British Journal of Nutrition (2006), **96**, 745–751

DOI: 10.1079/BJN20061883

Greater fruit and vegetable intake is associated with increased bone mass among postmenopausal Chinese women

Yu-ming Chen[1,2], Suzanne C. Ho[1]* and Jean L.F. Woo[3]

[1]*Department of Community & Family Medicine and School of Public Health, The Chinese University of Hong Kong, 4th Floor, School of Public Health, Prince of Wales Hospital, Shatin, N.T., Hong Kong SAR*

[2]*Department of Medical Statistics & Epidemiology, School of Public Health, Sun Yat-sen University, Guangzhou 510080, Peoples Republic of China*

[3]*Department of Medicine & Therapeutics, The Chinese University of Hong Kong, Clinical Sciences Building, Prince of Wales Hospital, Shatin, NT, Hong Kong SAR*

(Received 30 January 2006 – Revised 12 May 2006 – Accepted 18 May 2006)

Although studies in Caucasian populations have reported the beneficial effects of intakes of fruit and vegetables on bone mass, limited data are available in the Asian populations. We examined the association of the intake of fruits and vegetables with bone mineral density (BMD) in a population-based cross-sectional study of 670 postmenopausal Chinese women aged 48–63 years. Habitual dietary intakes were assessed using a food frequency questionnaire. BMD at the whole body, lumbar spine and left hip were measured with dual-energy X-ray absorptiometry. Univariate regression analyses showed that the total intake of fruits and vegetables was significantly associated with greater BMD at the whole body, lumbar spine (L1–L4), total hip, trochanter and intertrochanter. An independently positive association between fruit and vegetable intake and BMD at the whole body ($P=0{\cdot}005$), lumbar spine ($P<0{\cdot}001$) and total hip ($P=0{\cdot}024$) remained even after adjusting for age, years since menopause, body weight and height, dietary energy, protein and Ca, and physical activities. A daily increase of 100 g fruit and vegetable intake was associated with 0·0062 (95 % CI 0·0019, 0·0105) g/cm^2, 0·0098 (95 % CI 0·0041, 0·0155) g/cm^2 and 0·0060 (95 % CI 0·0011, 0·0109) g/cm^2 increases in BMD at the whole body, lumbar spine and total hip, respectively. In conclusion, greater fruit and vegetable intake is independently associated with better BMD among postmenopausal Chinese women.

Fruits: Vegetables: Bone mineral density: Postmenopausal women: Chinese

Previous studies have pointed towards the important role of nutritional factors in the maintenance of optimal bone health (New & Bonjour, 2003). Until recently, focus has primarily been placed on Ca and a few isolated nutrients. Except for milk and soya products, limited data are available on the association between food intake and bone health (Ho *et al.* 2001; Tucker *et al.* 2002; New & Bonjour, 2003; Macdonald *et al.* 2004).

As food usually contains biologically active components, consisting of both nutrients and non-nutrients, an association of a health effect with a single nutrient or phytochemical might also be attributable to other known or unknown components contained in foods. Because of collinearity, adjusting for these co-existing contributors may mask the true effect of the nutrients. Moreover, nutrient contents of foods from different sources and localities may vary widely, and contents based on food composition tables may not give a good estimation of actual intakes. An examination of the health effects of foods or food groups rather than nutrients may therefore be more informative and also more educationally meaningful to the target populations.

Nutrients, such as alkaline ions (K and Mg), vitamin K and vitamin C, found abundantly in fruits and vegetables, have been found to be associated with greater bone mass and lower urinary Ca excretion in human studies (Tucker *et al.* 1999). These earlier findings have led to the examination of linkages between fruit and vegetable consumption and bone health. A few studies have reported beneficial associations between fruit and vegetable consumption and bone mineral density (BMD) and bone size among children and adults in Caucasian populations with a habitual diet high in animal protein and low in fruits and vegetables (New *et al.* 2000; Tucker *et al.* 2002; Macdonald *et al.* 2004; Tylavsky *et al.* 2004). However, little is known of Chinese populations whose dietary habits differ from those of Western populations.

