88	5.37	3.44	0.168	0.563
Vigorous activities (hours/week)	1.66	5.74	1.97	6.60	1.81	5.33	0.50	1.37	0.322	0.271
Upstairs (flights/day)	2.40	5.26	2.08	5.10	2.20	4.69	3.51	4.56	0.209	0.225
Dietary intakes										
Energy (kcal/day)	1,056	310	1,196	415	1,200	378	1,256	353	0.051	0.007
Calcium (mg/day)	460	223	518	236	552	239	627	282	0.001	<0.001
Phosphorus (mg/day)	672	234	775	314	795	293	873	322	0.005	<0.001
Protein (g/day)	53.1	19.7	60.7	25.7	61.2	23.8	65.3	24.8	0.072	0.009
Soy protein (g/day)	2.58	2.39	3.98	5.17	4.60	4.34	6.31	7.46	0.000	<0.001
Animal protein (g/day)	32.7	17.6	36.8	19.9	36.9	18.9	38.6	17.9	0.429	0.110
Plant protein (g/day)	20.4	6.6	23.9	10.1	24.3	8.7	26.7	12.0	0.007	<0.001
Vegetables (g/day)	253	180	279	147	288	144	306	196	0.289	0.058
Fresh fruits (g/day)	147	96	167	98	171	99	208	126	0.010	0.002
	No.	%	No.	%	No.	%	No.	%	χ^2 test	
Current job										
Housewife	40	83.3	172	63.8	184	60.3	26	41.3	0.000	
White collar	0	0.0	3	1.1	34	11.2	29	46.0		
Blue collar	8	16.7	94	35.1	87	28.6	8	12.7		
Smoking (≥1 cigarette/week)	0	0.0	6	2.2	5	1.6	0	0	NS*	
Alcohol drinking (≥1 cup†/week)	2	4.2	10	3.7	12	4.0	3	4.8	NS	

* ANOVA, analysis of variance; SD, standard deviation; NS, not significant.
† One cup = 0.24 liter.

TABLE 2. Age-, body weight-, and years since menopause-adjusted means of bone mineral density among 685 postmenopausal Chinese women aged 48–63 years by educational levels, Hong Kong, 1999–2001

	Bone mineral density (g/cm^2)								% difference† (IV vs. I)	Partial η^2‡ (%)	*p* value from linear trend	*p* value from ANCOVA§
	No formal education¶ (*n* = 48)		Primary education (*n* = 269)		Secondary education (*n* = 305)		Tertiary education (*n* = 63)					
	Mean	SE§	Mean	SE	Mean	SE	Mean	SE				
Whole body	0.947	0.012	0.960	0.005	0.966	0.005	0.987	0.011*, **	4.22	1.1	0.011	0.065
Arms	0.617	0.006	0.620	0.003	0.620	0.002	0.627	0.005	1.62	0.3	0.210	0.589
Legs	0.925	0.009	0.945	0.004	0.950	0.004*	0.966	0.008***	4.43	1.7	0.001	0.009
Lumbar spine	0.810	0.017	0.835	0.007	0.853	0.007*	0.881	0.015***, ****	8.77	2.0	0.001	0.003
Total hip	0.755	0.014	0.797	0.006***	0.810	0.005***	0.837	0.012***, ****	10.86	3.5	<0.001	<0.001
Femoral neck	0.644	0.013	0.676	0.005*	0.688	0.005***	0.708	0.011***, ****	9.94	2.6	<0.001	<0.001
Trochanter	0.557	0.012	0.594	0.005***	0.600	0.005***	0.623	0.011**, ***	11.85	2.5	<0.001	<0.001
Intertrochanter	0.916	0.017	0.959	0.007*	0.978	0.007***	1.005	0.014**, ****	9.72	2.9	<0.001	<0.001

* $p < 0.05$; *** $p < 0.01$ (two-sided test from post hoc multiple-comparison tests (least significant difference, ANCOVA) compared with educational level I after adjusting for the above-mentioned covariates).

** $p < 0.05$; **** $p < 0.01$ (two-sided test from post hoc multiple-comparison tests (least significant difference, ANCOVA) compared with educational level II after adjusting for the above-mentioned covariates).

† % difference (level IV vs. level I): ((adjusted mean of group IV – adjusted mean of group I) × 100)/adjusted mean of group I.

‡ Partial η^2: the proportion of the bone mineral density variations accounted for by educational level in the final model.

