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A Healthier Lifestyle Pattern for Cardiovascular Risk Reduction Is Associated With Better Bone Mass in Southern Chinese Elderly Men and Women

Zhao-min Liu, PhD, Carmen Ka Man Wong, MBBCh, Samuel Yeung-shan Wong, MD, Jason Leung, MSc, Lap Ah Tse, PhD, Ruth Chan, PhD, and Jean Woo, MD

Abstract: Lifestyle factors have been linked to bone health, however little is known about their combined impact on bone. Cardiovascular disease (CVD) and osteoporosis are 2 major public health problems that share some common pathophysiology. We aimed to assess whether higher adherence to American Heart Association diet and lifestyle recommendations (AHA-DLR) was associated with better bone health in Chinese elderly.

This was a cross-sectional study using data from the largest population-based study on osteoporosis in Asia (Mr and Ms Os, Hong Kong). The study recruited 4000 independent walking Chinese men and women aged ≥65 year. Information on demographic, health, and lifestyle factors was obtained by standardized questionnaires. An overall lifestyle score was estimated based on a modified adherence index of AHA-DLR. Bone mineral measurements of the whole body, total hip, lumbar spine, and femoral neck were made by dual-energy X-ray absorptiometry.

Most lifestyle factors alone were not significantly associated bone mass. Overall lifestyle score in the highest quartile compared with the lowest quartile had significantly better bone mass at all sites in a dose–response manner. Every 10-unit of lifestyle score increase was associated with 0.005, 0.004, and 0.007 g/cm^2 increases of bone mineral density (BMD) at whole body, femur neck, and total hip, respectively (all $P < 0.05$), and 13.2% (odds ratio 0.868; 95% CI 0.784, 0.961) decreased risk of osteoporosis at total hip after adjustment for potential covariates.

Our study suggested that greater adherence to an overall healthy lifestyle for CVD risk reduction was associated with better bone mass among Chinese elderly.

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Abbreviations: AHA-DLR = American Heart Association diet and lifestyle recommendations, BMD = bone mineral density, BMI = body mass index, CVD = cardiovascular disease, DXA = dual-energy X-ray absorptiometry, F&V = fruits and vegetables, FFQ = food-frequency questionnaire, SD = standard deviation.

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From the Division of Family Medicine and Primary Care (ZmL, CKMW, SYsW); Division of Occupational and Environmental Health, Jockey Club School of Public Health and Primary Care (LAT); Jockey Club Centre for Osteoporosis Care and Control, The Chinese University of Hong Kong, Shatin (JL); and Department of Medicine and Therapeutics, the Chinese University of Hong Kong, Hong Kong SAR (RC, JW).
Correspondence: Zhao-min Liu, Research Assistant Professor of Division of Family Medicine and Primary Care, Jockey Club School of Public Health and Primary Care, The Chinese University of Hong Kong, Hong Kong SAR; (e-mail: liuzhaomin@cuhk.edu.hk).
Jean Woo, Division of Geriatrics, Department of Medicine and Therapeutics, The Chinese University of Hong Kong, Hong Kong SAR (e-mail: jeanwoowong@cuhk.edu.hk).
JW conceptualized and designed the study. ZmL conducted statistical analysis, interpreted the results, and wrote the manuscript. All the co-authors made critically comments and revisions on the manuscript.
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INTRODUCTION

Chronic diseases often coexist in the aging population. Cardiovascular disease (CVD) and osteoporosis are 2 chronic conditions of a major public health burden particularly in the elderly population. Although these 2 conditions appear to be independent, recent evidence from basic and epidemiologic research suggest that CVD and osteoporosis are linked with similar biological mechanisms (oxidative stress or inflammation,[1] endogenous sex hormones,[2] oxidized lipids, and vitamin D[3]) and shared common lifestyle-risk factors[4] (diet, physical activity, smoking, and alcohol consumption). Studies have implicated inflammation as the primary mediator of the accelerated bone loss.[1,2] There are similar pathways of vascular and bone calcification.[2] One meta-analysis reported that one standard deviation (SD) decrease of bone mineral density (BMD) was associated with 22% increased risk of stroke incidence in women.[5] This implies that strategies for CVD risk reduction may also reduce the risk of osteoporosis and fracture.

Identifying lifestyle factors associated with chronic conditions are of particular importance since they are potentially modifiable.[6] Studies have suggested the overall lifestyle pattern could capture potential synergistic effects and balance between protective and harmful components in lifestyle factors and have substantial advantages over single components.[7,8] The American Heart Association diet and lifestyle recommendations (AHA-DLR) are overall healthy lifestyle guidelines with the intention to reduce CVD risk.[9] Recently, an adherence index to the AHA-DLR has been developed and validated.[10] The combined score integrates the individual component of lifestyle factors into a summary measure with differential weights, providing a useful evaluation tool examining overall healthfulness of given lifestyles.

