

Higher Dairy Intakes Are Associated with Higher Bone Mineral Density among Adults with Sufficient Vitamin D Status: Results from the Boston Puerto Rican Osteoporosis Study

Kelsey M Mangano,^{1,2} Sabrina E Noel,¹ Shivani Sahni,² and Katherine L Tucker¹

¹Department of Biomedical and Nutritional Sciences, University of Massachusetts–Lowell, Lowell, MA and ²Institute for Aging Research, Hebrew SeniorLife, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA

ABSTRACT

Background: Dairy foods have been shown to improve bone mineral density (BMD) in non-Hispanic whites. Puerto Rican adults have a higher prevalence of osteoporosis and vitamin D deficiency than non-Hispanic whites. However, there is little understanding of lifestyle influences on bone in this population.

Objective: The aim of this study was to examine associations of dairy intakes with BMD among adults from the Boston Puerto Rican Osteoporosis Study with and without adequate serum vitamin D status.

Methods: A total of 904 participants in this cross-sectional analysis provided dietary intakes with a culturally tailored food-frequency questionnaire. Dairy food groups were calculated [total dairy, modified dairy (without cream or dairy desserts), fluid dairy (milk + yogurt), cheese, yogurt, and cream and desserts]. BMD (grams per centimeter squared) was measured using dual-energy X-ray absorptiometry. Vitamin D status was defined as sufficient (serum 25-hydroxyvitamin D [25(OH)D] ≥ 20 ng/mL) or insufficient (< 20 ng/mL). General linear models were used to examine associations between dairy intake and BMD, stratified by vitamin D status.

Results: Of the total sample, 73% were women, of whom 87% were postmenopausal. Mean \pm SD age was 60.0 ± 7.6 y and mean \pm SD body mass index (kg/m^2) was 32.3 ± 6.6 . Mean serum 25(OH)D (range: 4–48 ng/mL) was 14.3 ± 3.6 ng/mL in insufficient individuals and 26.0 ± 5.5 ng/mL in sufficient individuals. In the full sample, higher intakes of modified dairy foods ($\beta = 0.0015$, $P = 0.02$) and milk ($\beta = 0.0018$, $P = 0.04$) were associated with higher femoral neck (FN) BMD. Among those who were vitamin D sufficient, higher intakes of total dairy ($P = 0.03$ – 0.07), fluid dairy ($P = 0.01$ – 0.05), and milk ($P = 0.02$ – 0.09) were significantly related to higher FN and lumbar spine BMD, respectively. Among vitamin D–insufficient participants, dairy intakes were not associated with BMD (P -range = 0.11 – 0.94).

Conclusions: Dairy food intakes were associated with higher BMD among adults, particularly those with sufficient vitamin D status. Future studies should confirm findings longitudinally and assess culturally acceptable lifestyle interventions to improve bone health among Hispanic adults. This trial was registered at clinicaltrials.gov as NCT01231958. *J Nutr* 2019;149:139–148.

Keywords: osteoporosis, bone, Puerto Rican, dairy, vitamin D, milk

Introduction

Osteoporosis and low bone mass currently affect > 54 million US adults aged ≥ 50 y, and this is projected to increase to 71.4 million by 2030 (1). Osteoporotic fracture results in decreased quality of life (2), particularly hip fracture, which contributes

significantly to long-term disability, institutionalization, and mortality (3, 4). Osteoporosis-related fractures accounted for $> \$19$ billion in total costs in 2005, and these costs are projected to increase 50% by 2025 as the US population ages (5). Therefore, public health strategies that address risk factors for and early detection of osteoporosis are urgently needed.

Supported by the National Institute on Aging (P01 AG023394), the National Heart, Lung, and Blood Institute (P50 HL105185), and the NIH (R01 AG027087). Author disclosures: KLT, no conflicts of interest. KMM and SEN received a grant from the Yogurt in Nutrition Initiative. SS has received institutional grants from Dairy Management, Inc., and has reviewed grants as a member of the Nutrition Research Scientific Advisory Committee, National Dairy Council.

Supplemental Table 1 is available from the “Supplementary data” link in the online posting of the article and from the same link in the online table of contents at <https://academic.oup.com/jn/>.

Address correspondence to KMM (e-mail: kelsey_mangano@uml.edu). Abbreviations used: BMD, bone mineral density; BPROS, Boston Puerto Rican Osteoporosis Study; HEI, Healthy Eating Index; 25(OH)D, 25-hydroxyvitamin D.

Dairy foods provide more bone-benefiting nutrients (protein, calcium, magnesium, potassium, zinc, and phosphorus) per calorie than any other food (6). Dairy foods have been positively related to bone mineral density (BMD) and with reduced bone loss over time among non-Hispanic white adults (7–9). However, to date, no studies have examined dairy intakes of Hispanic adults and their relation to BMD, although Hispanics are the second fastest growing and largest ethnic minority population in the United States, comprising 17% of the population (10). Recent projections estimate that Hispanics will have one of the largest increases in fracture incidence and health care costs from osteoporotic fractures (\$754 million in 2005 to \$2 billion in 2025) (5), yet they remain underrepresented in nutrition and bone-related research. Although not widely appreciated, current evidence indicates that Hispanics have a higher prevalence of osteoporosis than non-Hispanic whites (11) and limited data show that Hispanic adults present with a similar risk of fracture compared with non-Hispanic whites and a higher risk compared with non-Hispanic blacks and Asian Americans (12, 13). The majority of limited existing research on bone health in Hispanics has focused on Mexican Americans as a result of their majority status in the United States. However, data suggest that the prevalence of osteoporosis differs among Hispanic subgroups (14). Data from the Boston Puerto Rican Osteoporosis Study (BPROS) showed that, compared with non-Hispanic white adults, Puerto Rican men had a higher prevalence of osteoporosis and Puerto Rican women a similar prevalence of osteoporosis (15). On the basis of projections, we expect the incidence of osteoporosis-related fractures to continue to increase by 175% in Puerto Rican men and women (5). Therefore, identifying risk factors for osteoporosis among Puerto Rican adults is a major gap in the literature that needs to be addressed to inform public health efforts to prevent osteoporosis.

Compared with other food groups in the Dietary Guidelines for Americans, dairy intake recommendations are the least likely to be followed among Hispanics (16). Hispanic individuals synthesize less vitamin D per unit of sun exposure than do non-Hispanic whites (17) and present with 3.2 times higher risk of vitamin D deficiency (18). Therefore, because of the high prevalence of osteoporosis among Hispanics, in addition to unique cultural differences in dairy intakes (19, 20), lower vitamin D status, and poor adherence to dairy dietary guidelines, it is vital to determine whether dairy intake influences bone health among this growing US subgroup. Data from the Framingham Osteoporosis Study showed higher intakes of dairy to be associated with less BMD loss but only among vitamin D-supplement users, not among nonusers (7). However, this study was limited because it could not assess serum vitamin D status. Therefore, the objectives of this cross-sectional study were as follows: 1) to examine the relation of dairy intakes with BMD among Hispanic adults from the BPROS and 2) to examine the relation of dairy intakes with BMD stratified by serum vitamin D status. We hypothesized that higher intakes of specific dairy foods would be associated with higher BMD and that participants with vitamin D sufficiency would realize more benefits than those with vitamin D insufficiency.

