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Original

Association between dietary antioxidant quality score (DAQs) and bone mineral density in Spanish women

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Abstract

Background: **Several lines of evidence suggest a tight association between oxidative stress and the pathogenesis of osteoporosis in humans. The intake of antioxidants may influence Bone Mineral Density by acting as free radical scavengers, preventing oxidation-induced damage to bone cells.**

Objective: **The aim of this study was to assess the association between the Dietary Antioxidant Quality Score and bone mineral density in a sample of healthy women.**

Methods: **A total of 280 women were grouped into three major groups: women aged ≤ 35 years; women aged 36-45, and finally women aged >45 years. Calcaneous Bone Mineral Density (g/cm²) was measured by dual energy X-ray absorptiometry. Data on the eating habits of each participant were collected with a structured 24-hour diet recall questionnaire. A Dietary Antioxidant Quality Score was used to calculate antioxidant-nutrient intake.**

Results: **A significant and positive association was observed among Bone Mineral Density and dietary intake of vitamin C and selenium. Zinc intake was significantly related to Bone Mineral Density in the youngest group. Low antioxidant consumers were considered individuals whose Dietary Antioxidant Quality Score was lower or equal than the median (3.5), and high antioxidant consumers were those whose Dietary Antioxidant Quality Score were higher than 3.5. Bone Mineral Density was higher in the participants defined as high antioxidant consumers in all aged groups.**

Conclusion: **The study showed that there is an association between Bone Mineral Density and the Dietary Antioxidant Quality Score in all the women studied. Therefore, new therapies for osteoporosis based on higher dietary antioxidant intakes might be developed basing on the results obtained in this study.**

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Key words: *Antioxidants. Nutrition. Bone mineral density.*

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ASOCIACIÓN ENTRE EL ÍNDICE DE CALIDAD ANTIOXIDANTE DE LA DIETA Y LA DENSIDAD MINERAL ÓSEA EN MUJERES ESPAÑOLAS

Resumen

Antecedentes: **Varias líneas de evidencia sugieren que existe una estrecha relación entre el estrés oxidativo y la patogénesis de la osteoporosis en humanos. La ingesta de nutrientes antioxidantes puede influenciar la densidad mineral ósea al neutralizar los radicales libres, previniendo el daño oxidativo a las células de hueso.**

Objetivo: **El objetivo del presente estudio es establecer la asociación entre un Índice de Calidad Antioxidante de la Dieta y la densidad mineral ósea en una muestra de mujeres sanas.**

Métodos: **Un total de 280 mujeres participaron en el estudio. Las participantes fueron agrupadas por edad en tres categorías: edad ≤ 35 años; edad entre 36 y 45 años y con edad superior a 45 años. Las medidas de la densidad mineral ósea (g/cm²) del calcáneo fueron realizadas por absorciometría dual de rayos X. Los datos sobre los hábitos alimentarios de cada participante fueron recogidos mediante recordatorios de 24 horas. El Índice de Calidad Antioxidante de la Dieta se utilizó para calcular la ingesta total de nutrientes antioxidantes.**

Resultados: **La ingesta de vitamina C y selenio está asociada significativamente a la densidad mineral ósea. En el grupo de mujeres de edad inferior, la ingesta de zinc está relacionada con la masa ósea. Los individuos cuyo Índice de Calidad Antioxidante de la Dieta es inferior o igual a la mediana (3,5) son considerados de bajo consumo antioxidante, y aquellos individuos cuyo Índice de Calidad Antioxidante de la Dieta es superior a 3,5 se consideran de alto consumo antioxidante. En todos los grupos estudiados, la densidad mineral ósea fue significativamente superior en los sujetos cuya dieta tiene un alto consumo de nutrientes antioxidantes.**

Conclusión: **El trabajo muestra que existe una asociación entre la densidad mineral ósea y el Índice de Calidad Antioxidante de la Dieta en todos los grupos de mujeres estudiadas. Por lo tanto, basándose en los resultados de este estudio, se pueden desarrollar nuevas terapias para la osteoporosis basadas en una ingesta elevada de nutrientes antioxidantes.**

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Palabras clave: *Antioxidantes. Nutrición. Densidad mineral ósea.*

Abbreviations

BMD: Bone mineral density.
DAQS: Dietary antioxidant score.
DEXA: Dual energy X-ray absorptiometry.
RDI: Recommended intake.
SD: Standard deviation.
BMI: Body mass index.