Despite the wealth of evidence of individual lifestyle factors associated with bone health, studies that evaluate a combination of lifestyle factors and its effects on bone mass were limited. Different populations can have unique lifestyle patterns which may have varying effects on bone health. It is thus necessary to qualify the association in different ethnic groups. To our knowledge, no study has assessed the utility of adherence to AHA recommendations on bone mass among Chinese population who generally exhibit lifestyle profile remarkably different from those of Western populations.[11] Since there are cumulative effects of adverse factors throughout life, it is particularly important for the elderly to adopt lifestyle practices that maximize their prospects for healthy aging.[12] The aim of this study was thus to investigate whether adherence to a healthy diet and lifestyle recommendation for CVD reduction was associated with better bone mass in a large, representative sample of Hong Kong Chinese elderly men and women.

MATERIALS AND METHODS

Subjects Recruitment

This was a cross-sectional study based on Mr Os and Ms Os (Hong Kong), which is the largest population-based study on osteoporosis in Asian men and women to date. The methodology of this project has been reported elsewhere.[13] In brief, 4000 Chinese men (n = 2000) and women (n = 2000) who were 65 years and older were recruited from the local communities from August 2001 to March 2003. All participants were volunteers, community dwelling, and able to walk without assistance and without bilateral hip replacement. They were recruited via notices and talks in community centers or housing estates by using a stratified sampling method to ensure that approximately one-third of the participants fall into each of the following age strata: 65 to 69, 70 to 74, and ≥75. Forty two subjects who were taking osteoporosis medications were excluded for this analysis resulting in 3958 subjects for analysis. The study protocol was reviewed and approved by the Clinical Research Ethics Committee of The Chinese University of Hong Kong and written informed consent was obtained from all subjects.

Bone Mineral Assessment

BMD, bone mineral content, and bone area at whole-body, total hip, lumbar spine (L1–L4), and femoral neck were measured by dual-energy X-ray absorptiometry (DXA) in a Hologic QDR-4500 W densitometers (Hologic, Waltham, MA). The coefficients of variation in our laboratory were 0.7%, 0.9%, and 1.3% at the total hip, lumbar spine, and femoral neck, respectively.[13] DXA software (version 5.61; Hologic Inc.) was used for whole-body measurements (enhanced analysis), and the performance mode (version 4.47P) was used for spine and hip measurements. Quality assurance was performed daily, and long-term instrument stability was assessed 2 to 3 times per week. We used the WHO definition for the determination of osteoporosis (T-score ≤−2.5 SD) and osteopenia (T-score −1.0 to −2.5 SD), with reference standard of normative data from the NHANES (the National Health and Nutrition Examination Survey) reference database on Caucasian women aged 20 to 29 years.[14]

Overall Lifestyle Assessment Based on AHA-DLR

The healthfulness of overall lifestyle was assessed by a modified AHA-DLR. The original adherence index of AHA-DLR has been developed and validated by Bhupathiraju et al.[10] As in Kanauchi's study[15] we used a simplified index with minor modifications (see Supplemental Table 1, http://links.lww.com/MD/A351, which indicated a modified components and scoring system for AHA-DLR). The modified scale included, consuming a diet rich in fruits and vegetables (F&V) and choosing a variety of F&V, choosing whole-grain products, consuming fish, consuming appropriate total fat and limiting intake of saturated fat and cholesterol, minimizing intake of sweetened beverages, consuming low salt foods, consuming alcohol in moderation, not smoking, and taking part in adequate physical activity. Participants with good adherence received the maximum points (4, 5, 6, or 10 points for each subcomponent) and those not adhering were assigned 0 points or intermediate points. The adherence index was the sum of the 10 subcomponents with a maxim score of 99. A higher score indicates a healthier lifestyle pattern and greater adherence to the AHA-DLR.