Methods

Study population

Data on 904 participants from the BPROS, an ancillary study to the Boston Puerto Rican Health Study, were included for analysis. The

Boston Puerto Rican Health Study is a longitudinal investigation of the health disparities experienced by Puerto Rican adults aged 45–75 y living in the Greater Boston area, as described in detail elsewhere (21). In brief, a total of 1504 Puerto Rican adults completed a baseline interview and 1265 of those participants completed a 2-y follow-up interview. Information on sociodemographic characteristics, health and health behaviors, migration history, medication use, and stress were conducted at baseline and a 2-y follow-up in participants' homes by bilingual interviewers. After completing the 2-y follow-up interview for the main cohort study, participants were asked to participate in the BPROS. Of the 1267 participants who completed 2-y interviews, 973 volunteered to participate in the BPROS, 205 declined participation, 13 had moved from the Greater Boston area, 47 had difficulty scheduling the interview, 11 were lost to follow-up, 2 did not participate for other reasons (e.g., health issues), and 20 participants had died since their 2-y interview. Four participants who did not complete the 2-y interview consented to participate in the BPROS. Those who declined to participate in the BPROS were older (60.9 y compared with 58.7 y; $P < 0.001$) and were more likely to have type 2 diabetes (47.8% compared with 40.4%; $P = 0.03$) than those who participated. There were no differences in participation by sex ($P = 0.91$), smoking status ($P = 0.16$), physical activity score ($P = 0.42$), or activities of daily living (none compared with some compared with considerable impairment; $P = 0.34$).

The 973 participants who agreed to participate in the BPROS completed an interview, which included questions on sunlight exposure and falls; had BMD measures taken; and provided a blood sample at the Metabolic Research Unit at the Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University. A total of 25 participants' lumbar spine (L2–L4) measures and 7 femoral neck measures were excluded from analyses, as determined by the study endocrinologist after reviewing all scans with T-scores >4.0 to check for nonanatomical parts or extraskeletal calcification. Of the 973 participants, 954 provided data on dietary intake. Participants with dietary intakes <600 or >4800 kcal/d were excluded from analyses ($n = 47$). Three participants were excluded due to missing covariate information on physical activity and smoking habits. Therefore, 904 participants were included in the dairy and bone analyses. A total of 880 of these participants had measured serum 25-hydroxyvitamin D [25(OH)D] concentrations (for stratified analyses). All of the participants provided informed consent. The institutional review boards at Tufts University, Northeastern University, and the University of Massachusetts–Lowell approved this study. The trial was registered at clinicaltrials.gov as NCT01231958.

Measures of BMD

BMD (grams per centimeter squared) of the hip and lumbar spine was measured using DXA (GE-Lunar model Prodigy scanner; General Electric) at the Bone Metabolism Laboratory at the Human Nutrition Research Center on Aging. All measures were obtained following standard procedures, and the right hip was routinely scanned unless the participant reported having a previous hip fracture or joint replacement. The root mean square precision was 1.31% for BMD measures of the femoral neck and 1.04% for the lumbar spine for this laboratory, as reported elsewhere (22). Each week, an external standard (aluminum spine phantom: Lunar Radiation Corp.) was scanned to assess stability of the DXA measures.

Dietary intakes

Dietary intakes were assessed at the interview closest to the BMD measurement (at the 2-y follow-up appointment). Dietary assessment was performed with an FFQ adapted specifically for use in this population of Hispanic adults. The food list for the FFQ was developed using the National Cancer Institute/Block food-frequency format but with data from the Hispanic Health and Nutrition Examination Survey dietary recalls for Puerto Rican adults. The FFQ was then tested in Puerto Ricans aged ≥ 60 y in Massachusetts. The typical Puerto Rican diet differs considerably from both the general US population and from other Hispanic subgroups (such as Mexican Americans). Therefore, foods like plantains and specific soup and rice-dish recipes, as well as

appropriate portion sizes, were added to the FFQ. The Boston Puerto Rican Health Study FFQ has been shown to be a better estimator of dietary intakes in this Hispanic population (23). It has been validated against plasma carotenoids (24), vitamin E (25), vitamin B-6 (26), and vitamin B-12 (27) in Hispanic adults aged ≥ 60 y. Nutrient intake profiles are calculated from the scanned FFQs using the Nutrient Data System for Research software (NDS-R; Nutrition Coordinating Center).

Dairy foods were expressed as a percentage of total energy intake (kilocalories from dairy food/total kilocalories intake per day \times 100). Dairy groups were created on the basis of nutrient similarity and overall distribution across the population by creating the sum of intakes across each dairy food. Dairy groups included the following: milk, yogurt, fluid dairy (milk + yogurt), cheese, cream and dessert dairy (common dairy desserts in the Puerto Rican population include pudding, custard, cheesecake, and ice cream), and total dairy (sum of cream, milk, yogurt, cheese, and dessert dairy). Additional dairy groups were created on the basis of total fat content [high-fat dairy (sum of all dairy foods with $>2\%$ fat) and reduced-fat dairy (sum of all dairy foods with $\leq 2\%$ fat)] because saturated fat has been associated with lower BMD (28). Therefore, each dairy group represents the percentage of energy contributed to total energy intakes per day. Tertiles of dairy groups were created on the basis of the distribution of dairy groups across the population and to represent “high,” “medium,” and “low” intakes within each dairy group.

Covariates

Covariates known to affect bone health were included in all statistical analyses. Covariates were measured at the same examination when diet was measured (2-y follow-up examination to the Boston Puerto Rican Health Study). These covariates included age (years), sex, menopause status, use of estrogen (women only), height (meters), BMI (kg/m^2), physical activity [continuous scores; range: 24.5 (none or little) to 60.5 (some)], total energy intake (kilocalories per day), smoking status (never, former, or current), alcohol intake (none, moderate, or heavy), and calcium supplement use and vitamin D supplement use (nonuser, moderate supplement use, or high supplement use). Height was measured with a SECA 214 portable stadiometer to the nearest centimeter and weight was measured in pounds using a clinical scale (Toledo Weight Plate, model I55; Bay State and Systems, Inc.). These measures were converted to meters and kilograms, respectively, and BMI was then calculated as weight in kilograms/height in meters squared. Physical activity level was assessed as a weighted 24-h score of typical daily activity on the basis of hours spent doing heavy, moderate, light, or sedentary activity as well as sleeping [modified from the Framingham Exercise and Physical Activity Questionnaire (29)].

Usual intake of total energy was assessed with the FFQ. The Healthy Eating Index (HEI) 2005 score was calculated according to the method recommended by the USDA Center for Nutrition Policy and Promotion. The fruit and vegetable subcomponent was used as a marker of an overall healthy diet. The total HEI score was not used, because its calculation includes dairy intake. Smoking status was defined as never, former, or current smoker. Alcohol intake was defined as none within the past year, moderate, or heavy. Women were classified as estrogenic (premenopausal or currently taking postmenopausal estrogen) or nonestrogenic (postmenopausal and non-estrogen user) on the basis of the following self-reported variables: current estrogen use (yes or no) and menopausal status [menstrual periods stopped for 1 y (yes or no)].

Supplement use was captured in the medication section of the FFQ. Calcium supplement use was categorized as non-supplement user (0 mg/d), moderate supplement use (supplemental calcium >0 to <300 mg/d), or high supplement use (supplemental calcium ≥ 300 mg/d). Vitamin D supplement use was categorized similarly, as follows: non-supplement user, moderate supplement use (vitamin D >0 and ≤ 400 IU/d), or high supplement use (vitamin D >400 IU/d). These supplement categories were selected to identify and separate individuals receiving calcium, vitamin D, or both from a multivitamin (a marker of a healthy lifestyle) from those who were using calcium and vitamin D supplements, possibly in an effort to improve their bone health.

Serum vitamin D

Fasting blood samples (12-h) were drawn by a certified phlebotomist at the participant's home on the morning after the home interview or as soon thereafter as possible. Aliquots were saved and stored at -80°C until processed. Serum 25(OH)D concentration was measured by extraction followed by RIA with a 25I radioimmunoassay Packard COBRA II Gamma Counter (catalog no. 68100E; DiaSorin, Inc.) with intra-assay and interassay CVs of 10.8% and 9.4%, respectively. Vitamin D status was defined as sufficient (≥ 20 ng/mL) or insufficient (<20 ng/mL) based on the 2011 report from the Institute of Medicine (30).