Introduction

Osteoporosis is a major growing public health problem worldwide.[1] The mechanisms involved in osteoporosis pathogenesis are not fully understood. Bone is a specialized connective tissue that functions as the load-bearing structure of the body. Free radicals may affect bone remodelling by regulating osteoclast activity in either the physiological or pathological condition.[2] Oxidative stress is a pivotal pathogenic factor for age-related bone loss in mice and rat, leading to an increase in osteoblast and osteocyte apoptosis, among other changes, and a decreased in osteoblast numbers and in the rate of bone formation via Wnt/β-catenin signalling.[3]

Several lines of evidence suggest a tight association between oxidative stress and the pathogenesis of osteoporosis in humans. It has been shown that osteoporotic women have lower serum antioxidants levels as compared with controls.[4] In addition, it has been demonstrated that postmenopausal women with osteoporosis had significantly lower serum antioxidant enzyme activity than non-osteoporotic healthy controls.[5]

The intake of antioxidants may influence Bone Mineral Density (BMD) by acting as free radical scavengers, preventing oxidation-induced damage to bone cells.[6] To date, studies on the relation between antioxidants and BMD have received little attention. It has been established that an inadequate dietary intake of antioxidants increases considerably the risk of hip fracture in current smokers, whereas current smokers with a more adequate intake of antioxidants seem to have a fracture risk similar to that observed among never smokers, thus supporting the theory that oxidative stress has important effects on human bone.[7] In addition, epidemiological studies have reported that there is an inverse association between antioxidant vitamins and carotenoid intake, and low BMD, the risk of fracture, and/or osteoporosis.[4,8,9]

To date, the most consistently followed approach to examine the potential relation between antioxidant dietary intake and skeletal health was based on particular nutrients.[10] However, people do not eat isolated nutrients but meals consisting of a variety of foods with complex combinations of antioxidant nutrients.[11] The traditional analysis considering the effect of a few isolated nutrients on bone health misses a lot of information regarding complex or cumulative correlations and interactions between these antioxidants contained in food. For this reason, there is an increasing interest in the study of diet quality indexes that could answer some questions and promote the development of appropriate recommendations for overall dietary habits.

It is necessary to conduct studies that clarify the effect of antioxidant intake on bone health, in order to establish the role of antioxidant-rich diet in the prevention of osteoporosis. The aim of this study was to assess the association between the Dietary Antioxidant Quality Score (DAQS) and bone mineral density in a sample of healthy women.

Materials and methods

Participants

In this survey, The original study participants (n = 328) were recruited from participants of an ongoing University of Granada project that is assessing the effect of aquatic activities on bone mineral density, in a sample of sedentary women.The study design was approved by the ethics committee of the University of Granada, and an individual written informed consent from the sample participants was obtained. We excluded individuals with known metabolic bone disease, osteoporosis defined as nontraumatic vertebral fractures, current estrogen or dietary supplement use, ever treatment with glucocorticoids for more than 6 months, current or past malignancy and chronic disease if newly diagnosed or out of control. In addition, we excluded participants with incomplete questionnaires, with missing bone mineral density measurements or those that did not meet the criteria of the study. Since age and menopausal status are some of the most important predictors of bone mass, the final participants (n = 280) were grouped into three major groups: women aged ≤ 35 years (n = 89), women aged 36-45 (n = 93), and women aged > 45 years (n = 98). These subgroups represented 31.79%, 33.21%, and 35% of the sample respectively. Women aged ≤ 35 years and 36-45 years were considered as women of reproductive age (premenopausal), and women aged > 45 were postmenopausal women that had ceased menstruating for at least 12 months.