The modifications we have made included:

(1) We removed the body mass index (BMI) from the original scale since body weight is a strong protective factor for bone mass; however, we adjusted it in all statistical analyses to control for potential confounding effects.
(2) Trans-fat intake was excluded since precise evaluation of trans-fat intake is difficult using a semiquantitative food-frequency questionnaire (FFQ). In addition, Asians tend to consume diets low in trans-fat with the average intake only 0.2% to 0.3% of total energy, much lower than caucasians (1.2%) and WHO/FAO recommendation (<1%).[16,17]
(3) The F&V serving size in our study was determined as 100 g for fruits and 70 g for vegetables.[18]
(4) The FFQ used in our study did not ask for F&V varieties, however we undertook a comprehensive investigation on F&V intake which included 28 kinds of fruits and 68 kinds of vegetables, covering almost all the varieties of F&V commonly sold in local markets. The number of F&Vs specifically reported was used for variety estimation.[15]
(5) Since sugar sweetened beverages are the leading dietary source of added sugar,[19] we used sweetened beverages to represent added sugar intake.
(6) The median of dietary salt intake by FFQ was 3.3 g/day (quartile range 2.3–4.8 g/day) in current study. This amount did not include the discretionary salt use. According to our recent report among 655 Hong Kong postmenopausal women,[20] the salt intake estimated from 24 hours urine excretion was 7.5 g/day with the discretionary salt accounting for around 50%. Thus, we adjusted the salt intake as 2-folds of the original amount.

Anthropometric Measurements

Body weight was measured to the nearest 0.1 kg with subjects wearing a light gown, using the Physician Balance Beam Scale (Healthometer, Alsip, IL). Height was measured to the nearest 0.1 cm using the Holtain Harpenden standiometer (Holtain, Crosswell, UK). BMI was calculated as body weight (kg)/height (m^2). Body composition parameters such as body fat%, lean muscle mass and fat mass were assessed by DXA.

Other Covariates

Standardized and structured questionnaires were administered by face-to-face interview to obtain demographic information, dietary intake, smoking habit, alcohol intake, physical activity, medical history, and use of calcium supplements, etc. Dietary intake was assessed using a validated semiquantitative FFQ.[21] Each subject was asked by a trained interviewer to report the frequency and the usual amount of consumption of each food item over the past year. Physical activity was measured by a validated Physical Activity Scale for the Elderly Questionnaire (PASE).[22] This is a 12-item scale measuring the average number of hours per day spent in leisure, household, and occupational physical activities over the previous 7-day period. Tobacco and alcohol consumptions were estimated by self-report using validated tools.[23] Smoking habit was classified in terms of former smoking, current smoking, and never smoking. For alcohol and other beverage consumption, subjects were asked to report their daily frequency of intake in portion sizes specified on the semiquantitative FFQ.

Statistical Analysis

Data analysis was performed by using IBM SPSS Statistic Software 19.0 (SPSS Inc., Chicago IL, USA). $P < 0.05$ was considered statistically significant. Differences in characteristics by sexes and bone mineral status (normal, osteopenia, and osteoporosis) were performed using Chi-square analyses for categorical variables and independent *t*-test/analysis of variance for continuous variables. Analyses were made by pairwise deletion with all cases in which the variables of interest were present.

The overall lifestyle score (adherence index) was treated as both continuous measure and quartile categories. The associations of bone mass parameters at various sites with overall lifestyle score were examined using general linear models and multivariate linear regression models by sequentially adjusting potential covariates. In model 1, we adjusted age, sex, season, and education levels. In model 2, we further adjusted BMI, height, and dietary factors such as total energy, energy-adjusted protein, calcium, vitamin D, milk products, caffeine, Chinese tea and supplemental calcium intake, sitting, and sleeping hours. In model 3, further adjustment was made for model 2 plus medical history (yes or no) of diabetes, hypertension, stroke, and cancers as well as medication usage for osteoporosis (yes or no). Tests for linear trend were conducted by treating the median value of each quartile of the overall lifestyle score as continuous variable in regression analyses. The highest and lowest quartiles were compared using Bonferroni method with the lowest quartile as the reference group. In all analyses, we tested for potential effect modification due to sex by including an interaction term with the quartiles of lifestyle scores in regression models. No significant interaction was observed with sex ($P > 0.05$) in majority of analyses. Thus, data from men and women were analyzed together, and sex was included as a covariate in regression models.

Binary logistic regression models were used to estimate the odds ratio of osteoporosis for each 10-unit increase in the combined lifestyle scores with adjustment for the covariates used in the linear regression models with exclusion of patients with chronic conditions. We also determined the associations of each subcomponent of recommendations with bone mass by inclusion of scores of each subcomponent as an independent variable in multivariate linear regression models. Each regression model was adjusted for above covariates plus the total scores minus the subcomponent being investigated. Subgroup analyses excluding subjects with diagnosed diabetes, hypertension, stroke, and any self-reported cancers were conducted to investigate the potential bias since chronic conditions may affect patients' dietary and other lifestyle choices after diagnosis.