§ ANCOVA, analysis of covariance (after controlling for age, body weight, and years since menopause. Only the significant covariates of body weight and years since menopause ($p < 0.01$) were kept in the final model. A manual forward stepwise method was used. *F*-to-entry and -remove criteria were 0.05 and 0.10, respectively); SE, standard error.

¶ Level of education: no formal (I); primary (II); secondary (III); tertiary (IV).

replacement therapy on BMD revealed differences of about 7 percent for the spine and 4 percent for the femoral neck. The substantial difference found in our study suggests that the enhancement of educational level could be an important social determinant for the prevention of osteoporosis in this population.

Educational attainment is a major determinant of income and occupation and, thus, an essential marker of an individual's social economic status, especially in regions undergoing economic transitions. Income and socioeconomic status are also important determinants of a host of social and environmental exposures (30, 31). Lifestyle, behavior, diet, and nutrition are closely linked with education and socioeconomic status, although such influences may vary among different population groups and stages of economic development.

Our data showed that taller height and younger age at menarche were significantly associated with higher educational level. Body height and age at menarche are important markers of nutrition and health status in childhood and adolescence. Adequate intakes of protein, calcium, and other vitamins and minerals are required for bone accretion and the attainment of the full genetic potential for peak bone mass. Many studies have demonstrated that dietary intakes in early life have a long-term effect on bone mass in adulthood (32, 33). Age at menarche is also a reflection of childhood nutrition, and previous studies have also reported an inverse association with bone mass in postmenopausal women (34, 35). Therefore, early nutritional status might contribute to the education-bone mass association.

After the early years, better education might directly influence bone health through the positive effect of better health knowledge on individuals' lifestyles and behaviors. Many studies have shown that better-educated individuals tend to exercise more, smoke less, and have better maintenance of body weight. They also tend to have more positive attitudes toward use of medications and more efficient use of health-care resources (16). Better educated individuals also tend to adopt healthier eating habits, including more dietary calcium, vegetables, soy foods, and fruits and less saturated fat and alcohol (10, 12, 36–38). An association between higher intakes of calcium, soy, and/or fresh fruits or vegetables with better bone mass in postmenopausal women has been reported (18, 21, 39, 40). Such education-associated favorable dietary habits might play a role in the improvement of bone health.

More of the less educated women were engaged in blue-collar work. They also tended to have higher levels of walking and of weight bearing and possibly vigorous activities compared with women who had a higher level of education. Thus, physical activity did not seem to serve as a crucial link between the positive association of education and bone mass. As few women in the study population smoked or consumed alcohol, we observed no differences in the prevalences of these behaviors among the different education groups. Because we excluded from this study all current or ever (>3 months) users of exogenous estrogens, corticosteroids, thiazine, and other medications known to affect bone mass, such factors are unlikely to influence the association between education and bone mass.

Reproductive factors may play a role in the maintenance of bone mass. Previous studies have found both positive and negative effects of pregnancy and lactation on BMD in postmenopausal women (41–43). Although, in our study, better-educated individuals tended to have a shorter duration of pregnancy and lactation, these factors have not been shown to have a significant influence on bone mass.

Body weight and years since menopause or age had a significant influence on BMD or osteoporosis but had little influence on the independent association between education and bone mass or osteoporosis. As education per se could not be a plausible causal factor of bone health, other factors associated or influenced by education are the probable explanations. To assess to what extent the measured covariates might explain the education-BMD association, we made further adjustments for these covariates in multivariate analyses. The adjusted covariates included body height, dietary factors, physical activities, age at menarche, duration of pregnancy and lactation, and current job. The inclusion of significant biologic and lifestyle factors had attenuated about 40 percent of the education-BMD association, but education still remained a significant predictor. One possible reason could be that the current status of some of the covariates might not represent their levels of life-long exposures. Another reason might be due to measurement errors and biases in the assessment of these covariates. There is also the possibility that other potentially important, education-associated causal factors (e.g., genetically related) have not been included in this study.

Our findings showed that the education-BMD association was more pronounced at the weight-bearing sites, such as the hip sites and spine, but not in the arms. The latter, being a non-weight-bearing site and consisting mainly of cortical bone, might be influenced by some other factors and pathways.