Anthropometry

Body weight was measured to the nearest 0.1 kg by using a precision scale with the participants wearing light clothing and without shoes.[12] Height was measured without shoes and recorded to the nearest millimetre on a portable stand meter. The BMI was calculated as body weight (kg) divided by height squared (m^2). Waist circumference was measured at the midpoint between the lower rib margin and the iliac crest and hip circumference at the level of the trocanter.

Each value represented the mean of three consecutive measurements performed by the same nutritionist to minimize interobserver variation.

Measurement of Bone Mineral Density

Calcaneous BMD (g/cm^2) were measured by Dual Energy X-ray Absorptiometry (DEXA, LUNAR-DPX-L, Lunar Co., Madison, WI). The equipment was calibrated every day. The variation coefficient was 0.32%. The equipment provided automatic T-scores for the measurements, which were derived from the difference between the measured value and the best mean value of young adults of the same gender expressed as a deviation from the normal value. T-scores were generated using peak gender-matched reference data from females. In addition, Z-score was automatically calculated by the equipment, and it is derived from the number of standard deviations below an average person of the same age. Measurements were performed by the same assistant.

Questionnaires

Data on the eating habits of each participant were collected by trained nutritionists with face-to-face interviews based on a structured 24-hour diet recall questionnaire, previously validated with a food frequency questionnaire.[13] The 24-hour recall was carried out three times during the study period, to avoid the influence of seasonal variations. Conversion of food into energy and nutrients was performed using the computer program DIETSOURCE version 1.2.

The number of hours devoted to aquatic activities —two to five hours/week— and the frequency and duration of participation in occupational and leisure-time physical activities were recorded on the questionnaire. Time spent on each of the above activities was multiplied by the metabolic equivalent (MET) value of the activity,[14,15] and all MET-hour products were summed to produce an estimate of daily physical activity. In addition, the socio-demographic data of each participant, as well as their occupation, medical record and smoking habits were recorded.

Measurement of Diet Adequacy

A dietary antioxidant quality score (DAQS) was used to calculate antioxidant-nutrient intake.[16] The score refers to the intake of certain vitamins and minerals that have been proven to act as dietary antioxidants: selenium, zinc, vitamin A, vitamin C and vitamin E. Daily nutrient intake was compared to that of the daily recommended intake for Spanish people[17] (RDI). The intake of each of the five antioxidant nutrients evaluated was assessed separately by assigning a value of 0 or 1 to each nutrient. When the intake was below 2/3 of the RDI, it was assigned a value of 0. Similarly, when the intake was higher than 2/3 of the RDI, it was assigned a value of 1. Thus, the total dietary antioxidant quality score ranged from 0 (very poor quality) to 5 (high quality).

Statistical Analysis

SPSS version 15.0 was used for the statistical analyses. Continuous variables are presented as mean ± standard deviation (SD) and categorical variables are presented as absolute frequencies. Distribution of variables was tested with the Kolmogorov-Smirnov test, showing most of the examined variables were normally distributed. ANOVA tests were used to compare anthropometric and sociological variables and food intake among the three groups of women. A enter multiple regression analysis was used to assess the association between BMD, antioxidants intake and DAQs score after adjustment for other factors, known to affect BMD such as age, body weight and height, calcium intake, cigarette consuming and aquatic physical activity. Standardized β-coefficients, R, R^2, adjusted R^2, t and p values are reported. The specific effect of nutrients significantly associated to bone mineral density was explored by partial correlations. Covariate-adjusted means of the BMD among low and high antioxidants consumers was conducted by analysis of covariance (ANCOVA). The same covariates to the multiple regression analysis were used in ANCOVA. Low antioxidant consumers were considered individuals whose DAQS was lower or equal than the median (3.5), and high antioxidant consumers were those whose DAQS were higher than 3.5.