RESULTS

Characteristics of Participants

Characteristics of participants by sexes and bone loss status are shown in Table 1. The mean age of the participants was 72.5 ± 5.2 years. Men were more likely to be smokers; had higher intake of energy, fat, cholesterol, sodium, and vitamin D; drunk more alcohol, coffee, Chinese tea, and sweetened beverages; and were more physically active than women. Women tended to have higher BMI, whole body fat % and sitting hours, higher intake of F&V, fish, and whole grains than men. Height, education above university, BMI, physical activities, dietary energy, protein, fat, cholesterol, calcium, sodium and vitamin D, fish, milk products, and whole grains intakes were significantly lower in subjects with osteoporosis than those with normal bone mass.

Adherence Status

The percentages of subjects meeting the optimal adherence for diet and lifestyle recommendation are shown in Table 2. The adherence rates were lowest in the consumption of adequate whole grains (% of total grains) and limiting saturated fat (% of total fat) in both men and women (both <10%). There were significant differences in good adherence rates between men and women, except for the amount of vegetable intakes.

The Associations of Lifestyle Scores and Bone Mass

The adjusted means of bone mass parameters (BMD, bone mineral content, and bone area) across quartiles of overall lifestyle scores are shown in Table 3. Those in the highest quartile compared with the lowest quartile of scores had a significantly better BMD at all sites and most had a significant dose–response manner. After adjustment for the above covariates, every 10-unit increase in the lifestyle scores was associated with a 0.005, 0.004, and 0.007 g/cm^2 higher BMD at whole body, femoral neck, and total hip, respectively ($P < 0.05$) (Table 4). After exclusion of subjects with a history of diabetes, stroke, and certain cancers, each 10-unit increase in the lifestyle score was associated with 13.2% decreased risk of osteoporosis at total hip with the multivariate-adjusted odds ratio 0.868 (0.784, 0.961, $P = 0.006$) (data not shown).

The association of each subcomponent of the recommendations with BMD is shown in Supplemental Table 2, http://links.lww.com/MD/A351. Except for fruits and physical activities, the other subcomponents were not significantly and positively associated with BMD ($P > 0.05$). Subgroup analyses (Table 4) with exclusion of patients with history of diabetes ($n = 579$), stroke ($n = 175$), and various cancers ($n = 177$) made a stronger association with BMD in multivariate regression models. The standardized coefficients in model 3 were 0.043 ($P = 0.003$), 0.047 ($P = 0.005$), and 0.054 ($P < 0.001$) for whole-body, femoral neck, and total hip, respectively (all $P < 0.001$).

DISCUSSION

Our results suggest that diet and lifestyle guidelines for CVD risk reduction also benefit bone health. To our knowledge, this is the first study to quantify the combined impact of lifestyle factors on bone mass in Chinese population. The findings highlight the importance of overall lifestyle modification in the maintenance of bone mass.

Although evidence used to determine the index of AHA diet and lifestyle recommendations were from non-Hispanic white individuals and with intention of CVD prevention, the AHA maintains that the recommendations are generalizable to other ethnic groups and protect against other chronic diseases besides CVD.[9,24] As the diet and lifestyle pattern in Hong Kong

TABLE 1. Characteristics of Chinese Elderly Men and Women by Sexes and Bone Mineral Status