Cumulative literature from the West has overwhelmingly suggested that income exerts a positive impact on health, but less is known about the nature and magnitude of the relation between wealth and health in regions such as Asia where rapid economic transitions have been taking place. However, it is inappropriate to generalize our findings to other populations and settings in the region. For example, in part of Asia, individuals with a lower level of education usually have high levels of physical activities due to engagement in manual labor. They also tended to have higher intakes of vegetables and plant protein due to limited income and availability of animal foods. Individuals with better education and income usually consume more animal foods and have less physical activities due to decreases in manual work and greater use of transportation by cars and elevators (44, 45). As such, the higher income and education group might have a "good," rather than a healthy, diet and a comfortable but not necessarily healthy lifestyle if their income increases more rapidly than their knowledge of health and diseases. In these settings, higher education might not be associated with better health outcomes (46).

Although this study is cross-sectional in design, educational achievement is a relatively stable characteristic and unlikely to be influenced by recall bias. However, as we have not assessed the participants' knowledge of, attitudes toward, and activities involved in the prevention of osteoporosis,

TABLE 3. Prevalence of osteoporosis and odds ratios for educational levels among 685 postmenopausal Chinese women aged 48–63 years, Hong Kong, 1999–2001*

Independent variables	%*	Univariate model R^2† (%)	Multivariate model I‡				Multivariate model II‡			
			Odds ratio	95% confidence interval	*p* value	R^2 change§ (%)	Odds ratio	95% confidence interval	*p* value	R^2 change (%)
Whole body										
Educational level		1.3				1.9				1.1
No formal	27.1		3.50	1.21, 10.11	0.020		2.93	0.94, 9.17	0.065	
Primary	23.4		3.14	1.32, 7.46	0.010		2.57	1.00, 6.63	0.051	
Secondary	19.7		2.41	1.02, 5.73	0.046		1.90	0.75, 4.79	0.173	
Tertiary	11.1		1.00¶				1.00¶			
Covariates						12.0				17.6
Body weight		6.0	0.52	0.41, 0.67	<0.001	6.0	0.52	0.40, 0.68	0.000	5.7
Years since menopause		5.6	0.121	1.13, 1.29	<0.001	6.0	1.19	1.11, 1.27	0.000	6.1
Fruit intake		1.3					0.72	0.56, 0.93	0.011	1.2
Vigorous activity		2.2					0.93	0.87, 1.00	0.044	1.1
Plant protein		1.3					0.98	0.95, 1.00	0.083	0.9
Current job		2.6								2.5
White collar							0.46	0.18, 1.20	0.112	
Blue collar							0.65	0.40, 1.06	0.086	
Lumbar spine										
Educational level		1.8				2.8				1.8
No formal	41.7		5.34	2.01, 14.18	0.001		4.84	1.70, 13.79	0.003	
Primary	30.5		3.46	1.57, 7.63	0.002		2.89	1.22, 6.84	0.016	
Secondary	27.9		2.92	1.33, 6.41	0.007		2.47	1.08, 5.68	0.033	
Tertiary	14.3		1.00¶				1.00¶			
Covariates						14.7				18.1
Body weight		9.8	0.45	0.35, 0.57	<0.001	9.5	0.43	0.34, 0.55	0.000	9.1
Years since menopause		5.1	1.18	1.11, 1.26	<0.001	5.2	1.18	1.11, 1.26	0.000	5.5
Fruit intake		1.1					0.77	0.61, 0.96	0.020	1.2
Age at menarche		0.8					1.09	0.99, 1.21	0.086	0.9
Current job		1.6								1.3
White collar							0.73	0.33, 1.59	0.425	
Blue collar							0.67	0.44, 1.02	0.064	
Total hip										
Educational level		1.9				2.3				1.5
No formal	22.9		5.31	1.55, 18.22	0.008		3.74	1.04, 13.46	0.043	
Primary	11.2		1.78	0.62, 5.05	0.282		1.42	0.49, 4.13	0.522	
Secondary	9.9		1.59	0.56, 4.49	0.382		1.26	0.43, 3.62	0.674	
Tertiary	7.9		1.00¶				1.00¶			
Covariates						20.3				24.5
Body weight		17.3	0.24	0.16, 0.36	<0.001	16.8	0.23	0.15, 0.36	0.000	16.5
Years since menopause		3.0	1.17	1.07, 1.28	0.001	3.5	1.15	1.05, 1.27	0.004	3.3
Age at menarche		2.0					1.20	1.04, 1.40	0.016	2.6
Animal protein		4.2					0.98	0.96, 0.99	0.012	2.1
Femoral neck										
Educational level		1.9				2.4				1.4
No formal	58.3		4.71	1.92, 11.54	0.001		3.29	1.26, 8.61	0.015	
Primary	40.5		1.78	0.93, 3.39	0.081		1.46	0.71, 3.01	0.307	
Secondary	36.4		1.40	0.74, 2.65	0.304		1.18	0.59, 2.37	0.638	
Tertiary	32.3		1.00¶				1.00¶			
Covariates						21.3				22.9
Body weight		19.3	0.24	0.16, 0.36	<0.001	19.1	0.31	0.24, 0.40	0.000	18.9
Years since menopause		2.1	1.11	1.04, 1.18	0.001	2.2	1.09	1.03, 1.16	0.005	2.0
Current job		1.4								2.0
White collar							0.47	0.24, 0.95	0.034	
Blue collar							0.66	0.44, 0.97	0.037	