Results

Descriptive characteristics of the participants per age groups are as shown in table I. Besides age and menopausal status, the groups significantly differed in mean weight, BMI, waist/hip ratio, and educational level. Nutrient intakes expressed as the percentage of recommended dietary intake are presented in table II. The average caloric intakes were lower than the recommended dietary guidelines in the studied population. The percentage of energy from protein and lipids exceeded the dietary goals, and energy from carbohydrates was lower than the desirable levels, as compared with the Nutritional Objectives for the Spanish Population. The intake of nutrients known to be important for bone health (Ca, vitamin D) was lower than the recommended in all age groups.

Table III summarizes the intake of antioxidant nutrients and the percentage of population which intakes are below 2/3 of the RDI. In general terms, we can observe that the average intakes of vitamin E was lower than the

Table I
Anthropometric and sociological characteristics of the study population

	Mean (SD)	*Minimum*	*Macimum*	*p**
Weight (kg)				
18-35 y.	62.4 (8.45)	51.0	91.0	
36-45 y.	66.9 (9.61)	52.1	96.0	0.005
> 45 y.	71.4 (11.9)	53.1	98.0	
Height (cm)				
18-35 y.	161.2 (5.30)	149.0	173.0	
36-45 y.	159.1 (6.64)	147.0	175.5	0.007
> 45 y.	156.1 (6.33)	146.0	170.0	
BMI (kg/m²)				
18-35 y.	23.9 (3.20)	19.32	33.83	
36-45 y.	26.5 (4.11)	21.13	37.97	0.001
> 45 y.	29.31 (4.53)	21.73	42.86	
Waist/hip ratio				
18-35 y.	0.75 (0.06)	0.64	0.89	
36-45 y.	0.80 (0.09)	0.66	1.07	0.001
> 45 y.	0.84 (0.08)	0.71	1.13	
Cigarretes/day				
18-35 y.	1.65 (3.88)	0.0	15.0	
36-45 y.	3.73 (7.68)	0.0	25.0	0.232
> 45 y.	1.50 (4.28)	0.0	20.0	
Physical activity (MET-hour/day)				
18-35 y.	40.05 (2.50)	32.20	45.60	
36-45 y.	39.20 (1.40)	30.10	41.50	0.040
> 45 y.	38.60 (1.30)	30.60	40.50	
	Primary school	*Secundary school*	*University degree*	*P*
Educational level frequency (%)				
18-35 y.	5.63	25.84	68.53	
36-45 y.	29.03	34.41	36.56	0.037
> 45 y.	41.84	34.69	23.47	

y: years; BMI: Body mass index.
*Anova test.

recommended, whereas the intake of the rest of antioxidant nutrients reached the dietary goals. In addition, inadequate antioxidant nutrient intakes (defined as intakes below 2/3 of the RDI) were more prevalent for vitamin E.

The association between BMD and antioxidant nutrients was examined using multiple regression analysis models adjusted by age, body weight and height, calcium intake, smoking habits and aquatic physical activity (table IV). A significant and positive association was observed among BMD and dietary intake of vitamin C and selenium in all age groups. Zinc intake was significantly related to BMD in the youngest group. In addition, multiple linear regression models show that Dietary Antioxidant Quality Score was significantly associated to bone mineral density in the studied population.

Partial correlations were conducted to study the specific effects of vitamin C, zinc and selenium, after controlling the rest of variables. In the youngest group, vitamin C ($r = 0.435$, $p < 0.0001$), Zn ($r = 0.398$, $p < 0.0001$) and Se ($r = 0.398$, $p < 0.0001$) were significantly correlated with BMD. In the 36-45 age group, a significant positive association was observed among BMD and dietary intake of vitamin C ($r = 0.252$, $p = 0.031$) and Se ($r = 0.463$, $p < 0.0001$). In the older group, vitamin C ($r = 0.244$, $p = 0.032$) and Se ($r = 0.223$, $p = 0.035$) were related to BMD after controlling the rest of variables.