The objective of this population-based cross-sectional study was to examine the independent association between fruit and vegetable consumption and BMD in postmenopausal Chinese women.

Materials and methods

Study subjects

We conducted a population-based cross-sectional study on fruit and vegetable consumption and bone mass among 685

Abbreviations: ANCOVA, analysis of covariance; BMD, bone mineral density; YSM, years since menopause.

* **Corresponding author:** Prof. Suzanne C. Ho, fax +852 2602 6986, email suzanneho@cuhk.edu.hk

postmenopausal Chinese women from October 1999 to January 2001. The study methods have been described in previous reports (Ho *et al.* 2004, 2005). The study participants were recruited from community subjects residing in housing estates in Shatin, Hong Kong SAR. Because of differences in socioeconomic status of residents in different housing types, a stratified sampling method was used to select the housing estates in Shatin district according to the population distribution of 3:2:1, ratios in public, private and home ownership housings. Housing estates and then housing blocks within the estates were randomly selected. All eligible women residing in the selected housing blocks were then recruited via methods of both door-to-door as well as written invitations placed in mailboxes. Women within the specified age range were screened for eligibility. They were required to be Hong Kong residents of Chinese origin aged between 48 and 63 years, within 12 years of natural menopause, defined as at least 12 months since the last menstrual cycle. We excluded women who were current users of exogenous oestrogens exceeding 3 months, corticosteroids, thiazine and other medications known to affect bone mass. Written informed consent was obtained from all the participants prior to enrolment. The Ethical Committee of the Chinese University of Hong Kong approved the study. A total of 685 volunteers were recruited and met the screening criteria.

Data collection

BMD at the whole body, lumbar spine (L1–L4) and left hip were measured by dual-energy X-ray absorption using a Hologic QDR-4500 absorptiometer (Hologic Inc., Waltham, MA, USA). Independent variables included habitual intake of fruits and vegetables; co-variables included age, years since menopause (YSM), body weight and height, dietary protein and Ca, and physical activities including average hours spent in sitting, standing, walking, mild and vigorous physical activities, and going up flights of stairs per day.

Questionnaire interview

Information was collected by trained interviewers with face-to-face interviews based on a structured and previously validated questionnaire on general characteristics, YSM, physical activities and other factors that may affect bone mass (Ho *et al.* 1994, 1997). The dietary assessment of intakes of fruits, vegetables, Ca and protein was based on a quantitative food frequency questionnaire that included sixty food groups/items as described in previous studies (Chen *et al.* 2003; Ho *et al.* 2004). The mean intake of food per day, week or month was reported at the face-to-face interviews, using the past 12 months prior to the interview as a reference period. Foods with intake frequency less than once per month were ignored. Food pictures and food models in the reference portion sizes were provided as visual aids.

Fruit intake was estimated based on six main fruit items/groups: I, orange, grapefruit and lemon; II, apple, pear, peach, pineapple, plum, mango; III, water melons, papaya and various muskmelons; IV, lychee, longan, grapes and strawberry; V, banana; VI, durian. Vegetable intake was estimated based on five main vegetable groups: I, dark-green leafy vegetables (e.g. including pak choi, choi sum, lettuce, spinach, Chinese spinach, water spinach, Chinese kale, mustard); II, light-green leafy vegetables (e.g. broccoli, cabbage, cauliflower, celery); III, yam and potato, taro, fresh corn, and other tubers; IV, various vegetable melons (e.g. Chinese waxgourd, pumpkin, cucumber, towel gourd, bitter gourd, luffa-smooth loofah), eggplants, peppers, tomato, turnip and carrots; V, mushrooms. A separate analysis noted the reproducibilities of fruit and vegetable intakes based on the food frequency questionnaire over a 9-month period, which were r 0·605, $P<0·0001$ and r 0·471, $P<0·0001$, respectively (n 369); 84·1 % and 82·7 % of subjects had within one unit quintile agreements in fruit and vegetable intakes, respectively. Nutrients were calculated from the *Food Composition Tables* (Wang, 1991) and *Food Composition Table for Use in East Asia* (US Department of Health, Education and Welfare & Food & Agriculture Organization of the United Nations, 1972).