Trochanter										
Educational level		3.2				3.9				2.5
No formal	31.3		8.58	2.64, 27.86	<0.001		5.78	1.71, 19.49	0.005	
Primary	13.4		2.24	0.81, 6.24	0.122		1.82	0.65, 5.16	0.257	
Secondary	12.5		2.24	0.81, 6.21	0.123		1.81	0.64, 5.09	0.260	
Tertiary	7.9		1.00¶				1.00¶			
Covariates						15.5				18.3
Body weight		13.2	0.31	0.22, 0.44	<0.001	12.8	0.32	0.22, 0.45	0.000	12.3
Age		2.3	1.11	1.01, 1.19	0.002	2.7	1.09	1.02, 1.17	0.017	2.0
Age at menarche		2.4					1.17	1.03, 1.34	0.020	2.8
Animal protein		3.0					0.99	0.97, 1.00	0.054	1.2
Intertrochanter										
Educational level		2.0				2.3				0.8
No formal	16.7		5.72	1.32, 24.77	0.020		2.81	0.57, 13.92	0.205	
Primary	12.7		3.78	1.07, 13.32	0.039		2.05	0.52, 8.12	0.308	
Secondary	8.9		2.50	0.71, 8.88	0.156		1.43	0.36, 5.65	0.610	
Tertiary	4.8		1.00¶				1.00¶			
Covariates						19.6				28.6
Body weight		17.0	0.25	0.17, 0.37	<0.001	16.4	0.23	0.15, 0.35	0.000	16.1
Years since menopause		2.7	1.17	1.07, 1.29	0.001	3.2	1.17	1.06, 1.29	0.002	3.2
Age at menarche		2.0					1.22	1.05, 1.43	0.010	2.7
Calcium intake		3.6					0.85	0.74, 0.97	0.017	2.2
Weight-bearing load		1.2					0.62	0.41, 0.96	0.031	1.5
Current job		3.1								2.8
White collar							0.14	0.02, 1.18	0.071	
Blue collar							0.61	0.32, 1.17	0.135	

* Osteoporosis was defined as a *T* score of ≤−2.5 for bone mineral density at the various bone sites. The referent values of peak means of bone mineral density for an Oriental population in the calculation of *T* scores were the following: whole body: 1.102 (standard deviation (SD): 0.087), lumbar spine: 1.047 (SD: 0.110), total hip: 0.975 (SD: 0.120), neck: 0.895 (SD: 0.100), trochanter: 0.722 (SD: 0.090), intertrochanter: 1.148 (SD: 0.141), and Ward's triangle: 0.796 (SD: 0.110) g/cm^2. Because of no referent data for the arms and legs, the association between educational level and prevalences of osteoporosis at these sites could not be evaluated.

† From univariate logistic regression models fitted separately for each independent variable by forcing into the models.

‡ Multivariate models: multivariate logistic regression models. Dependent variable: osteoporosis at the various sites (yes = 1, no = 0); independent variables: educational level (forced into the models). Model I covariate selection included age (years); body weight (10 kg); and years since menopause. Model II covariate selection included age; body weight; years since menopause; age at menarche (years); total pregnancy time (months); total lactation time (months); body height (cm); physical activities including time spent walking (hours/day) and weight bearing (carrying a load over 5 pounds (2.268 kg), hours/day); mild activities (hours/day); vigorous activities (hours/week); dietary intakes including energy (kcal/day), calcium (100 mg/day), animal protein (g/day), plant protein (g/day), vegetables (g/day), and fresh fruits (g/1,000 kcal); and current job including housewife (referent), white collar, and blue collar. Covariates were selected into the models by using a forward stepwise procedure. *F*-to-entry and -remove criteria were 0.05 and 0.10.