Covariate-adjusted means of the BMD among major categories of Dietary Antioxidant Quality Score were compared by analysis of covariance (ANCOVA) to assess differences in bone mineral density between low antioxidant consumers (Individuals who DAQS < 3.5) and high antioxidant consumers (Individuals who DAQS > 3.5). Factors that are known to affect BMD such as age, body weight and height, calcium and vitamin D intake, cigarette consuming and physical activity were used as covariates in ANCOVA analysis. After implementing the ANCOVA model in the studied participants, we found that a significant association exists between the DAQS and BMD. Figure 1 shows the adjusted means of BMD in the major categories of Dietary Antioxidant Quality Score. In the

Table II
Nutrient intake expressed as percentage of recommended dietary intake

	18-35 y.	*36-45 y.*	*> 45 y.*	*p**
Energy (kcal)	85.98 (28.42)	84.59 (19.67)	84.42 (28.72)	0.961
Carbohydrates (%)[1]	71.48 (19.02)	68.04(±15.02)	85.32 (91.97)	0.447
Protein (%)[1]	112.2 (33.94)	123.07(±35.69)	113.83 (30.01)	0.399
Fat (%)[1]	144.7 (31.98)	146.36(±27.60)	151.68 (31.93)	0.644
Thiamin (mg)	119.4 (53.81)	125.50 (47.90)	121.90 (55.53)	0.906
Riboflavin (mg)	125.4 (61.37)	137.47 (33.90)	146.14 (46.07)	0.249
Niacin (mg)	101.1 (43.81)	130.10 (60.70)	122.70 (61.17)	0.134
Vitamin B-6 (mg)	80.59 (29.07)	86.49 (34.38)	88.35 (31.57)	0.628
Folate (ug)	44.14 (32.92)	36.33 (11.30)	43.09 (23.75)	0.401
Vitamin D (ug)	80.95 (93.69)	96.32 (108.3)	83.75 (138.8)	0.863
Vitamin E (mg)	46.60 (22.93)	46.46 (24.83)	56.55 (29.15)	0.214
Vitamin A (ug)	140.22 (20.14)	160.36 (14.25)	110.23 (11.32)	0.418
Vitamin C (mg)	117.5 (69.30)	117.12 (70.18)	131.88 (84.61)	0.677
Zn (mg)	122.2 (51.11)	137.52 (49.37)	126.28 (71.32)	0.587
Se (ug)	109.4 (74.66)	126.47 (50.71)	123.42 (20.56)	0.411
Fe (mg)	101.2 (214.0)	68.39 (19.48)	108.0 (49.21)	0.405
Ca (mg)	87.56 (34.81)	90.73 (39.77)	92.27 (46.36)	0.463
Magnesium (mg)	63.40 (15.56)	71.10 (23.32)	80.77 (84.76)	0.450

y: years.
[1]Percentage of energy consumption.
*Anova test.

youngest group, 41.57% of the population was classified as low antioxidant consumers and 58.43% of the sample was defined as high antioxidant consumers, with covariate adjusted mean BMD values of 0.4970 (0.018) and 0.5540 (0.010), respectively. In the 36-45 age group, low antioxidant consumers (43% of participants) showed mean BMD value of 0.4963 (0.013), and high antioxidant consumers (57% of participants), with a mean BMD value of 0.5538 (0.002). In the older group, bone mineral density was 0.4294 (0.018) in low antioxidant consumers (54% of participants) and 0.5096 (0.010) in high antioxidant consumers (46%).

Discussion

The objective of this study was to investigate the association between dietary patterns of antioxidant nutrient intake and BMD in different age groups of Spanish women. The results indicate that the intake of vitamin C, selenium and zinc was associated with BMD. Furthermore, we found that the overall antioxidant intake was significantly associated with BMD in all age groups. To our knowledge, this is the first study that examines the relation between Dietary Antioxidant Quality Score and bone mineral density.