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. The BMD of the whole body and the sub-sites, the lumbar spine (L1–L4), as well as the left hip sites was measured by dual-energy X-ray absorptiometry (Hologic QDR-4500) (Chen *et al.* 2003; Ho *et al.* 2004). The CV of measurements with the spine phantom was 0·4 %. The *in vivo* CV for BMD measurements were 1·53, 1·72, 1·15, 4·86 and 1·2 % for the spine, femoral neck, trochanter, intertrochanter and whole body, respectively.

Statistical analysis

A univariate regression model was used to assess the association between fruit and vegetable consumption and BMD. Multiple stepwise regression analysis was used to examine whether the association was independent after adjustment for other potential risk factors, such as age, YSM, body weight and height, dietary total energy, protein and Ca, and physical activities (including time spent in walking, standing, mild and weight-bearing activities and going up flights of stairs per day). To avoid collinearity, fruits, vegetables or their total intake were separately forced into a regression model to examine their independent association with BMD. As vegetables and fruits are an important source of dietary Ca in the Chinese diet, and its adjustment might attenuate the vegetable/fruit–BMD association, we examined the association with and without Ca in the regression model.

Subjects were stratified into quintiles by total intake of fruit and vegetable. Covariate-adjusted means of the BMD at the various bone sites among the quintile groups were compared by *post hoc* multiple comparison tests (Bonferroni method) of analysis of covariance (ANCOVA). The same covariates to the multiple regression analysis were used in ANCOVA. However, only the covariates that remained significant ($P<0·05$) were retained in the final model. A manual forward stepwise method was used in adding the potential covariates. Significance level for entry and removal from the model were 0·05 and 0·10. The linear dose–response relations between fruit and vegetable intake and BMD were also calculated using ANCOVA models.

SPSS for Windows, version 12 (SPSS Inc., Chicago, IL, USA) was used for the analysis. Fifteen subjects with unreasonably high or low intakes of dietary energy (<2090 kJ (500 kcal) or >11 704 kJ (2800 kcal)) and total fruit and vegetable intake (<100 g/d or >1100 g/d) were excluded from the analyses. Two factors not included in the multivariate analyses were smoking and drinking alcohol because few women were smokers (1·8 % of subjects were an ever or current smoker defined as at least one cigarette daily for 3 months or over) and/or alcohol drinkers (4·3 % of subjects had one or more cups of alcoholic drink weekly).

Results

The 670 subjects had a mean age of 55 (SD 3·5) years, ranging from 48 to 63 years. The mean YSM was 4·6 (SD 2·8) years with a range of 1–12·5 years. The average intakes of fruits and vegetables were 175 (SD 101) and 295 (SD 150) g, respectively (Table 1). Around half of the fruit intake was from the group of orange, grapefruit and lemon, followed by the fruit groups of apple, pear, peach, pineapple, plum, mango; water melons, Chinese flowering quince and various muskmelons; banana. Of the mean 295 g vegetable intake, 179 (110) and 49 (45) g were of dark and light green leafy vegetables, respectively (Table 2). Of the 670 subjects, 412 (61 %) were housewives, sixty-five (10 %) were clerical and the remaining 193 (29 %) were sales, services or other blue-collar workers. Forty-five (6·7 %) subjects had no formal education, 262 (39·1 %) had attained primary, 301 (44 %) secondary and 62 (9·3 %) tertiary education. Except for a lower proportion of ‘no formal education’ and a higher proportion of ‘primary education’, the distribution of educational attainment is similar to that of women aged 45–54 years in Hong Kong (Hong Kong Census and Statistics Department, 2002).