Statistical analysis

Means \pm SDs for continuous variables and proportions of participants for categorical variables were calculated for the total sample. Dairy groups were created as a percentage contribution to overall energy intake. Statistical differences in descriptive variables were tested between vitamin D-sufficient and -insufficient groups by independent *t* test for continuous variables and chi-square test for categorical variables. Food contributions to bone-beneficial nutrients such as calcium, vitamin D, and protein were calculated using the PROC RANK procedure. General linear modeling was used to assess the relation between each dairy food group [milk, yogurt, fluid dairy (milk + yogurt), cheese, dessert dairy + cream, high-fat dairy, and low-fat dairy] as a continuous variable and each BMD outcome (femoral neck, trochanter, total femur, and lumbar spine) in the combined sample of men and women. General linear modeling was used to compare least-squares means of BMD across tertiles of each dairy food group intake. For categorical analyses, *P*-trend was calculated across the medians of each tertile using general linear modeling. Initial models were adjusted for sex and estrogen status, age, height, BMI, and total energy intake. Subsequent models were further adjusted for physical activity score, smoking status, alcohol intake, and fruit and vegetable HEI score. Final models were further adjusted for calcium and vitamin D supplementation. All regression models were tested for sex interaction, because BMD differs greatly by sex, and models with $P < 0.1$ were stratified by sex.

Fully adjusted multivariate models (including calcium and vitamin D supplement use) were then stratified by vitamin D status (sufficient or insufficient), as planned in the original hypothesis. All analyses were performed with the use of SAS software, SAS Institute Inc. (version 9.4).

Results

Descriptive characteristics of the study population are outlined in **Table 1**, stratified by vitamin D status [sufficient compared with insufficient serum 25(OH)D]. In the total sample, 54.2% of the participants had insufficient serum 25(OH)D concentrations; 73% were women, of whom 87% were postmenopausal; mean age was 60.0 ± 7.6 y (range: 46, 79 y); and mean BMI was 32.3 ± 6.6 . This cohort of Puerto Rican adults had relatively low dairy intake, with a mean total intake of ~ 1.5 servings/d, excluding cream and dessert dairy products, which is lower than the current recommendation of 3 servings of dairy foods/d. The highest percentage of dairy food intake from individual sources was from fluid dairy, a composite variable of milk and yogurt ($\sim 7.1\% \pm 5.7\%$ of total energy intake). Full-fat dairy contributed $8.7\% \pm 5.8\%$ of energy intake, whereas reduced-fat dairy contributed $4.1\% \pm 4.9\%$. Average total (food + supplements) calcium (1005 ± 573 mg/d) and vitamin D (6.9 ± 4.7 $\mu\text{g}/\text{d}$) intakes in this population were below national recommendations for this age group (1200 mg/d and 15–20 $\mu\text{g}/\text{d}$, respectively). Average serum 25(OH)D was 14.3 ± 3.6 ng/mL in vitamin D-insufficient individuals and 26.0 ± 5.5 ng/mL in vitamin D-sufficient individuals ($P = <0.001$). Participants who were vitamin D sufficient were older; reported higher intakes of dairy, calcium, and vitamin D;

TABLE 1 Descriptive characteristics of participants from the Boston Puerto Rican Osteoporosis Study¹

Characteristics	Vitamin D–sufficient participants [25(OH)D ≥ 20 ng/mL] (n = 403)	Vitamin D–insufficient participants [25(OH)D < 20 ng/mL] (n = 477)	P
Women, %	76	70	0.06
Age, y	60.8 ± 7.6 (range: 46–79)	59.1 ± 7.6 (range: 46–77)	<0.001
Height, cm	158.0 ± 8.4	158.2 ± 8.5	0.68
BMI, kg/m ²	31.8 ± 6.6	32.6 ± 6.5	0.09
Physical activity score	31.8 ± 4.7	31.9 ± 4.8	0.69
Total energy intake, kcal/d	2069 ± 854	2114 ± 889	0.44
Dietary protein, g/d	89 ± 38	89 ± 39	0.91
Calcium, mg/d			
Dietary	915 ± 492	860 ± 481	0.10
Total	1056 ± 573	965 ± 577	0.02
Vitamin D, μg/d			
Dietary	5.4 ± 3.4	4.9 ± 3.3	0.02
Total	7.8 ± 4.9	6.3 ± 4.4	<0.001
Fruit and vegetable HEI score	7.4 ± 1.8	7.3 ± 1.8	0.32
Serum 25(OH)D, ng/mL	26.0 ± 5.5	14.3 ± 3.6	<0.001
Alcohol intake, g/d	2.5 ± 7.4	4.4 ± 14.1	0.01
Smoking status (current), %	18	24	0.07
Postmenopausal (women), %	91	84	0.003
Supplement users, %			
Calcium			0.005
None	45	55	
Low (>0 and <300 mg/d)	37	33	
High (≥300 mg/d)	18	12	
Vitamin D			0.001
None	55	66	
Low (>0 to <5 μg/d)	31	25	
High (≥5 μg/d)	15	9	
BMD, g/cm ²			
Femoral neck	0.936 ± 0.141	0.942 ± 0.145	0.54
Trochanter	0.820 ± 0.140	0.836 ± 0.143	0.10
Total femur	1.020 ± 0.152	1.037 ± 0.156	0.12
Lumbar spine	1.144 ± 0.182	1.170 ± 0.181	0.04
Dairy food groups, ² % of energy			
Total dairy	13.5 ± 7.0	12.4 ± 7.1	0.02
Modified total	11.4 ± 6.5	10.0 ± 6.7	0.003
Fluid dairy	7.7 ± 5.6	6.5 ± 5.6	0.001
Cheese	3.6 ± 3.2	3.5 ± 3.5	0.65
Milk	6.5 ± 5.0	5.7 ± 5.1	0.02
Yogurt	1.2 ± 2.2	0.9 ± 1.9	0.006
Dessert dairy + cream	2.2 ± 2.9	2.3 ± 2.9	0.33
High-fat dairy (all)	8.9 ± 5.8	8.7 ± 5.7	0.62
Reduced-fat dairy (all)	4.5 ± 4.9	3.7 ± 4.8	0.03

¹Values are means ± SDs unless otherwise indicated. P values were calculated by using Student's *t* test for continuous variables and chi-square tests for categorical variables. BMD, bone mineral density; HEI, Healthy Eating Index; 25(OH)D, 25-hydroxyvitamin D.

²Total dairy = milk + yogurt + cheese + cream + dessert dairy; modified dairy = milk + yogurt + cheese; fluid dairy = milk + yogurt.

reported lower use of alcohol; and had lower lumbar spine BMD than participants who were vitamin D insufficient (Table 1).

Major food contributors to nutrient intakes related to dairy consumption and protection of bone health (calcium, vitamin D, and protein) are provided in Supplemental Table 1. Foods are ranked from 1 to 10, with 1 being the food contributing the greatest amount of the listed nutrient to the overall diet. Eight

dairy foods are listed as top contributors to calcium, vitamin D, or protein intake. Nondairy sources of calcium intakes include nutrition supplements (no. 1), beans (no. 9), and bread (no. 10). Nondairy sources of vitamin D intake include nutrition supplements (no. 1), tuna salad (no. 4), cold cereal (no. 7), shell fish (no. 8), and eggs (no. 10). Nondairy contributors to protein intake include beans (no. 1), chicken (nos. 2, 4, and 8), white rice (no. 3), deli meat (no. 6), shell fish (no. 7), and beef (nos. 9 and 10).

Interaction by sex

No sex interactions were observed in fully adjusted multivariable models at any BMD site with any dairy source (P -range: 0.06–0.95). Therefore, results are presented for men and women combined (Tables 2 and 3).

Association of dairy foods with BMD in the combined sample of men and women

In final regression models, adjusted for common covariates, higher intakes of modified dairy (milk + yogurt + cheese; $\beta = 0.0015$, $P = 0.02$) and milk ($\beta = 0.0018$, $P = 0.04$) were associated with higher femoral neck BMD among men and women; with every 1% increase in total energy intake from modified dairy, BMD was 0.15% higher at the femoral neck. Similar associations also approached significance for total dairy ($\beta = 0.0012$, $P = 0.05$) and fluid dairy ($\beta = 0.0014$, $P = 0.07$) at the femoral neck, and with modified dairy ($\beta = 0.0015$, $P = 0.09$) at the lumbar spine. There were no significant associations between other dairy products and BMD (P -range: 0.10–0.99) nor significant associations with high- or low-fat dairy intakes with any BMD site (P -range: 0.07–0.89; Table 2), although an association approached significance between reduced-fat dairy intake and the trochanter ($\beta = 0.0016$, $P = 0.07$). There were no significant trends across tertiles of dairy intake for any BMD site after adjustment for covariates (P -range: 0.09–0.96), but modified dairy approached significance with femoral neck BMD (P -trend = 0.09) (Table 3).