Several studies have supported an association between select dietary antioxidants and BMD. Most studies have focused on single antioxidants and examined the relationship between antioxidant intake and/or

Table III
Description of the antioxidant nutrient daily consumption in the study population

	Intake mean ± SD	*% sample < 2/3 RDI*
Vitamin C (mg)		
18-35 y.	88.14 (51.97)	14.60
36-45 y.	87.84 (4.08)	16.12
> 45 y.	98.91 (63.46)	15.30
Vitamin E (mg)		
18-35 y.	6.99 (3.44)	73.03
36-45 y.	6.96 (3.72)	68.81
> 45 y.	8.48 (4.37)	59.18
Vitamin A (ug)		
18-35 y.	859.4 (668.5)	11.23
36-45 y.	1,102.8 (729.2)	7.86
> 45 y.	944.4 (1634.8)	53.33
Zn (mg)		
18-35 y.	9.77 (4.08)	14.60
36-45 y.	11.0 (3.95)	18.27
> 45 y.	10.11 (5.70)	11.22
Se (ug)		
18-35 y.	60.21 (41.1)	16.12
36-45 y.	69.56 (427.8)	11.23
> 45 y.	75.81 (48.04)	10.20

y: years.
RDI: Recommended Dietary intake for the Spanish population.

Table IV
Multiple regression analysis models exploring the association of nutrient intake with BMD

Variables	*R*	*R2*	*Adjusted R2*	*SE*	*Coefficient*	*t*	*p*
Vitamin C (mg)							
18-35 y.	0.623	0.388	0.329	0.101	0.417	2.808	0.019
36-45 y.	0.687	0.472	0.424	0.092	0.344	2.130	0.041
> 45 y.	0.458	0.210	0.143	0.102	0.366	2.130	0.020
Vitamin E (mg)							
18-35 y.	0.580	0.337	0.273	0.106	0.331	1.571	0.191
36-45 y.	0.662	0.439	0.388	0.0957	-0.114	0.549	0.615
> 45 y.	0.402	0.162	0.091	0.1059	0.235	1.219	0.239
Vitamin A (ug)							
18-35 y.	0.559	0.313	0.246	0.107	0.008	0.437	0.969
36-45 y.	0.661	0.436	0.386	0.095	0.024	0.224	0.907
> 45 y.	0.394	0.155	0.084	0.106	0.255	0.962	0.189
Zn (mg)							
18-35 y.	0.598	0.358	0.295	0.104	0.452	2.130	0.050
36-45 y.	0.661	0.437	0.386	0.095	-0.083	-0.704	0.694
> 45 y.	0.388	0.150	0.078	0.106	0.134	0.704	0.532
Se (ug)							
18-35 y.	0.603	0.364	0.302	0.103	0.347	2.282	0.047
36-45 y.	0.733	0.538	0.496	0.086	0.554	3.841	0.0001
> 45 y.	0.451	0.203	0.136	0.103	0.366	2.290	0.041
DAQS							
18-35 y.	0.598	0.357	0.295	0.104	0.326	2.127	0.046
36-45 y.	0.686	0.471	0.423	0.092	0.395	2.092	0.045
> 45 y.	0.459	0.210	0.144	0.102	0.435	2.435	0.021

y: years.
DAQS: Dietary Antioxidant Quality Score.
*Adjusted by age, weight, height, smoking habits and physical activity.

serum level and the status of bone health.[8] Our findings support the hypothesis that high intakes of single antioxidants micronutrients may provide benefits to bone. In the present study, a positive association between vitamin C, selenium and zinc intakes and BMD was observed after adjustments for age, weight, height, smoking habits and physical activity.

This study shows evidence of a relation between vitamin C and BMD by itself. Numerous studies have assessed the relation between vitamin C intake and bone mineral density in the last two decades. Vitamin C has been proven to limit bone resorption, thus it might reduce the effects of free radicals and antioxidants, as it is a powerful antioxidant.[6] Similarly, vitamin C is essential for the synthesis of collagen —which represents 90% of the bone matrix—, and for the synthesis of hydroxyprolline and hydroxylysine required for the formation of stable triple helixes.[18] The association between vitamin C and bone mineral density has been analysed in different epidemiological studies.[19,20,21] However, only some of these studies proved that vitamin C intake has beneficial effects on bone mineral density.