Univariate regression analyses showed that fruit intake was significantly associated with greater BMD at the whole body, lumbar spine, left total hip, trochanter and intertrochanter. The associations between vegetable intake and BMD were also significant at the whole body, left total hip, trochanter and intertrochanter. The associations were more pronounced when using the total intake of fruits and vegetables as independent variable (Table 3).

To examine whether the intake of fruits, vegetables or their total intake had an independent favourable correlation with bone mass, potential confounders such as age, YSM, body weight and height, dietary total energy, protein and Ca, and physical activities were included in multiple stepwise regression models (Table 4). We found that the significant associations between the total consumption of fruits and vegetables and BMD at the whole body ($P=0·005$), lumbar spine ($P<0·001$) and total left hip ($P=0·002$) remained. And total fruit and vegetable intake accounted for about 1·0, 1·3 and 0·5 % of the variations in BMD at these three respective bone sites. A daily increase of 100 g fruit and vegetable intake was associated with 0·0062 (95 % CI 0·0019, 0·0105), 0·0098 (95 % CI 0·0041, 0·0155) and 0·0060 (95 % CI 0·0011, 0·0109) g/cm^2 increases in BMD at the whole body, lumbar spine and total left hip, respectively (Table 4).

Covariate-adjusted means of BMD at the whole body, lumbar spine and total left hip increased by 2·1, 4·1 and 2·2 % in subjects of the top quintile in comparison with those belonging to the lowest quintile of fruit and vegetable intake. Significant linear trends between total fruit and vegetable intake and BMD were observed at the whole body ($P=0·024$) and lumbar spine ($P=0·003$) (Fig. 1). As observed in the multivariate regression analysis, fruits had more pronounced association with BMD at the whole body and lumbar spine (data not shown).

When using fruits or vegetables as the independent variables, greater fruit intake was associated with increased BMD of the whole body ($P=0·032$), spine ($P<0·001$) and total hip ($P=0·074$), whereas vegetable intake was positively correlated with the whole body ($P=0·082$) and total hip BMD ($P=0·025$) after adjustment for the potential confounders such as age, YSM, body weight and height, dietary total energy and protein, and physical activities. When Ca was included in the model, the association at the total hip was greatly attenuated (Table 4). We further adjusted for education status and current job, and found that the associations between total intake of vegetables and fruits and BMD was slightly attenuated, but remained to be statistically significant ($P=0·007$ at the whole body; $P=0·001$ at the lumbar spine) (data not shown). The associations between the sub-categories of fruits or vegetables with BMD were generally less significant than that of their total intake (data not shown).

Table 1. Characteristics of the participants (*n* 670)
(Values are means and standard deviations together with median values)

	Mean	Median	SD	Minimum	Maximum
Age (years)	54·9	54·4	3·5	47·6	63·0
Years since menopause	4·6	4·1	2·8	1·0	12·3
Height (cm)	153·6	153·5	5·3	137·4	172·0
Weight (kg)	57·6	56·5	8·9	34·5	94·3
Daily dietary intakes					
Energy (kJ)	5010	4770	1550	2100	1152
Diet protein (g)	61·0	56·9	23·4	20·0	160·0
Vegetable (g)	295	259	150	22	894
Fruits (g)	175	160	102	0	640
Fruits and vegetables (g)	470	434	200	117	1090
Bone mineral density (g/cm^2)					
Whole body	0·965	0·963	0·091	0·734	1·273
Lumbar spine (L1–L4)	0·848	0·841	0·125	0·523	1·240
Total left hip	0·804	0·793	0·110	0·553	1·174

For details of subjects and procedures, see p. 745.