§ R^2 change: the change in the Nagelkerke R^2 statistic that is produced by adding the relevant independent variable.

¶ Referent.

TABLE 4. Adjusted means of bone mineral density of 685 postmenopausal Chinese women aged 48–63 years by educational levels, Hong Kong, 1999–2001

	Bone mineral density (g/cm^2)												
	No formal education# (n = 48)		Primary education (n = 269)		Secondary education (n = 305)		Tertiary education (n = 63)		% difference (IV vs. I)†	Covariates included for ANCOVA‡	Partial η^2 (%)§	p value from linear trend¶	p value from ANCOVA¶
	Mean	SE††	Mean	SE	Mean	SE	Mean	SE					
Whole body	0.950	0.016	0.992	0.016	0.976	0.006	0.986	0.012	3.79	Weight, years since menopause, height, fruits, menarche*, job*	0.6	0.114	0.243
Arms	0.623	0.007	0.624	0.003	0.624	0.003	0.627	0.006	0.64	Weight, years since menopause, job, height, walking, age, calcium*, lactation*	0.1	0.634	0.970
Legs	0.926	0.009	0.945	0.004	0.950	0.004	0.966	0.008	4.32	Weight, years since menopause, walking, calcium*	1.7	0.001	0.012
Lumbar spine	0.814	0.017	0.837	0.007	0.854	0.006	0.871	0.015	7.00	Weight, years since menopause, height, menarche, fruits, plant protein	1.4	0.006	0.023
Total hip	0.773	0.014	0.805	0.007	0.818	0.006	0.833	0.012	7.76	Weight, years since menopause, menarche, calcium, walking, job	2.0	0.001	0.005
Femoral neck	0.647	0.013	0.677	0.005	0.688	0.005	0.706	0.011	9.12	Weight, years since menopause, menarche	2.1	<0.001	0.002
Trochanter	0.571	0.013	0.598	0.006	0.604	0.006	0.619	0.011	8.41	Weight, years since menopause, menarche, calcium*, job*	1.3	0.004	0.033
Intertrochanter	0.939	0.017	0.972	0.009	0.988	0.007	1.000	0.014	6.50	Weight, years since menopause, menarche, walking, calcium, job	1.5	0.005	0.022

* $p < 0.10$ from ANCOVA as described in the double-dagger (‡) footnote below; $p < 0.05$ for all the other variables.

† % difference (level IV vs. level I): ((adjusted mean of group IV – adjusted mean of group I) $\times$ 100)/adjusted mean of group I.

‡ ANCOVA, analysis of covariance, after controlling for age, body weight (weight) and height, years since menopause, age at menarche (menarche), total pregnancy time, total lactation time (lactation), time spent in walking (walking), carrying a load over 5 pounds (2.268 kg), mild activities, vigorous activities, dietary energy intakes (animal protein, plant protein, calcium, vegetables, and fruits), and current job (job, classified as housewife, white collar, and blue collar). Only the covariates that remained significant or of borderline significance ($p < 0.10$, as indicated by *) were retained in the final model. A manual forward stepwise method was used. F-to-entry and -remove criteria were 0.05 and 0.10. Among the significant covariates ($p < 0.10$, two sided), age, years since menopause, and age at menarche were negatively associated with bone mineral density.

§ Partial η^2: the proportion of the bone mineral density variations accounted for by educational level in the final models.

¶ Tests for linear dose-response relation or ANCOVA after adjusting for the covariates in the final models.

\# Level of education: no formal (I); primary (II); secondary (III); tertiary (IV).

†† SE, standard error.

further studies in these areas might help to elucidate the mechanisms by which education improves bone health. Public health intervention programs might thus take into consideration the socioeconomic and educational backgrounds of target populations. Because half of the world's hip fractures are projected to occur in Asia by 2050 (30), the steep rise of this disease and the income disparity in this part of the world would call for more research into the social determinants of osteoporosis.

In conclusion, our findings showed that a higher level of education was associated with significantly higher BMDs at the whole body, lumbar spine, and hip sites and with lower prevalences of osteoporosis at these sites in a dose-response manner, even after controlling for the strong confounders. More attention should be paid to education as a determinant of bone health in future research and health promotion activities.