	Sexes			Bone Mineral Status			
Characteristics	**Men**	**Women**	***P***	**Normal**	**Osteopenia**	**Osteoporosis**	***P***
N	1994	1964		494	1866	1598	
Age, year	72.4 ± 5.0	72.6 ± 5.4	0.302	71.2 ± 4.6	71.8 ± 4.8	73.7 ± 5.6*	<0.001
Education (≥University %)	270 (13.5)	116 (5.9)	<0.001	82 (16.6)	194 (10.4)†	110 (6.9)*	<0.001
Current smoker, %	237 (11.9)	36 (1.8)	<0.001	45 (9.1)	132 (7.1)†	96 (6.0)*	<0.001
Alcohol > 12 drinks/year, %	470 (23.5)	50 (2.5)	<0.001	111 (22.4)	290 (15.4)†	121 (7.5)*	<0.001
Medication treatment for OS, %	5 (0.3)	36 (1.8)	<0.001	2 (0.4)	14 (0.7)	25 (1.5)*	0.022
Medical history							
Diabetes, %	293 (14.7)	285 (14.3)	0.876	112 (22.6)	279 (14.8)†	188 (11.6)*	<0.001
Stroke, %	108 (5.4)	66 (3.3)	0.002	27 (5.8)	79 (4.2)†	67 (4.1)*	<0.001
Hypertension, %	834 (41.7)	855 (42.8)	0.271	244 (49.1)	850 (45.2)	613 (37.8)	0.234
Cancers, %	87 (4.4)	89 (4.5)	0.794	15 (3.0)	89 (4.7)	73 (4.5)	0.250
Height (cm)	163.1 ± 5.7	150.9 ± 5.3	<0.001	162.7 ± 7.1	158.7 ± 7.6†	153.3 ± 7.6*	<0.001
BMI, kg/m^2	23.4 ± 3.1	23.9 ± 3.4	<0.001	25.5 ± 3.1	24.2 ± 3.0	22.5 ± 3.2*	<0.001
Whole body fat%	24.4 ± 3.1	35.6 ± 3.4	<0.001	27.4 ± 6.1	29.2 ± 7.1†	30.4 ± 7.5*	<0.001
Dietary factors							
Total energy, kcal/day	2099 ± 587	1582 ± 462	<0.001	2075 ± 621	1891 ± 586†	1712 ± 547*	<0.001
Protein (g/1000 kcal)	41.2 ± 9.4	40.7 ± 9.4	0.079	42.3 ± 9.3	41.2 ± 9.4	40.2 ± 9.4*	<0.001
Fat (g/1000 kcal)	29.0 ± 6.4	27.6 ± 6.3	<0.001	32.1 ± 7.1	31.8 ± 7.0	30.9 ± 7.1*	<0.001
(P + M)/SFA, %	2.7 ± 0.6	3.0 ± 0.8	<0.001	2.7 ± 0.6	2.8 ± 0.7	2.9 ± 0.7*	<0.001
Cholesterol, mg/day	230.4 ± 145.8	156.0 ± 166.1	<0.001	250.9 ± 301.8	200.6 ± 138.3†	166.9 ± 108.7*	<0.001
Calcium (mg/1000 kcal)	299.4 ± 116.1	361.0 ± 137.0	<0.001	321.6 ± 120.3	326.4 ± 129.6	337.3 ± 134.6*	0.019
Sodium, g/day	1.7 ± 1.0	1.3 ± 0.9	<0.001	1.7 ± 0.9	1.5 ± 0.9†	1.4 ± 1.1*	0.001
Vitamin D, IU/day	14.5 ± 25.4	12.1 ± 15.3	<0.001	16.1 ± 31.4	12.8 ± 19.4†	13.1 ± 18.7*	0.005
Vegetables (g/1000 kcal)	118.5 ± 74.8	151.8 ± 86.8	<0.001	123.4 ± 69.0	133.0 ± 78.1†	141.2 ± 90.8*	<0.001
Fruits (g/1000 kcal)	132.1 ± 87.9	156.0 ± 95.4	<0.001	140.4 ± 84.3	143.3 ± 90.0	146.0 ± 97.2	0.232
Fish (g/1000 kcal)	44.1 ± 35.6	47.3 ± 40.9	0.008	48.7 ± 42.7	45.4 ± 35.4	45.2 ± 40.2	0.073
Milk products (g/1000 kcal)	19.1 ± 41.2	16.4 ± 3.3	0.030	21.6 ± 55.6	18.6 ± 37.1†	15.8 ± 34.6*	0.004
Beverage (g/1000 kcal)	337.3 ± 304.5	262.5 ± 323.6	<0.001	325.2 ± 303.0	309.0 ± 306.7†	280.2 ± 329.1*	0.005
Whole grains (% total grains)	6.6 ± 10.6	11.6 ± 13.2	<0.001	8.3 ± 11.7	8.4 ± 11.6	10.1 ± 13.0*	0.005
Caffeine, mg/day	81.5 ± 67.7	46.6 ± 53.3	<0.001	78.9 ± 64.8	68.1 ± 64.6†	54.9 ± 60.1*	<0.001
Chinese tea, mL/day	583 ± 550	346 ± 431	<0.001	535.6 ± 496.7	492.2 ± 523.2†	410.6 ± 488.8*	<0.001
Physical activities score (PASE)	97.3 ± 50.3	85.4 ± 33.2	<0.001	100.5 ± 48.2	94.5 ± 45.0†	84.8 ± 37.8*	<0.001
Sitting time, h/day	3.3 ± 1.3	3.6 ± 1.1	<0.001	3.3 ± 1.3	3.4 ± 1.2	3.5 ± 1.2*	<0.001
Sleeping hours, h/day	7.4 ± 1.3	7.1 ± 1.3	<0.001	7.3 ± 1.2	7.3 ± 1.2	7.3 ± 1.4	0.627