Interaction by serum 25(OH)D

Fully adjusted multivariable regression models were stratified by serum 25(OH)D status as sufficient (≥ 20 ng/mL) and insufficient (< 20 ng/mL) (Table 4). Among vitamin D-sufficient participants, higher intakes of total dairy, fluid dairy, and milk (each $P = 0.03$) were significantly related to higher femoral neck BMD. Similar associations were seen for intake of fluid dairy, total dairy, and milk with lumbar spine BMD; however, these associations were marginally significant ($P = 0.053$, 0.07, and 0.09, respectively). With every 1% increase in total energy intake from total or fluid dairy, BMD was 0.2% higher at the femoral neck (0.3% higher with milk). Among vitamin D-insufficient participants, dairy intakes were not associated with BMD at any site (P -range: 0.16–0.96). When dairy foods were grouped by high- or low-fat dairy, no associations were observed with BMD at any site in the full group or in vitamin D-sufficient or -insufficient participants (P -range: 0.11–0.94).

Discussion

Overall, among Puerto Rican adults aged 46–79 y, intakes of modified dairy (milk + yogurt + cheese) and of milk were significantly associated with femoral neck BMD. However, when stratified by vitamin D status [25(OH)D ≥ 20 compared with < 20 ng/mL], total dairy intake, fluid dairy (milk + yogurt) intake, and milk intake were significantly related to higher femoral neck BMD and fluid dairy with lumbar spine BMD only among those with vitamin D sufficiency. Perceived or actual lactose intolerance can be a primary reason for limiting or avoiding dairy intake (31). Due to high levels of osteoporosis in this population compared with non-Hispanic white counterparts (15), dietary differences and other lifestyle factors require attention to determine culturally appropriate

and biologically meaningful intervention strategies to improve bone health, with particular attention to those who are vitamin D insufficient.

Dairy products provide more protein, calcium, magnesium, potassium, zinc, and phosphorus per calorie than any other food (6). In addition, the bioavailability of calcium is greatest from dairy products (32). Therefore, dietary guidelines suggest the consumption of 3–4 servings of dairy/d to maintain healthy bone (33). However, despite these recommendations, studies evaluating the association between dairy intakes and BMD and fracture risk in other populations of adults are conflicting (34). A meta-analysis of 6 prospective cohort studies in $> 39,000$ men and women found that low dairy intake [< 8 oz (236 mL) milk/d] was not associated with increased risk of fracture (35). A more recent meta-analysis of 7 prospective cohort studies in $> 195,000$ women and 75,000 men found no association between total milk intake and hip fracture risk in women. However, in men, each additional glass of milk per day was associated with a 9% reduction in relative risk of fracture (36). Some large cohort studies have found protective associations between dairy intake and risk of fracture. In the Framingham Original Cohort, across 830 men and women over an 11.6-y follow-up, medium or high intakes of milk (more than one 8-ounce serving/wk) were associated with a 40% lower risk of hip fracture compared with low milk intakes (one or fewer 8-ounce servings/wk) (37). The different findings of these studies may be due to variation in age of the participants, differences in physical activity participation, varied intakes of calcium- and vitamin D-rich foods, interaction with other background dietary components, and variation in vitamin D status across participants.

Dairy intakes, particularly milk and milk + yogurt, were significantly related to higher BMD among Puerto Rican adults with sufficient vitamin D status. These results are similar to those seen in the Framingham Osteoporosis Study, where higher intakes of milk and milk + yogurt + cheese were associated with higher lumbar spine BMD and protective against trochanter BMD loss among vitamin D supplement users but not among nonusers (7). Adequate vitamin D is a prerequisite for calcium absorption. A 2011 report from the Institute of Medicine established that a minimum 25(OH)D concentration of 20 ng/mL is necessary to support the positive actions of vitamin D and calcium on bone health (30). Therefore, the benefits of dairy intake on the skeleton are likely dependent on vitamin D status. Vitamin D can be consumed in the diet from fortified foods or converted in the skin in response to UV exposure. Vitamin D-sufficient individuals in the current study were consuming a mean of 1.5 μg (60 IU) vitamin D/d more than their insufficient counterparts. Because those with sufficient serum vitamin D had 11.7 ng/mL higher 25(OH)D than insufficient individuals, it is likely that they were also converting more vitamin D in their skin, in addition to greater food intake. One explanation may be the large variation in skin pigmentation in this population of Puerto Rican adults. The interaction between vitamin D sufficiency and dairy intakes on bone health should be considered when evaluating the past and present literature on dairy intake and bone.

The current study also shows that the main contributors of bone-benefiting nutrients in the Puerto Rican diet are different from those of non-Hispanic whites. Average protein intake in the current study population was high for this age group compared with other populations of similar ages and is consistent with literature showing that Puerto Ricans consume more protein than non-Hispanic whites (38). Dietary protein

TABLE 2 Multivariable associations between dairy food groups (expressed as percentage of energy intake) and BMD (grams per centimeter squared) at the hip and spine in men and women from the Boston Puerto Rican Osteoporosis Study¹