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REFERENCES

1. Lau EM, Lee JK, Suriwongpaisal P, et al. The incidence of hip fracture in four Asian countries: the Asian Osteoporosis Study (AOS). Osteoporos Int 2001;12:239–43.
2. Wasnich RD. Epidemiology of osteoporosis in the United States of America. Osteoporos Int 1997;7(suppl 3):S68–72.
3. Johnell O. The socioeconomic burden of fractures: today and in the 21st century. Am J Med 1997;103:20S–6S.
4. Dawson-Hughes B, Harris SS, Krall EA, et al. Effect of withdrawal of calcium and vitamin D supplements on bone mass in elderly men and women. Am J Clin Nutr 2000;72: 745–50.
5. Lee WT, Leung SS, Leung DM, et al. A follow-up study on the effects of calcium-supplement withdrawal and puberty on bone acquisition of children. Am J Clin Nutr 1996;64:71–7.
6. Hodgson SF, Watts NB, Bilezikian JP, et al. American Association of Clinical Endocrinologists 2001 medical guidelines for clinical practice for the prevention and management of postmenopausal osteoporosis. Endocr Pract 2001;7:293–312.
7. Kanis JA, Delmas P, Burckhardt P, et al. Guidelines for diagnosis and management of osteoporosis. The European Foundation for Osteoporosis and Bone Disease. Osteoporos Int 1997;7:390–406.
8. Corral F, Cueva P, Yepez J, et al. Limited education as a risk factor in cervical cancer. Bull Pan Am Health Organ 1996; 30:322–9.
9. La Vecchia C, Negri E, Pagano R, et al. Education, prevalence of disease, and frequency of health care utilisation. The 1983 Italian National Health Survey. J Epidemiol Community Health 1987;41:161–5.
10. Woo J, Leung SS, Ho SC, et al. Influence of educational level and marital status on dietary intake, obesity and other cardiovascular risk factors in a Hong Kong Chinese population. Eur J Clin Nutr 1999;53:461–7.
11. Lauderdale DS, Salant T, Han KL, et al. Life-course predictors of ultrasonic heel measurement in a cross-sectional study of immigrant women from Southeast Asia. Am J Epidemiol 2001;153:581–6.
12. Varenna M, Binelli L, Zucchi F, et al. Prevalence of osteoporosis by educational level in a cohort of postmenopausal women. Osteoporos Int 1999;9:236–41.
13. Berarducci A, Lengacher C, Keller R. The impact of osteoporosis continuing education on nurses' knowledge and attitudes. J Contin Educ Nurs 2002;33:210–16.
14. Brecher LS, Pomerantz SC, Snyder BA, et al. Osteoporosis prevention project: a model multidisciplinary educational intervention. J Am Osteopath Assoc 2002;102:327–35.
15. Mullen PD, Simons-Morton DG, Ramirez G, et al. A meta-analysis of trials evaluating patient education and counseling for three groups of preventive health behaviors. Patient Educ Couns 1997;32:157–73.
16. MacDowell M, Guo L, Short A. Preventive health services use, lifestyle health behavior risks, and self-reported health status of women in Ohio by ethnicity and completed education status. Womens Health Issues 2002;12:96–102.
17. Rolnick S, Kopher R, Jackson J, et al. What is the impact of osteoporosis education and bone mineral density testing for postmenopausal women in a managed care setting? Menopause 2001;8:141–8.
18. Ho SC, Chen YM, Woo JLF, et al. High habitual calcium intake attenuates bone loss in early postmenopausal Chinese women: an 18-month follow-up study. J Clin Endocrinol Metab 2004;89:2166–70.
19. Ho SC, Leung PC, Swaminathan R, et al. Determinants of bone mass in Chinese women aged 21–40 years. II. Pattern of dietary calcium intake and association with bone mineral density. Osteoporos Int 1994;4:167–75.
20. Ho SC, Wong E, Chan SG, et al. Determinants of peak bone mass in Chinese women aged 21–40 years. III. Physical activity and bone mineral density. J Bone Miner Res 1997; 12:1262–71.
21. Chen YM, Ho SC, Lam SSH, et al. Soy isoflavones have a favorable effect on bone loss in Chinese postmenopausal women with lower bone mass: a double-blind, randomized, controlled trial. J Clin Endocrinol Metab 2003;88: 4740–7.
22. US Department of Health, Education, and Welfare and Food and Agriculture Organization of the United Nations. Food composition table for use in East Asia. Bethesda, MD: National Institute of Arthritis, Metabolism, and Digestive Diseases, 1972. (http://www.fao.org/docrep/003/X6878E/X6878E00.htm).
23. Wang GY. Food composition tables. (In Chinese). Beijing, People's Republic of China: People's Medical Publishing House, 1991.
24. del Rio Barquero L, Romera Baures M, Pavia Segura J, et al. Bone mineral density in two different socio-economic population groups. Bone Miner 1992;18:159–68.
25. Elliot JR, Gilchrist NL, Wells JE. The effect of socioeconomic status on bone density in a male Caucasian population. Bone 1996;18:371–3.
26. Lauderdale DS, Kuohung V, Chang SL, et al. Identifying older Chinese immigrants at high risk for osteoporosis. J Gen Intern Med 2003;18:508–15.
27. Shaw C. An epidemiologic study of osteoporosis in Taiwan. Ann Epidemiol 1993;3:64–71.
28. Colon-Emeric C, Biggs D, Schenck A, et al. Risk factors for hip fracture in skilled nursing facilities: who should be evaluated? Osteoporos Int 2003;14:484–9.