Table 2. Components of fruit and vegetable consumption among the participants (g/d) (*n* 670)
(Values are means and standard deviations together with median values)

	Mean	Median	SD	Proportion (%)
Fruit groups				
Orange, grapefruit, lemon	86	73	74	49·0
Apple, pear, peach, pineapple, plum and mango	44	32	48	25·2
Water melons, papaya and various muskmelons	23	14	30	12·9
Banana	19	10	26	10·9
Grapes, lichee, longan	3	0	6	1·8
Vegetable groups				
Dark green leafy vegetables*	179	150	110	60·8
Light green leafy vegetables†	49	37	45	16·5
Melons, carrot and radish‡	39	30	39	13·3
Starchy tubers and fresh corn§	13	8	16	4·5
Mushrooms	9	6	13	3·1
Fresh beans	6	3	7	2.0

* For example, pak choi, choi sum, lettuce, spinach, Chinese spinach, water spinach, Chinese Kale, mustard.
† For example, broccoli, cabbage, cauliflower, celery.
‡ For example, Chinese waxgourd, pumpkin, cucumber, towel gourd, bitter gourd, luffa-smooth loofah.
§ For example, yam, potato, taro, lotus root, fresh corn.
For details of subjects and procedures, see p. 745.

Table 3. Association between fruit and vegetable intake and bone mineral density among postmenopausal women in Hong Kong (*n* 670)†

	Fruit intake			Vegetable intake			Fruit and vegetable intake		
Bone mineral density (g/cm^2)	R^2 (%)‡	β‡	SE	R^2 (%)‡	β	SE	R^2 (%)‡	β	SE
Whole body	0·6	0·070	0·034*	0·6	0·048	0·023*	0·8	0·041	0·017*
Spine (L1–L4)	1·5	0·151	0·047**	0·3	0·046	0·032	1·2	0·062	0·024**
Total hip	0·9	0·102	0·042*	1·3	0·083	0·028**	1·5	0·069	0·021**
Neck	0·5	0·068	0·037	0·5	0·045	0·025	0·6	0·038	0·019*
Trochanter	0·8	0·086	0·037*	0·9	0·062	0·025*	1·1	0·055	0·019**
Intertrochanter	0·6	0·104	0·051*	0·9	0·087	0·034*	1·1	0·071	0·026**

Values were significantly different: *$P<0·05$; **$P<0·01$.
† For details of subjects and procedures, see p. 745.
‡ From univariate regression analyses. Regression coefficient (g/cm^2 per 1000 g/d).

Table 4. Multivariate linear regression analysis on association between intakes of fruit and vegetable and bone mineral density (BMD) (*n* 670)*

Dependent variable (BMD)	Independent variables in final model†	Total R^2 (%)	R^2 change (%)‡	β§	SE of β	*P* value of β
Total intake of fruits and vegetables and BMD						
Whole body	*wt*, *ysm*, *ht*, *mild*, *Fru_veg*	17·5	1·0	0·062	0·022	0·005
Spine L1–L4	*wt*, *ysm*, *ht*, *Fru_veg*	25·2	1·3	0·098	0·029	<0·001
Total hip	*wt*, *ysm*, *mild*, *ca*, *Fru_veg*	30·3	0·5	0·060	0·025	0·024
Total hip‖	*wt*, *ysm*, *prot*, *mild*, *Fru_veg*	29·7	0·9	0·076	0·024	0·004
Fruit intake and BMD						
Whole body	*wt*, *ysm*, *ht*, *mild*, *prot*, *Fru*	17·2	0·6	0·091	0·042	0·032
Spine L1–L4	*wt*, *ysm*, *ht*, *prot*, *Fru*	25·3	1·4	0·194	0·055	<0·001
Total hip	*ysm*, *wt*, *ca*, *mild*, *Fru*	29·9	0·2	0·058	0·046	0·214
Total hip‖	*ysm*, *wt*, *mild*, *prot*, *Fru*	32·3	0·4	0·061	0·033	0·074
Vegetable intake and BMD						
Whole body	*wt*, *ysm*, *ht*, *mild*, *Veg*	17·0	0·3	0·050	0·029	0·082
Spine L1–L4	*wt*, *ysm*, *ht*, *Veg*	24·2	0·3	0·058	0·037	0·117
Total hip	*ysm*, *wt*, *ca*, *mild*, *Veg*	29·8	0·1	0·030	0·032	0·369
Total hip‖	*ysm*, *wt*, *mild*, *prot*, *Veg*	29·4	0·5	0·053	0·023	0·025