Dairy group ²	BMD site							
	Femoral neck (n = 904)		Trochanter (n = 904)		Total femur (n = 895)		Lumbar spine (n = 885)	
	$\beta \pm SE$	P	$\beta \pm SE$	P	$\beta \pm SE$	P	$\beta \pm SE$	P
Model 1 (initial) ³								
Total dairy	0.0007 ± 0.0006	0.24	0.0004 ± 0.0006	0.50	0.0004 ± 0.0006	0.51	0.0006 ± 0.0008	0.48
Modified dairy	0.0010 ± 0.0006	0.12	0.0004 ± 0.0006	0.51	0.0006 ± 0.0006	0.37	0.0010 ± 0.0008	0.22
Fluid dairy	0.0011 ± 0.0007	0.15	0.0006 ± 0.0007	0.38	0.0007 ± 0.0008	0.37	0.0012 ± 0.0010	0.22
Cheese	0.0008 ± 0.0012	0.50	-0.0002 ± 0.0012	0.89	0.0004 ± 0.0014	0.79	0.0006 ± 0.0017	0.71
Cream + dessert dairy	-0.0010 ± 0.0015	0.48	0.0002 ± 0.0015	0.89	-0.0007 ± 0.0016	0.67	-0.0021 ± 0.0020	0.29
Yogurt	-0.0001 ± 0.0020	0.99	0.00007 ± 0.0020	0.97	0.0004 ± 0.0022	0.86	0.0009 ± 0.0027	0.74
Milk	0.0014 ± 0.0008	0.11	0.0008 ± 0.0008	0.34	0.0009 ± 0.0009	0.35	0.0014 ± 0.0011	0.22
High-fat dairy	0.0004 ± 0.0007	0.61	-0.0004 ± 0.0007	0.59	-0.0002 ± 0.0008	0.77	-0.0001 ± 0.0010	0.92
Reduced-fat dairy	0.0008 ± 0.0008	0.35	0.0014 ± 0.0009	0.12	0.0012 ± 0.0009	0.21	0.0013 ± 0.0012	0.25
Model 2 (lifestyle) ⁴								
Total dairy	0.0009 ± 0.0006	0.12	0.0005 ± 0.0006	0.37	0.0006 ± 0.0007	0.33	0.0008 ± 0.0008	0.32
Modified dairy	0.0010 ± 0.0006	0.05	0.0006 ± 0.0006	0.36	0.0009 ± 0.0007	0.22	0.0014 ± 0.0009	0.11
Fluid dairy	0.0013 ± 0.0008	0.09	0.0007 ± 0.0008	0.35	0.0009 ± 0.0008	0.29	0.0015 ± 0.0010	0.15
Cheese	0.0012 ± 0.0013	0.33	0.0003 ± 0.0012	0.80	0.0009 ± 0.0014	0.51	0.0012 ± 0.0017	0.47
Cream + dessert dairy	-0.0010 ± 0.0015	0.51	0.0001 ± 0.0015	0.95	-0.0008 ± 0.0016	0.64	-0.0024 ± 0.0020	0.23
Yogurt	-0.0001 ± 0.0021	0.98	0.0004 ± 0.0020	0.84	0.0007 ± 0.0023	0.76	0.0017 ± 0.0028	0.53
Milk	0.0016 ± 0.0016	0.06	0.0008 ± 0.0008	0.34	0.0010 ± 0.0009	0.29	0.0016 ± 0.0012	0.17
High-fat dairy	0.0005 ± 0.0007	0.45	-0.0002 ± 0.0007	0.80	0.0001 ± 0.0008	0.98	0.0002 ± 0.0010	0.83
Reduced-fat dairy	0.0010 ± 0.0009	0.27	0.0014 ± 0.0009	0.12	0.0013 ± 0.0010	0.18	0.0015 ± 0.0012	0.22
Model 3 (nutrients) ⁵								
Total dairy	0.0012 ± 0.0006	0.05	0.0008 ± 0.0006	0.20	0.0010 ± 0.0007	0.16	0.0011 ± 0.0008	0.21
Modified dairy	0.0015 ± 0.0006	0.02	0.0008 ± 0.0006	0.20	0.0012 ± 0.0007	0.10	0.0015 ± 0.0009	0.09
Fluid dairy	0.0014 ± 0.0008	0.07	0.0008 ± 0.0008	0.30	0.0010 ± 0.0009	0.24	0.0016 ± 0.0010	0.14
Cheese	0.0021 ± 0.0013	0.11	0.0010 ± 0.0013	0.45	0.0019 ± 0.0014	0.20	0.0017 ± 0.0017	0.35
Cream + dessert dairy	-0.0010 ± 0.0015	0.51	0.0003 ± 0.0015	0.82	-0.0006 ± 0.0017	0.71	-0.0019 ± 0.0021	0.36
Yogurt	0.0001 ± 0.0021	0.99	0.0004 ± 0.0020	0.85	0.0004 ± 0.0023	0.84	0.0018 ± 0.0028	0.52
Milk	0.0018 ± 0.0009	0.04	0.0009 ± 0.0009	0.28	0.0012 ± 0.0009	0.20	0.0017 ± 0.0012	0.16
High-fat dairy	0.0009 ± 0.0007	0.23	0.0001 ± 0.0007	0.89	0.0004 ± 0.0008	0.64	0.0005 ± 0.0010	0.61
Reduced-fat dairy	0.0011 ± 0.0009	0.19	0.0016 ± 0.0009	0.07	0.0016 ± 0.0010	0.11	0.0016 ± 0.0013	0.20

¹BMD, bone mineral density; HEI, Healthy Eating Index.

²Total dairy = milk + yogurt + cheese + cream + dessert dairy; modified dairy = milk + yogurt + cheese; fluid dairy = milk + yogurt.

³Model 1: adjusted for sex and estrogen status, age, height, BMI, total energy intake.

⁴Model 2: adjusted as for model 1 plus physical activity score, smoking status, alcohol intake, and fruit and vegetable HEI score.

⁵Model 3: adjusted as for model 2 plus poverty status, calcium supplement use (3 levels), and vitamin D supplement use (3 levels).

has been shown to be beneficial to bone health, particularly in combination with adequate calcium intakes (39). Protein intake among US adults has been shown to come primarily from poultry, meats, mixed meat dishes, breads, milk, cured meats/poultry, pizza, and cheese (mostly processed) (40). This is in comparison to the current population of Puerto Rican adults, in whom major sources of protein intake included poultry, beans, white rice, whole milk, processed meat, and shellfish. The top 3 sources of calcium and vitamin D intakes in the Puerto Rican adults were nutrient supplements, whole milk, and 2% milk. Despite milk being a major contributor to calcium, vitamin D, and protein intakes in this population, dairy food intakes were not associated with BMD among participants with insufficient vitamin D status.

Diet is complex and varies between groups from different cultural and ethnic backgrounds. Dietary intakes of Hispanics vary by country of origin and are influenced by cultural beliefs and traditions, acculturation, food availability, socioeconomic status, and education (41, 42). The traditional dietary pattern of Puerto Rican adults is high in oil (mainly corn), rice,

and beans and is associated with a higher likelihood of metabolic syndrome (43). Diets high in starchy roots and fried-meat products and low in fruit and leafy vegetables may contribute to the lower intake of calcium, vitamins, and other substances essential for bone health (42, 44). In addition, low fruit and vegetable (45, 46) and high saturated fat or polyunsaturated fat intakes (47) are potentially harmful to bone health. Furthermore, Puerto Ricans are less likely to engage in physical activity than non-Hispanic whites (48); >50% of Puerto Rican adults report no leisure-time physical activity (49). Puerto Ricans also have disproportionately high rates of chronic disease and inflammation (21), which are additional factors detrimental to bone health. The lack of association between dairy intakes and bone health in Puerto Rican vitamin D-insufficient adults may be due to other health and lifestyle factors that contribute to poor bone health.

Although associations were observed between current dairy intakes and bone health only among vitamin D-sufficient Puerto Ricans adults, there may be potential for improving bone health with culturally appropriate dairy interventions. A

TABLE 3 BMD (grams per centimeter squared) at the hip and spine across tertiles of dairy food intakes in the total sample of men and women from the Boston Puerto Rican Osteoporosis Study¹

Dairy food group ²	Tertile 1	Tertile 2	Tertile 3	P-trend
Femoral neck				
<i>n</i>	293	295	296	
Total dairy	0.933 ± 0.01	0.953 ± 0.01	0.952 ± 0.01	0.10
Modified dairy	0.933 ± 0.01	0.954 ± 0.01	0.952 ± 0.01	0.09
Fluid dairy	0.943 ± 0.01	0.954 ± 0.01	0.956 ± 0.01	0.11
Cream + dessert dairy	0.947 ± 0.01	0.943 ± 0.01	0.946 ± 0.01	0.94
Cheese	0.950 ± 0.01	0.948 ± 0.01	0.938 ± 0.01	0.30
High-fat dairy	0.938 ± 0.01	0.946 ± 0.11	0.955 ± 0.01	0.13
Low-fat dairy	0.935 ± 0.01	0.952 ± 0.01	0.949 ± 0.01	0.23
Trochanter				
<i>n</i>	293	295	296	
Total dairy	0.837 ± 0.01	0.848 ± 0.01	0.850 ± 0.01	0.24
Modified dairy	0.837 ± 0.01	0.847 ± 0.01	0.851 ± 0.01	0.23
Fluid dairy	0.843 ± 0.01	0.848 ± 0.01	0.848 ± 0.01	0.41
Cream + dessert dairy	0.845 ± 0.01	0.841 ± 0.01	0.847 ± 0.01	0.90
Cheese	0.845 ± 0.01	0.852 ± 0.01	0.836 ± 0.01	0.42
High-fat dairy	0.844 ± 0.01	0.839 ± 0.01	0.850 ± 0.01	0.58
Low-fat dairy	0.839 ± 0.01	0.845 ± 0.01	0.850 ± 0.01	0.34
Total femur				
<i>n</i>	290	292	293	
Total dairy	1.030 ± 0.01	1.043 ± 0.01	1.047 ± 0.01	0.16
Modified dairy	1.030 ± 0.01	1.045 ± 0.01	1.045 ± 0.01	0.24
Fluid dairy	1.038 ± 0.01	1.046 ± 0.01	1.046 ± 0.01	0.30
Cream + dessert dairy	1.043 ± 0.01	1.037 ± 0.01	1.039 ± 0.01	0.78
Cheese	1.042 ± 0.01	1.044 ± 0.01	1.032 ± 0.01	0.46
High-fat dairy	1.039 ± 0.01	1.033 ± 0.01	1.048 ± 0.01	0.48
Low-fat dairy	1.033 ± 0.01	1.042 ± 0.01	1.044 ± 0.01	0.38
Lumbar spine				
<i>n</i>	285	291	289	
Total dairy	1.157 ± 0.01	1.167 ± 0.02	1.179 ± 0.02	0.16
Modified dairy	1.157 ± 0.01	1.168 ± 0.02	1.179 ± 0.02	0.15
Fluid dairy	1.163 ± 0.01	1.160 ± 0.02	1.183 ± 0.02	0.13
Cream + dessert dairy	1.169 ± 0.02	1.168 ± 0.02	1.165 ± 0.02	0.96
Cheese	1.172 ± 0.02	1.174 ± 0.02	1.155 ± 0.02	0.27
High-fat dairy	1.164 ± 0.01	1.160 ± 0.02	1.178 ± 0.02	0.37
Low-fat dairy	1.169 ± 0.02	1.171 ± 0.02	1.1681 ± 0.02	0.82