29. Wells G, Tugwell P, Shea B, et al. V. Meta-analysis of the efficacy of hormone replacement therapy in treating and preventing osteoporosis in postmenopausal women. Endocr Rev 2002;23:529–39.
30. Cooper C, Campion G, Melton LJ 3rd. Hip fractures in the elderly: a world-wide projection. Osteoporos Int 1992;2:285–9.
31. Leigh J, Dhir R. Schooling and frailty among seniors. Econ Educ Rev 1997;16:45–57.
32. Murphy S, Khaw KT, May H, et al. Milk consumption and bone mineral density in middle aged and elderly women. BMJ 1994;308:939–41.
33. Neville C, Robson P, Murray L, et al. The effect of nutrient intake on bone mineral status in young adults: the Northern Ireland Young Hearts Project. Calcif Tissue Int 2002;70:89–98.
34. Gerdhem P, Obrant K. Bone mineral density in old age: the influence of age at menarche and menopause. J Bone Miner Metab 2004;22:372–5.
35. Zhang Y, Liu P, Deng H. The impact of reproductive and menstrual history on bone mineral density in Chinese women. J Clin Densitom 2003;6:289–96.
36. Basler H. Patient education with reference to the process of behavioral change. Patient Educ Couns 1995;26:93–8.
37. Orces C, Casas C, Lee S, et al. Determinants of osteoporosis prevention in low-income Mexican-American women. South Med J 2003;96:458–64.
38. Ho SC, Woo JL, Leung SS, et al. Intake of soy products is associated with better plasma lipid profiles in the Hong Kong Chinese population. J Nutr 2000;130:2590–3.
39. Chen YM, Ho SC, Lee R, et al. Fruit intake is associated with better bone mass among Hong Kong Chinese early post-menopausal women. (Abstract). J Bone Miner Res 2001; 16:S386.
40. New SA, Bonjour JP. Nutritional aspects of bone health. Cambridge, United Kingdom: The Royal Society of Chemistry, 2003.
41. Gur A, Nas K, Cevik R, et al. Influence of number of pregnancies on bone mineral density in postmenopausal women of different age groups. J Bone Miner Metab 2003;21:234–41.
42. Michaelsson K, Baron JA, Farahmand BY, et al. Influence of parity and lactation on hip fracture risk. Am J Epidemiol 2001;153:1166–72.
43. Paton LM, Alexander JL, Nowson CA, et al. Pregnancy and lactation have no long-term deleterious effect on measures of bone mineral in healthy women: a twin study. Am J Clin Nutr 2003;77:707–14.
44. Ge KY, Zhai FY, Yan HC. The dietary and nutritional status of Chinese population. (In Chinese). Beijing, People's Republic of China: People's Medical Publishing House, 1996.
45. Hu G, Hu G, Pekkarinen H, et al. Comparison of dietary and non-dietary risk factors in overweight and normal-weight Chinese adults. Br J Nutr 2002;88:91–7.
46. Li CP, Ma J. Relationship between socioeconomic status and coronary heart disease. J Tianjin Med Univ 2003;9: 198–9.