Data were presented as mean ± SD or number (%). Independent *t*-test or analysis of variance was used for continuous variables. Chi-square test was used for categorical variables. Physical activity was measured by a validated PASE. Dietary intakes were assessed from a validated food frequency questionnaire. Bone mineral parameters were measured by DXA in Hologic QDR-4500 W densitometers. The diagnosis of osteopenia and osteoporosis were based on the femoral neck BMD (T-score of −1.0 to −2.5 SD for osteopenia and ≤−2.5 SD for osteoporosis) by comparison with normative data from the NHANES reference database on Caucasian women aged 20 to 29 years. BMD = bone mineral density, BMI = body mass index, DXA = dual-energy X-ray absorptiometry, OS = osteoporosis, PASE = Physical Activity Scale for the Elderly Questionnaire, (P + M)/SFA = (polyunsaturated fatty acid + monounsaturated fatty acid)/saturated fatty acid.

* Osteoporosis group compares with normal BMD group $P < 0.05$.

† Osteopenia group compares with normal BMD group $P < 0.05$

has become more westernized over the past few decades,[25] it could be rational to adopt the guideline in Hong Kong Chinese population.

Study Implications

In this cross-sectional study among Chinese elderly, the effect sizes (0.004–0.007 g/cm^2) observed for a 10-unit increase in the composite lifestyle scores are comparable with the annual age-related bone loss in elderly men and perimenopausal women,[26,27] suggesting appropriate lifestyle modification could counteract the annual bone loss due to aging. Meta-analyses reported that the risk of hip and osteoporotic fracture increased 2.6- or 1.5-folds for each SD decrease in femoral neck BMD.[28,29] Thus, the observed changes at the femoral neck (0.046 SD) in our study could translate to 11.9% reduction in hip fractures or 6.6% reduction in osteoporotic fractures. This magnitude can be of essential clinical and public health importance, particularly as bone mass changes in our study are expected to be larger if the scale includes other nutritional or lifestyle factors such as dietary and supplemental calcium and vitamin D intake, BMI, and weight bearing physical activities which have essential implications on the improvement of bone mass. Furthermore, the favorable associations might be underestimated due to random errors in the self-reported lifestyle factors, and inclusion of patients with chronic diseases in which reverse associations may exist.

TABLE 2. Percentages of Participants Meeting the Modified Recommendations of AHA Diet and Lifestyle

Recommendations	Criteria of Good Adherence	Percent With Good Adherence		
Dietary Factors	**(Score for Good Adherence)**	**Men, %**	**Women, %**	***P***
Fruits, g/day	≥200 (5)	60.7	55.4	0.002
Vegetables, g/day	≥350 (5)	17.3	15.2	0.142
Variety/week in F&V intake	≥15 (10)	16.5	10.3	<0.001
Whole grains (% total grains)	≥50% (10)	0.6	1.3	<0.001
Fish intake, g/week	≥400 (10)	60.8	52.7	<0.001
Total fat intake (% energy)	25–35% (4)	56.3	52.6	<0.001
Saturated fat intake (% total fat)	<3.5 (6)	1.9	3.5	<0.001
Dietary cholesterol, mg/day	<150 (4)	30.1	58.6	<0.001
Sweetened beverages, oz/week	≤12 (10)	12.9	30.6	<0.001
Salt intake, g/day	<6 (10)	31.0	55.2	<0.001
Alcohol intake, drinks/day	>0 or <2 (10)	21.7	2.5	<0.001
Smoking	Never smoking (5)	36.2	90.5	<0.001
Physical activity	Vigorous (10)	17.5	7.4	<0.001

Data were presented % and Chi-square tests were used for comparison by sex. F&V, fruits and vegetables; Scores were based on adherence index of American Heart Association on dietary and life style recommendations. The scores for good adherence were in parenthesis.

Compared With Other Studies and Results Explanation

Our findings are in line with a previous report[30] among 933 Puerto Ricans (a minority population in the Boston area), which indicated that for every 5-unit increase in AHA scores, BMD was associated with a 0.005 to 0.008 g/cm^2 ($P < 0.05$) higher value, or reduction of the risk of osteoporosis or osteopenia by 9% to 17%. The magnitudes of the bone mass changes were

TABLE 3. Adjusted Means of Bone Mass Parameters at Various Sites by Quartiles of Overall Lifestyle Scores