Bone material and the structure of animal models have been confirmed to improve with vitamins E and A, so they help prevent osteoporosis.[2] The results obtained in the limited studies on the relation between vitamins E and A, and BMD have been combined.[21,22,23] Our results did not show any association between these vitamins and BMD in any of the age groups studied.

Besides vitamin C, Zinc also plays a role in collagen synthesis and bone mineralization, so it is likely to be important for bone health.[24] Patients with osteoporosis have been found to have lower levels of skeletal and serum zinc than controls.[25] A relationship between low bone mass and low zinc intake in women has been established in previous studies,[26] and the bone loss caused by certain bone disorders has been shown to improve with dietary zinc supplementation.[25] Thus, the results obtained in the present study are consistent with those of previous studies, as an association between dietary zinc intake and BMD in the youngest group has been found.

The present study reveals an association between dietary intake of selenium and BMD in all age groups of women. Different studies have found that selenium deficiency combined with iodine deficiency caused bone and cartilage growth disorders, and negatively affected bone tissues.[24,27] Conversely, other studies did not found any significant differences in hip fracture risk between high and low dietary selenium intake participants.[5]

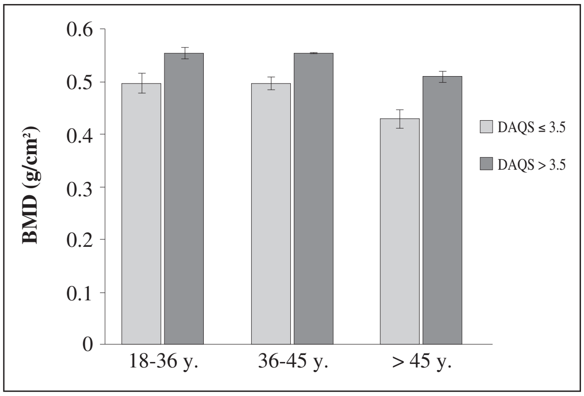

Fig. 1.—Bone mineral density in relation to Dietary Antioxidant Quality Score, DAQS, in studied women. Values are covariate adjusted means with their standard errors represented by vertical bars. Analysis of covariance (ANCOVA) in all studied women showed a p = 0.048 in Group 18-35 years; p = 0.045 in Group 36-45 years and p < 0.036 in Group > 45 years.

An important limitation of the studies that focused on the effects of the intake of particular nutrients on health is that the potential interactions between the different dietary intakes are overlooked. For this reason, recent studies are centring on diet quality indexes, which is a more realistic approach.[28] The same occurs in epidemiological studies on the relation between antioxidants and bone health, a limitation that should be overcome. In a recent study, the relation between BMD and dietary intake of antioxidant vitamins and carotenoids was proven.[8] In this study, its authors stress the importance of assessing dietary patterns rather than single antioxidant nutrient intakes, and the need for the development of recommendations for overall dietary habits.

In the present study, a positive association was found between bone mass and individual dietary intake of vitamin C, Zn and Se. On the contrary, vitamin E and vitamin A did not show any effect. However, this approach focused on single nutrients may not adequately account for the complicated interactions of these nutrients because people eat foods with combination of antioxidants. For this reason, we further considered to examine the association of an antioxidant diet quality index with BMD. The results indicate that Dietary Antioxidant Quality Score is significant associated to bone mineral density in all study participants. Our findings support the hypothesis that high intakes of antioxidants, may be beneficial to bone health.

This study has some limitations. A major limitation of this study is that dietary changes or lifetime dietary intake were not assessed, as this was a cross-sectional study that only analysed dietary intake partially. Another limitation is that the sample size was limited, and thus further large-scale studies are required. Lastly, the dietary intakes of other antioxidants such as flavonoids were not evaluated.

Further studies that examine dietary patterns, the interaction between different antioxidant nutrients and their effects on bone health would be useful to the population.[29] In fact, our study showed that there is an association between BMD and the Dietary Antioxidant Quality Score in all the women studied. Therefore, new therapies for osteoporosis based on higher dietary antioxidant intakes might be developed basing on the results obtained in this study.

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