* For details of subjects and procedures, see p. 745.
† Independent variables: the first block variables included age, years since menopause (*ysm*), body weight (*wt*), height (*ht*), dietary energy, protein (*prot*) and Ca (*ca*), and physical activities (including time spent in walking (*walk*), standing (*std*), mild (*ma*) and weight bearing (*wb*) activities and going up flights of stairs per day) (method step-wise); either fruit intake (*Fru*), vegetable (*Veg*) or total intake of fruits and vegetables (*Fru_veg*) were put in the second block (method enter). Significance levels for entry and removal from the model were 0·05 and 0·10.
‡ R^2 changes due to fruit intake, vegetable intake or total fruit and vegetable intake.
§ Regression coefficients for fruit intake, vegetable intake or total fruit and vegetable intake (g/cm^2 per kg per d).
‖ Dietary Ca was excluded from the regression model. It was not significant at the whole body and lumbar spine BMD.

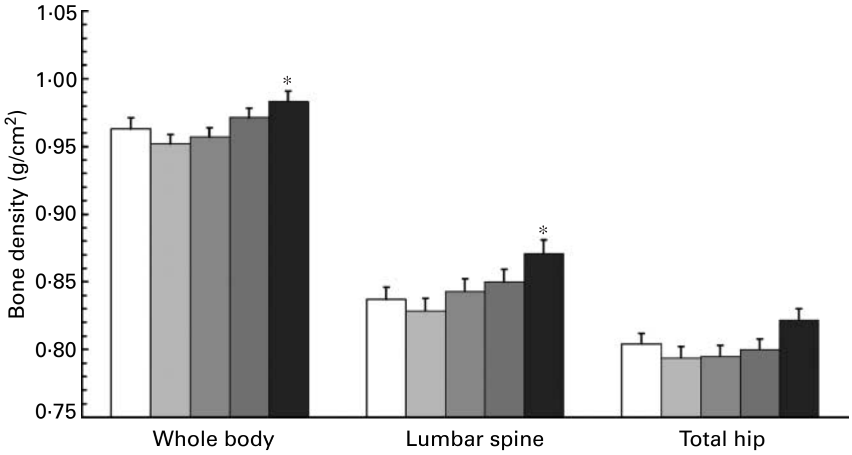

Fig. 1. Bone mineral density by quintiles (Q1, □; Q2, ▩; Q3, ▩; Q4, ▩; Q5, ■) of fruit and vegetable intake (*n* 670). For details of subjects and procedures, see p. 745. Values are covariate adjusted means with their standard errors represented by vertical bars. Mean values across the quintiles were 222 (SD 42), 328 (SD 25), 421 (SD 35), 541 (SD 41) and 749 (SD 111) g/d. Analysis of covariance (ANCOVA) *P* values: from ANCOVA, after adjusting for body weight, height, years since menopause, dietary energy, protein and Ca and physical activity. Only the covariates that remained significant ($P < 0·05$) were retained in the final model. *P* value for trends: tests for linear dose–response relationship: whole body 0·024, ANCOVA $P = 0·040$; lumbar spine 0·003, ANCOVA $P = 0·024$; total hip 0·108, ANCOVA $P = 0·089$. *: Group Q2 compared with group Q5; $P < 0·05$, obtained from *post hoc* tests (Bonferroni method).