¹Values are adjusted least-squares means ± SEs unless otherwise indicated. Models adjusted for sex and estrogen status, age, height, BMI, total energy intake, physical activity score, current smoking status (never, former, or current), alcohol intake (none, moderate, or heavy), fruit and vegetable HEI score, calcium supplement use (none, moderate use, or high use), vitamin D supplement use (none, moderate use, or high use), and poverty status (poverty line or below, above the poverty line). BMD, bone mineral density; HEI, Healthy Eating Index.

²Total dairy = milk + yogurt + cheese + cream + dessert dairy; modified dairy = milk + yogurt + cheese; fluid dairy = milk + yogurt.

number of clinical trials have shown fortified milk (50–54), skimmed soft cheese (55, 56), and fortified yogurt (57) to reduce bone turnover in older adults; however, to our knowledge, there are no clinical trials in Hispanic adults. A study in 101 women with a mean age of 60 y showed that supplementation with fortified milk and yogurt 3 times/d increased BMD over 12 mo (58). In addition, a study in 130 younger (mean age: 45 y) men and women showed attenuated bone loss over a 12-mo weight-loss trial with 3 servings of dairy/d compared with adults consuming a conventional high-carbohydrate diet (9). Future intervention studies in Puerto Rican adults should consider culturally acceptable dairy food sources in addition to improvements in lifestyle behaviors known to affect bone, such as increasing physical activity and increasing intakes of fruit and vegetables and fiber while reducing intakes of refined grains and saturated and omega-6 fats.

The current study has many strengths. To date, this is the largest cohort study in older Puerto Rican adults living on the US mainland. In addition, bone health was measured using the gold standard of measurement by DXA and all questionnaires were previously validated in this cohort and culturally appropriate. There are, however, limitations to the current study, including inherent limitations to self-reported dietary data (59). To overcome these obstacles, the current study used a validated, culturally tailored FFQ to appropriately estimate usual dietary intakes. In addition, all statistical models and nutrients were adjusted for total energy to reduce measurement bias. The cross-sectional study design is a limitation, and in any observational study, residual confounding may occur, despite control for several potential confounders. The effect sizes of the associations between dairy intakes and bone are small and should be interpreted with caution. In

TABLE 4 Association between dairy food groups (expressed as percentage of energy intake) and BMD (grams per centimeter squared) at the hip and spine, stratified by 25(OH)D (nanograms per milliliter) concentrations in men and women from the Boston Puerto Rican Osteoporosis Study¹

Dairy food group ²	Vitamin D-sufficient participants [25(OH)D ≥ 20 ng/mL] (n = 392)		Vitamin D-insufficient participants [25(OH)D < 20 ng/mL] (n = 465)	
	β ± SE	P	β ± SE	P
Femoral neck BMD				
Total dairy	0.002 ± 0.001	0.03	0.001 ± 0.001	0.32
Fluid dairy	0.002 ± 0.001	0.03	0.001 ± 0.001	0.44
Cheese	0.001 ± 0.002	0.26	0.002 ± 0.002	0.22
Cream + dessert dairy	0.001 ± 0.002	0.99	-0.001 ± 0.002	0.53
Yogurt	0.002 ± 0.003	0.57	-0.001 ± 0.003	0.96
Milk	0.003 ± 0.001	0.03	0.001 ± 0.001	0.38
High-fat dairy	0.002 ± 0.001	0.17	0.001 ± 0.001	0.67
Reduced-fat dairy	0.002 ± 0.001	0.15	0.001 ± 0.001	0.33
Trochanter BMD				
Total dairy	0.002 ± 0.001	0.09	0.001 ± 0.001	0.41
Fluid dairy	0.002 ± 0.001	0.24	0.001 ± 0.001	0.45
Cheese	0.002 ± 0.002	0.30	0.001 ± 0.002	0.74
Cream + dessert dairy	0.002 ± 0.002	0.50	0.001 ± 0.002	0.90
Yogurt	0.002 ± 0.003	0.64	0.001 ± 0.003	0.89
Milk	0.002 ± 0.001	0.27	0.001 ± 0.001	0.44
High-fat dairy	0.001 ± 0.001	0.48	-0.001 ± 0.001	0.94
Reduced-fat dairy	0.002 ± 0.001	0.11	0.002 ± 0.001	0.19
Total femur BMD				
Total dairy	0.002 ± 0.001	0.11	0.001 ± 0.001	0.30
Fluid dairy	0.002 ± 0.001	0.21	0.001 ± 0.001	0.37
Cheese	0.002 ± 0.002	0.31	0.001 ± 0.002	0.35
Cream + dessert dairy	0.001 ± 0.002	0.73	-0.001 ± 0.002	0.67
Yogurt	0.002 ± 0.003	0.76	0.002 ± 0.003	0.63
Milk	0.002 ± 0.001	0.20	0.001 ± 0.001	0.42
High-fat dairy	0.001 ± 0.001	0.39	-0.001 ± 0.001	0.79
Reduced-fat dairy	0.002 ± 0.001	0.21	0.002 ± 0.001	0.16
Lumbar spine BMD				
Total dairy	0.002 ± 0.001	0.07	0.001 ± 0.001	0.40
Fluid dairy	0.003 ± 0.001	0.05	0.001 ± 0.001	0.33
Cheese	0.002 ± 0.003	0.55	0.001 ± 0.002	0.41
Cream + dessert dairy	0.001 ± 0.003	0.99	-0.003 ± 0.003	0.37
Yogurt	0.005 ± 0.004	0.23	0.002 ± 0.004	0.67
Milk	0.003 ± 0.002	0.09	0.001 ± 0.002	0.36
High-fat dairy	0.002 ± 0.002	0.24	-0.001 ± 0.001	0.91
Reduced-fat dairy	0.002 ± 0.002	0.26	0.003 ± 0.002	0.17

¹Models adjusted for sex and estrogen status, age, height, BMI, total energy intake, physical activity score, current smoking status (never, former, or current), alcohol intake (none, moderate, or heavy), fruit and vegetable HEI score, calcium supplement use (none, moderate use, or high use), vitamin D supplement use (none, moderate use, or high use), poverty status (poverty line or below, above the poverty line). BMD, bone mineral density; HEI, Healthy Eating Index; 25(OH)D, 25-hydroxyvitamin D.

²Total dairy = milk + yogurt + cheese + cream + dessert dairy; modified dairy = milk + yogurt + cheese; fluid dairy = milk + yogurt.

addition, statistical tests were performed between bone sites and dairy food groups without multiple comparison adjustment; therefore, some findings may be due to chance. Last, diet was measured after BMD assessment. It is possible that the lack of associations for some dairy foods was due to limited variation in intake.