	Quartiles of Overall Lifestyle Scores				Mean Difference		
AHA Score	**Q1**	**Q2**	**Q3**	**Q4**	**Q4-Q1**	***P* for Difference**	***P* for Trend**
Median(min–max)	34 (8–38)	42 (39–46)	49 (47–53)	58 (54–84)			
N	1028	1016	969	931			
Whole body							
BMD, g/cm^2	0.981 ± 0.003	0.983 ± 0.003	0.991 ± 0.003	0.996 ± 0.003	0.015 ± 0.005	0.002	<0.001
BMC, g	1748 ± 8.461	1759 ± 7.425	1775 ± 7.818	1789 ± 8.069	41.48 ± 12.15	0.001	<0.001
BA, cm^2	1760 ± 3.194	1765 ± 2.803	1770 ± 2.951	1773 ± 3.046	13.34 ± 4.586	0.004	<0.001
Femoral neck							
BMD, g/cm^2	0.635 ± 0.003	0.636 ± 0.003	0.641 ± 0.003	0.646 ± 0.003	0.011 ± 0.005	0.025	0.052
BMC, g	3.206 ± 0.017	3.218 ± 0.015	3.241 ± 0.016	3.258 ± 0.016	0.052 ± 0.024	0.031	0.118
BA, cm^2	5.030 ± 0.011	5.045 ± 0.010	5.039 ± 0.010	5.023 ± 0.011	−0.007 ± 0.016	0.665	0.995
Total hip							
BMD, g/cm^2	0.785 ± 0.004	0.786 ± 0.003	0.796 ± 0.004	0.801 ± 0.004	0.016 ± 0.005	0.003	0.005
BMC, g	28.02 ± 0.155	28.34 ± 0.136	28.56 ± 0.144	28.63 ± 0.148	0.604 ± 0.223	0.025	0.004
BA, cm^2	35.34 ± 0.101	35.66 ± 0.089	35.52 ± 0.094	35.34 ± 0.098	−0.004 ± 0.145	0.975	0.960
Lumber spine							
BMD, g/cm^2	0.846 ± 0.006	0.852 ± 0.006	0.862 ± 0.005	0.861 ± 0.005	0.015 ± 0.007	0.038	<0.001
BMC, g	44. 96 ± 0.414	45.22 ± 0.472	46.41 ± 0.436	45.74 ± 0.450	0.525 ± 0.678	0.439	0.076
BA, cm^2	46.36 ± 0.241	46.52 ± 0.211	47.24 ± 0.222	46.55 ± 0.229	0.187 ± 0.345	0.588	0.736

Data were presented as mean ± SE; Lifestyle scores were derived from adherence index based on AHA on dietary and life style recommendations, BMD, BMC, and BA. The adjusted means of bone mass parameters across quartiles of the modified AHA scores were analyzed by general linear models by adjusting potential covariates such as age, sex, season, education levels, BMI, height, dietary total energy, protein, milk products, dietary calcium and vitamin D intake, dietary calcium supplementation (yes or no), sitting and sleeping time, and history of chronic diseases (yes or no) such as diabetes, stoke, hypertension, and cancers (yes or no). AHA = American Heart Association, BA = bone area, BMC = bone mineral content, BMD = bone mineral density, BMI = body mass index.

TABLE 4. Associations Between the Overall Lifestyle Scores (Each 10-unit Increase) and Bone Mineral Density (g/cm^2) at Various Sites

	N	Adjusted R^2	B Coefficients (95% CI)	Standardized B	P
Whole body					
Model 1	3922	0.405	0.005 (0.002, 0.008)	0.044	<0.001
Model 2	3922	0.469	0.005 (0.002, 0.008)	0.040	0.002
Model 3	3922	0.472	0.005 (0.002, 0.008)	0.041	0.001
Model 4*	3140	0.475	0.005 (0.001, 0.009)	0.043	0.003
Femoral neck					
Model 1	3922	0.237	0.004 (0.000, 0.007)	0.032	0.007
Model 2	3922	0.409	0.004 (0.001, 0.007)	0.035	0.010
Model 3	3922	0.413	0.004 (0.001, 0.007)	0.036	0.007
Model 4*	3140	0.415	0.004 (0.001, 0.008)	0.047	0.005
Total hip					
Model 1	3922	0.321	0.006 (0.002, 0.010)	0.042	0.002
Model 2	3922	0.498	0.006 (0.003, 0.010)	0.045	0.010
Model 3	3922	0.502	0.007 (0.003, 0.010)	0.046	<0.001
Model 4*	3140	0.505	0.007 (0.001, 0.009)	0.054	<0.001
Lumber spine					
Model 1	3847	0.269	0.004 (−0.002, 0.009)	0.019	0.187
Model 2	3847	0.408	0.003 (−0.002,0.008)	0.018	0.182
Model 3	3847	0.420	0.004 (−0.001, 0.009)	0.020	0.131
Model 4*	3140	0.421	0.002 (−0.005, 0.008)	0.021	0.289