Discussion

Chinese populations generally have a diet rich in vegetables and fruits, but low in animal protein (Leung *et al.* 1997; Ma, 2004). Previous studies have demonstrated that higher fruit and vegetable consumption is associated with lower risks of many chronic diseases (Lampe, 1999) such as certain cancers (Terry *et al.* 2001; Flood *et al.* 2002), stroke (Johnsen *et al.* 2003) and CVD (Bazzano *et al.* 2002). Some recent studies have also focused on the role of fruits and vegetables on bone health (Tucker *et al.* 1999, 2002; New *et al.* 2000; Kaptoge *et al.* 2003; McGartland *et al.* 2004; Tylavsky *et al.* 2004; Macdonald *et al.* 2005*a*; Vatanparast *et al.* 2005). Except for one study (Kaptoge *et al.* 2003), associations of fruit and vegetable consumption with larger bone size in early pubertal children and adolescents (McGartland *et al.* 2004; Tylavsky *et al.* 2004; Vatanparast *et al.* 2005), with better bone mass in perimenopausal Caucasian women (New *et al.* 2000), in postmenopausal women (Macdonald *et al.* 2005*a*) and in elderly Caucasian adults (Tucker *et al.* 1999, 2002) have been noted. However, no study has yet examined the association between fruit and vegetable consumption and bone mass or osteoporotic fractures in Asian populations.

In the present population-based cross-sectional study, we found that greater fruit and vegetable intake was independently associated with greater BMD at the whole body and lumbar spine among postmenopausal Chinese women with mean fruit and vegetables intakes of 175 and 295 g/d, respectively. Consistent with most previous studies (Tucker *et al.* 1999, 2002; New *et al.* 2000; McGartland *et al.* 2004; Tylavsky *et al.* 2004; Vatanparast *et al.* 2005), the present findings also confirmed the positive association between fruit and vegetable intake and BMD. A daily increase of 100 g fruit and vegetable intake was associated with 0·0062 (95 % CI 0·0019, 0·0105) g/cm^2 (whole body), 0·0098 (95 % CI 0·0041, 0·0155) g/cm^2 (lumbar spine) and 0·0060 (95 % CI 0·0011, 0·0109) g/cm^2 (total left hip) increases in BMD even after adjustment for age, YSM, body weight and height, dietary total energy, protein and Ca and physical activities. However, the associations tended to be attenuated when using the intakes of sub-categories of fruits or vegetables as the independent variables.

Previous studies have proposed several mechanisms by which vegetables and fruits improve bone health (Lampe, 1999). The most important theory might be the acid–base hypothesis in which an acidic environment leads to progressive bone loss (Tucker *et al.* 2001; Alexy *et al.* 2005; Macdonald *et al.* 2005*a*; Sebastian, 2005). The modern diet typically has high acid-burden due to high consumption of animal protein food. It has been hypothesized that alkaline cations (e.g. K, Mg and Ca) from vegetables and fruits could neutralize the calciuric effects of acids derived from acid-forming components in diets (Frassetto *et al.* 2005).

In addition, vegetables and fruits might affect bone health via the roles of vitamin C, vitamin K, β-carotene, carotenoids, phyto-oestrogens and other phytochemicals highly enriched in fruits and vegetables. Many studies have reported that greater intakes of vitamin C, vitamin K and phyto-oestrogens are associated with greater bone mass (Morton *et al.* 2001; Arjmandi & Smith, 2002; Booth *et al.* 2003; Chen *et al.* 2003; Ho *et al.* 2003). Vitamin C might affect bone mass in the formation of various cross-links between amino acids in collagen via the vitamin C-dependent hydroxylation of proline and lysine residues (New *et al.* 2000). Vitamin K, mainly present in green leafy vegetables, fermented foods or produced by intestinal bacteria, might play a role in fighting age-related bone loss through the vitamin K-dependent γ-carboxylation of certain proteins in bone (Binkley & Suttie, 1995; Shearer, 1997). Phyto-oestrogens might inhibit bone resorption and stimulate bone formation partially by imitating the oestrogen effects via oestrogen receptors (Arjmandi & Smith, 2002). Furthermore, the bone-protective effects of these nutrients and phytochemicals may be mediated by scavenging oxygen radicals (Lachnicht *et al.* 2002; Lean *et al.* 2003).