In conclusion, higher total dairy, milk, and milk + yogurt intakes among Puerto Rican adults residing in the United States who are sufficient in vitamin D were associated with higher BMD at the femoral neck and lumbar spine. No associations were observed in Puerto Rican adults who were insufficient in vitamin D. Calcium and vitamin D intakes in this population were lower than in the Dietary Guidelines, whereas protein intakes were higher than in other adult populations. This

unique dietary pattern may detrimentally affect bone health, because dietary protein intakes appear to be protective only under conditions of adequate calcium intake (39). Puerto Rican adults have high levels of osteoporosis and are in need of interventions to improve bone health. Future studies should be conducted to verify these findings longitudinally and assess culturally acceptable lifestyle intervention strategies to improve bone health in Hispanic adults.

Acknowledgments

The authors' responsibilities were as follows—KMM, KLT, and SS: contributed to the study design; KLT and SEN: conducted research and data collection of the original study cohort; KMM:

performed data analysis and had primary responsibility for final content; KMM, KLT, SS, and SEN: contributed to manuscript preparation and revision; and all authors: read and approved the final manuscript.

References

1. Wright NC, Looker AC, Saag KG, Curtis JR, Delzell ES, Randall S, Dawson-Hughes B. The recent prevalence of osteoporosis and low bone mass in the United States based on bone mineral density at the femoral neck or lumbar spine. *J Bone Miner Res* 2014;29(11):2520–6.
2. Cauley JA. Public health impact of osteoporosis. *J Gerontol A Biol Sci Med Sci* 2013;68(10):1243–51.
3. Magaziner J, Hawkes W, Hebel JR, Zimmerman SI, Fox KM, Dolan M, Felsenthal G, Kenzora J. Recovery from hip fracture in eight areas of function. *J Gerontol A Biol Sci Med Sci* 2000;55(9):M498–507.
4. Marks R, Allegrante JP, Ronald MacKenzie C, Lane JM. Hip fractures among the elderly: causes, consequences and control. *Ageing Res Rev* 2003;2(1):57–93.
5. Burge R, Dawson-Hughes B, Solomon DH, Wong JB, King A, Tosteson A. Incidence and economic burden of osteoporosis-related fractures in the United States, 2005–2025. *J Bone Miner Res* 2007;22(3):465–75.
6. Rizzoli R. Dairy products, yogurts, and bone health. *Am J Clin Nutr* 2014;99(5 Suppl):1256S–62S.
7. Sahni S, Mangano KM, Kiel DP, Tucker KL, Hannan MT. Dairy intake is protective against bone loss in older vitamin D supplement users: The Framingham study. *J Nutr* 2017;147(4):645–52.
8. Langsetmo L, Shikany JM, Burghardt AJ, Cawthon PM, Orwoll ES, Cauley JA, Taylor BC, Schousboe JT, Bauer DC, Vo TN, et al. High dairy protein intake is associated with greater bone strength parameters at the distal radius and tibia in older men: a cross-sectional study. *Osteoporos Int* 2018;29(1):69–77.
9. Thorpe MP, Jacobson EH, Layman DK, He X, Kris-Etherton PM, Evans EM. A diet high in protein, dairy, and calcium attenuates bone loss over twelve months of weight loss and maintenance relative to a conventional high-carbohydrate diet in adults. *J Nutr* 2008;138(6):1096–100.
10. US Census Bureau. Asians fastest-growing race or ethnic group in 2012, Census Bureau Reports. Release No.: CB13-112. US Census Bureau; 2013, Washington, DC, USA.
11. Looker AC, Borrud LG, Dawson-Hughes B, Shepherd JA, Wright NC. Osteoporosis or low bone mass at the femur neck or lumbar spine in older adults: United States, 2005–2008. *NCHS Data Brief* 2012;93:1–8.
12. Barrett-Connor E, Siris ES, Wehren LE, Miller PD, Abbott TA, Berger ML, Santora AC, Sherwood LM. Osteoporosis and fracture risk in women of different ethnic groups. *J Bone Miner Res* 2005;20(2):185–94.
13. Looker AC. Femur neck bone mineral density and fracture risk by age, sex, and race or Hispanic origin in older US adults from NHANES III. *Arch Osteoporos* 2013;8:141.
14. Araujo AB, Travison TG, Esche GR, Holick MF, Chen TC, McKinlay JB. Serum 25-hydroxyvitamin D and bone mineral density among Hispanic men. *Osteoporos Int* 2009;20(2):245–55.
15. Noel SE, Mangano KM, Griffith JL, Wright NC, Dawson-Hughes B, Tucker KL. Prevalence of osteoporosis and low bone mass among puertorican older adults. *J Bone Miner Res* 2018;33(3):396–403.
16. Sharma S, Murphy SP, Wilkens LR, Shen L, Hankin JH, Monroe KR, Henderson B, Kolonel LN. Adherence to the food guide pyramid recommendations among African Americans and Latinos: results from the Multiethnic Cohort. *J Am Diet Assoc* 2004;104(12):1873–7.
17. Taksler GB, Cutler DM, Giovannucci E, Keating NL. Vitamin D deficiency in minority populations. *Public Health Nutr* 2015;18(3):379–91.
18. Forrest KY, Stuhldreher WL. Prevalence and correlates of vitamin D deficiency in US adults. *Nutr Res* 2011;31(1):48–54.
19. Ayala GX, Baquero B, Klinger S. A systematic review of the relationship between acculturation and diet among Latinos in the United States: implications for future research. *J Am Diet Assoc* 2008;108(8):1330–44.
20. Bermudez OI, Falcon LM, Tucker KL. Intake and food sources of macronutrients among older Hispanic adults: association with ethnicity, acculturation, and length of residence in the United States. *J Am Diet Assoc* 2000;100(6):665–73.
21. Tucker KL, Mattei J, Noel SE, Collado BM, Mendez J, Nelson J, Griffith J, Ordovas JM, Falcon LM. The Boston Puerto Rican Health Study, a longitudinal cohort study on health disparities in Puerto Rican adults: challenges and opportunities. *BMC Public Health* 2010;10:107.
22. White J, Harris SS, Dallal GE, Dawson-Hughes B. Precision of single vs bilateral hip bone mineral density scans. *J Clin Densitom* 2003;6(2):159–62.
23. Tucker KL, Bianchi LA, Maras J, Bermudez OI. Adaptation of a food frequency questionnaire to assess diets of Puerto Rican and non-Hispanic adults. *Am J Epidemiol* 1998;148(5):507–18.
24. Bermudez OI, Ribaya-Mercado JD, Talegawkar SA, Tucker KL. Hispanic and non-Hispanic white elders from Massachusetts have different patterns of carotenoid intake and plasma concentrations. *J Nutr* 2005;135(6):1496–502.
25. Gao X, Martin A, Lin H, Bermudez OI, Tucker KL. alpha-Tocopherol intake and plasma concentration of Hispanic and non-Hispanic white elders is associated with dietary intake pattern. *J Nutr* 2006;136(10):2574–9.
26. Ye X, Maras JE, Bakun PJ, Tucker KL. Dietary intake of vitamin B-6, plasma pyridoxal 5'-phosphate, and homocysteine in Puerto Rican adults. *J Am Diet Assoc* 2010;110(11):1660–8.
27. Kwan LL, Bermudez OI, Tucker KL. Low vitamin B-12 intake and status are more prevalent in Hispanic older adults of Caribbean origin than in neighborhood-matched non-Hispanic whites. *J Nutr* 2002;132(7):2059–64.
28. Corwin RL, Hartman TJ, Maczuga SA, Graubard BI. Dietary saturated fat intake is inversely associated with bone density in humans: analysis of NHANES III. *J Nutr* 2006;136(1):159–65.
29. Albanes D, Conway JM, Taylor PR, Moe PW, Judd J. Validation and comparison of eight physical activity questionnaires. *Epidemiology* 1990;1(1):65–71.
30. Ross AC, Taylor CL, Yaktine AL, Del Valle HB, editors. *Dietary Reference Intakes for calcium and vitamin D*. National Academies Press (US); Washington (DC); 2011.
31. Bailey RK, Fileri CP, Keith J, Tropez-Sims S, Price W, Allison-Ottery SD. Lactose intolerance and health disparities among African Americans and Hispanic Americans: an updated consensus statement. *J Natl Med Assoc* 2013;105(2):112–27.
32. Weaver CM, Proulx WR, Heaney R. Choices for achieving adequate dietary calcium with a vegetarian diet. *Am J Clin Nutr* 1999;70(3 Suppl):543S–8S.
33. USDA; US Department of Health and Human Services. 2015–2020 Dietary guidelines for Americans. 8th ed. Available from : <https://health.gov/dietaryguidelines/2015/guidelines/>. Accessed: October 13, 2017.
34. Rozenberg S, Body JJ, Bruyere O, Bergmann P, Brandi ML, Cooper C, Devogelaer JP, Gielen E, Goemaere S, Kaufman JM, et al. Effects of dairy products consumption on health: benefits and beliefs—a commentary from the Belgian Bone Club and the European Society for Clinical And Economic Aspects of Osteoporosis, Osteoarthritis and Musculoskeletal Diseases. *Calcif Tissue Int* 2016;98(1):1–17.
35. Kanis JA, Johansson H, Oden A, De Laet C, Johnell O, Eisman JA, Mc Closkey E, Mellstrom D, Pols H, Reeve J, et al. A meta-analysis of milk intake and fracture risk: low utility for case finding. *Osteoporos Int* 2005;16(7):799–804.
36. Bischoff-Ferrari HA, Dawson-Hughes B, Baron JA, Kanis JA, Orav EJ, Staehelin HB, Kiel DP, Burckhardt P, Henschkowski J, Spiegelman D, et al. Milk intake and risk of hip fracture in men and women: a meta-analysis of prospective cohort studies. *J Bone Miner Res* 2011;26(4):833–9.
37. Sahni S, Mangano KM, Tucker KL, Kiel DP, Casey VA, Hannan MT. Protective association of milk intake on the risk of hip fracture: results from the Framingham Original Cohort. *J Bone Miner Res* 2014;29(8):1756–62.
38. Loria CM, Bush TL, Carroll MD, Looker AC, McDowell MA, Johnson CL, Sempos CT. Macronutrient intakes among adult Hispanics: a comparison of Mexican Americans, Cuban Americans, and mainland Puerto Ricans. *Am J Public Health* 1995;85(5):684–9.