Multivariate linear regression models were used for data analysis. Model 1 adjusted for age (year), sex, education levels, and seasons; Model 2 adjusted for model 1 plus body mass index (BMI), height (cm); total dietary energy(kcal/day), dietary calcium (mg/1000 kcal), dietary vitamin D intake (IU/day), dietary protein (g/1000 kcal), caffeine (mg/day), Chinese tea (mL/day), soy foods (g/1000 kcal) and milk products (g/1000 kcal) intakes, calcium supplements (yes or no), and sitting and sleeping hours (h/day); Model 3 adjusted for model 2 plus medical history of diabetes (yes or no), cancers (yes or no), hypertension (yes or no), and stroke (yes or no).

* Model 4 indicated the results of sensitivity analysis; the adjusted variables were the same as model 2, but exclusion of patients with diabetes, stroke, and various cancers. The overall lifestyle scores were derived from adherence index based on American Heart Association on dietary and life style recommendations.

almost twice as big as those observed in our study with the same increase of AHA scores. The discrepancy could be due to ethnic differences or other population features. For example, our participants tended to be older (72 vs 60 years), less obese (BMI: 23.6 vs 32.0), and had lower prevalence of diabetes (14.5% vs 39.3% to 49.1%) than those of the Puerto Ricans study. Age-related changes, including the decreased ability for absorption of nutrients, deficiency of sex hormones, and reduced bone turnover rates due to aging might partly explain the difference in results. Our data also support earlier observations that a dietary pattern based on fruit, vegetables, whole grain is associated with a higher BMD[31] and reduced risk of fracture,[32] while Western die pattern (high dietary fat and cholesterol) tended to be inversely associated with BMD.[33]

Our findings indicated that most scores of single lifestyle factors alone were not significantly and positively associated with bone mass, and the contribution of individual subcomponent was minor. Servings of vegetables, varieties of F&V, and levels of physical activity were unmet by most (all <10%), suggesting that most Chinese elderly has a great potential to improve their lifestyle profiles. Our findings on subcomponents analyses confirmed that composite measures of diet and lifestyle factors were more strongly associated with bone mass than single measures. It is possible that the components of lifestyle factors may act synergistically.[34] There is even evidence that lifestyle factors have a multiplicative rather than additive effect on health risk.[35] Our findings implicated public interventions may achieve a greater improvement if they address multiple risk factors at the same time.

Strengths and Limitations

The study has several strengths. The comprehensive lifestyle tool allows information regarding diet and lifestyle to be incorporated into a single useful indicator and can be used easily in clinical and public health practice. The other strengths include the relatively large sample size and the comprehensive measurement of bone mineral parameters at various sites and extensive collection of potential confounders. Individual lifestyle factors such as dietary intake, physical activity, smoking, alcohol and tea drinking, etc. were assessed using validated tools in this population.

The study had several limitations. First, the cross-sectional nature of our associations limited our ability to address causality. Despite adjusting for a number of potential confounders, residual and unmeasured confounding factors remain a possibility. Second, although diet and lifestyle habits generally reflect lifelong health behavior, it is possible that participants with diagnosed osteoporosis or other chronic conditions may make healthier lifestyle choices. Our sensitivity analyses also suggested a certain reversal bias. However, the reversal association would only bias the true association towards the null. In addition, even among those who already have chronic illness, modifiable lifestyle factors still have a pivotal role in disease management. Third, measurement error, particularly for self-reported data on diet, is another potential concern despite using validated tools. However, FFQ have been shown to rank usual intakes well[36] and the nondifferential errors or misclassification could only underestimate the associations. Fourth, although the AHA guidelines are considered appropriate for all ethical populations, the adherence index has been extrapolated from studies mostly of Caucasians and there is no established index specifically for Asian or Chinese populations. Different ethical groups may have different risk profiles of chronic conditions. Thus, future studies addressing the discrepancies among various ethical populations are warranted as the promotion of a healthy diet and lifestyle pattern should be culturally sensitive. Finally, the participants had a higher education level which was different from that of the general population, thus the results may not be entirely generalizable, although this would not affect the estimates of exposure-outcome associations.[37]

CONCLUSIONS

Our study indicated that following AHA recommendations for a healthy lifestyle pattern for CVD risk reduction was associated with better bone mass in Chinese elderly men and women. The findings highlight the importance of overall lifestyle modification in prevention and management of bone loss due to aging.

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