Ca might also play a role in the effect of vegetables and fruits on BMD. Vegetables and fruits supplied about 43·5 % (vegetables 37·3 %, fruits 6·2 %) of total dietary Ca intake in the present study population. Weaver *et al.* (1997) reported that true fractional Ca absorption from several commonly consumed Chinese vegetables is higher than that from milk by almost 10 %. We also found higher Ca intake was independently associated with increased BMD (Ho *et al.*, unpublished results) and decreased bone loss in the population studied (Ho *et al.* 2004). When excluding Ca from the multivariate regression models, the association between vegetables and/or fruits and BMD at the total hip was much more pronounced. The present findings suggested that vegetables and fruits might improve BMD partially through the Ca effect.

Our previous report indicated that better education was significantly associated with increased BMD; and better-educated women typically consumed more vegetables and fruits in the population studied (Ho *et al.* 2005). However, the association between total intake of vegetables and fruits and BMD remained statistically significant at the whole body and lumbar spine even further adjusting for education status and current job. The present findings suggested the association of vegetables and fruits with BMD was independent of the main socioeconomic determinants.

The intake (470 g) of fruits and vegetables in the present population is similar to that of 427 g per reference person per day in Guangzhou (the capital of Guangdong province that borders on Hong Kong), China reported in the 2002 Chinese National Nutritional Survey (Ma, 2004). Caucasians self-reported a comparatively lower amount of vegetables than the Chinese population (Djousse *et al.* 2004; Ma, 2004). Our population also had a higher intake of fruits and vegetables than that of 3·5 (SD 1·8) servings (approximately 280 g) observed in US women aged 52·2 (SD 13·7) years in the National Heart, Lung, and Blood Institute Family Heart Study (Djousse *et al.* 2004). In general, a typical Chinese diet comprises higher components of vegetables and fruits, and lower intake of protein than their Western counterparts, and this plant-based diet might be beneficial for bone health.

Although the major determinants of bone mass are genetic factors, body weight and YSM, nutritional factors are of particular importance to bone health because they are modifiable. Previous studies have focused primarily on the role of Ca and vitamin D in bone health. Recent studies have also investigated the role of many micronutrients and phytochemicals (Arjmandi & Smith, 2002; Chen *et al.* 2003; New & Bonjour, 2003; Wattanapenpaiboon *et al.* 2003; Macdonald *et al.* 2004). Due to the complexity of food composition, and the collinearity among nutrients/phytochemicals, it is difficult to delineate the association of an individual nutrient/phytochemical with bone health. The study of whole foods may thus be more revealing, and recommendation based on particular food groups/items is also a more practical approach in nutrition education.

The present population-based study is cross-sectional in design and the dietary investigation is based on current consumptions. However, adults generally maintain a relatively stable dietary habit over a long period. Macdonald *et al.* (2005*b*) has reported small, though statistically significant, differences in intakes over 5–7 years for most nutrients (<8 % change) in 898 middle-aged women. Less than 15 % of women had a change of more than one quartile classification in their study (Macdonald *et al.* 2004). The present findings based on the food frequency questionnaire method have also noted good long-term reproducibility, with 84 % and 83 % having within one unit quartile agreements in fruit and vegetable intakes, respectively. Current habitual intake might reasonably reflect long-term habitual intake in adults. Further investigations based on a randomized controlled trial would be necessary to confirm the beneficial effects of fruits and vegetables on bone health.

In conclusion, the present findings showed that greater fruit and vegetable consumption was independently associated with significantly higher BMD at the whole body, lumbar spine and total hip, even after controlling for potential confounders.

Acknowledgements

The study was partially supported by the Health Services Research Fund (#831010) of Hong Kong.

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