39. Mangano KM, Sahni S, Kerstetter JE. Dietary protein is beneficial to bone health under conditions of adequate calcium intake: an update on clinical research. *Curr Opin Clin Nutr Metab Care* 2014;17(1):69–74.
40. Phillips SM, Fulgoni VL 3rd, Heaney RP, Nicklas TA, Slavin JL, Weaver CM. Commonly consumed protein foods contribute to nutrient intake, diet quality, and nutrient adequacy. *Am J Clin Nutr* 2015;101(6):1346S–52S.
41. Lin H, Bermudez OI, Tucker KL. Dietary patterns of Hispanic elders are associated with acculturation and obesity. *J Nutr* 2003;133(11):3651–7.
42. Siega-Riz AM, Sotres-Alvarez D, Ayala GX, Ginsberg M, Himes JH, Liu K, Loria CM, Mossavar-Rahmani Y, Rock CL, Rodriguez B, et al. Food-group and nutrient-density intakes by Hispanic and Latino backgrounds in the Hispanic Community Health Study/Study of Latinos. *Am J Clin Nutr* 2014;99(6):1487–98.
43. Noel SE, Newby PK, Ordovas JM, Tucker KL. A traditional rice and beans pattern is associated with metabolic syndrome in Puerto Rican older adults. *J Nutr* 2009;139(7):1360–7.
44. van Rompay MI, McKeown NM, Castaneda-Sceppa C, Falcon LM, Ordovas JM, Tucker KL. Acculturation and sociocultural influences on dietary intake and health status among Puerto Rican adults in Massachusetts. *J Acad Nutr Diet* 2012;112(1):64–74.
45. Benetou V, Orfanos P, Feskanich D, Michaëlsson K, Pettersson-Kymmer U, Eriksson S, Grodstein F, Wolk A, Bellavia A, Ahmed LA, et al. Fruit and vegetable intake and hip fracture incidence in older men and women: the CHANCES project. *J Bone Miner Res* 2016;31(9):1743–52.
46. Tucker KL, Hannan MT, Chen H, Cupples LA, Wilson PW, Kiel DP. Potassium, magnesium, and fruit and vegetable intakes are associated with greater bone mineral density in elderly men and women. *Am J Clin Nutr* 1999;69(4):727–36.
47. Wauquier F, Leotoing L, Philippe C, Spilmont M, Coxam V, Wittrant Y. Pros and cons of fatty acids in bone biology. *Prog Lipid Res* 2015;58:121–45.
48. Pescatello LS, Alonso M, Schaffino R, Leavitt R. Determinants of physical activity among a convenience sample of Puerto Rican women residing in the Northeastern United States. *J Strength Cond Res* 2008;22(5):1515–21.
49. Neighbors CJ, Marquez DX, Marcus BH. Leisure-time physical activity disparities among Hispanic subgroups in the United States. *Am J Public Health* 2008;98(8):1460–4.
50. Adolphi B, Scholz-Ahrens KE, de Vrese M, Acil Y, Laue C, Schrezenmeir J. Short-term effect of bedtime consumption of fermented milk supplemented with calcium, inulin-type fructans and caseinphosphopeptides on bone metabolism in healthy, postmenopausal women. *Eur J Nutr* 2009;48(1):45–53.
51. Bonjour JP, Brandolini-Bunlon M, Boirie Y, Morel-Laporte F, Braesco V, Bertiere MC, Souberbielle JC. Inhibition of bone turnover by milk intake in postmenopausal women. *Br J Nutr* 2008;100(4):866–74.
52. Kruger MC, Booth CL, Coad J, Schollum LM, Kuhn-Sherlock B, Shearer MJ. Effect of calcium fortified milk supplementation with or without vitamin K on biochemical markers of bone turnover in premenopausal women. *Nutrition* 2006;22(11–12):1120–8.
53. Kruger MC, Ha PC, Todd JM, Kuhn-Sherlock B, Schollum LM, Ma J, Qin G, Lau E. High-calcium, vitamin D fortified milk is effective in improving bone turnover markers and vitamin D status in healthy postmenopausal Chinese women. *Eur J Clin Nutr* 2012;66(7):856–61.
54. Kruger MC, Schollum LM, Kuhn-Sherlock B, Hestiantoro A, Wijanto P, Li-Yu J, Agdeppa I, Todd JM, Eastell R. The effect of a fortified milk drink on vitamin D status and bone turnover in post-menopausal women from South East Asia. *Bone* 2010;46(3):759–67.
55. Bonjour JP, Benoit V, Pourchaire O, Ferry M, Rousseau B, Souberbielle JC. Inhibition of markers of bone resorption by consumption of vitamin D and calcium-fortified soft plain cheese by institutionalised elderly women. *Br J Nutr* 2009;102(7):962–6.
56. Bonjour JP, Benoit V, Rousseau B, Souberbielle JC. Consumption of vitamin D-and calcium-fortified soft white cheese lowers the biochemical marker of bone resorption TRAP 5b in postmenopausal women at moderate risk of osteoporosis fracture. *J Nutr* 2012;142(4):698–703.
57. Bonjour JP, Benoit V, Payen F, Kraenzlin M. Consumption of yogurts fortified in vitamin D and calcium reduces serum parathyroid hormone and markers of bone resorption: a double-blind randomized controlled trial in institutionalized elderly women. *J Clin Endocrinol Metab* 2013;98(7):2915–21.
58. Manios Y, Moschonis G, Trovas G, Lyrakis GP. Changes in biochemical indexes of bone metabolism and bone mineral density after a 12-mo dietary intervention program: the Postmenopausal Health Study. *Am J Clin Nutr* 2007;86(3):781–9.
59. Maki KC, Slavin JL, Rains TM, Kris-Etherton PM. Limitations of observational evidence: implications for evidence-based dietary recommendations. *Adv Nutr* 2014;5(1):7–15.