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ORIGINAL ARTICLE

Mediterranean diet, diet quality, and bone mineral content in adolescents: the HELENA study

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Abstract

Summary Dietary scores, rather than individual nutrients, allow exploring associations between overall diet and bone health. The aim of the present study was to assess the associations between the Mediterranean Diet Score for Adolescents (MDS-A) and the Diet Quality Index for Adolescents (DQI-A) and bone mineral content (BMC) among Spanish adolescents. Our results do not support an association between dietary scores or indices and BMC in adolescents.

Introduction To assess the associations between the MDS-A and a DQI-A with the BMC measured with dual-energy X-ray absorptiometry.

Methods The MDS-A and the DQI-A were calculated in 179 Spanish adolescents, based on two 24-h dietary recalls from the HELENA cross-sectional study. The associations between the diet scores and the BMC outcomes [total body less head (TBLH), femoral neck (FN), lumbar spine (LS), and hip] were analyzed using logistic regression models adjusting for several confounders.

Results Four hundred ninety-two models were included and only fruits and nuts and cereal and roots were found to provide significant ORs with regard to BMC. The risk of having low BMC reduced by 32% (OR 0.684; CI 0.473–0.988) for FN when following the ideal MDS-A, but this association lost significance when adjusting for lean mass and physical activity. For every 1-point increase in the cereal and root and the fruit and nut components, the risk of having low FN diminished by 56% (OR 0.442; CI 0.216–0.901) and by 67% (OR 0.332; CI 0.146–0.755), respectively.

Conclusion An overall dietary score or index is not associated with BMC in our adolescent Spanish sample.

Keywords Diet scores · Dietary patterns · Diet quality index · Fruits · Osteoporosis

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Introduction

Bone mineral content (BMC) in adulthood is determined both by peak bone mass attained in young adulthood and by adult bone loss. When bone mineral content is reduced and the bone microarchitecture is disrupted, the bone becomes fragile and this triggers future fractures. While the clinical consequences of adverse bone health occur predominantly in older age, accumulating evidence indicates that many predisposing factors, like diet, arise in childhood and adolescence [1, 2].

Considerable research has examined the intake of nutrients involved in bone health, such as protein, calcium, or vitamin D [3]; however, suboptimal single-nutrient intake generally does not occur in isolation. Describing and quantifying diet through dietary scores or indexes enables to study the holistic diet, rather than individual foods and nutrients, and thus, it takes into account the interaction between the food items consumed. Hence, assessing dietary patterns seems to be the preferred approach to explain the association between overall diet and bone health [4].

Indices such as the Mediterranean Diet Score for Adolescents (MDS-A) and the Diet Quality Index for Adolescents (DQI-A) are based upon dietary recommendations. The MDS and DQI are built upon different dietary recommendations. While the MDS is characterized by a high intake of vegetables, legumes, fruits, nuts, and cereal grains, moderate-to-high fish intakes, and high intakes of unsaturated lipids but low intakes of saturated fats, together with low intake of meat products, the DQI is more based upon principles of balance and variation, including considering that all foods and food groups (including dairy and meat products) may contribute to a healthy diet. These indices are indicators of the overall diet and are known to be inversely associated with mortality in adults [5], as well as with a number of chronic diseases including cardiovascular diseases [6, 7], obesity, and type 2 diabetes [8].

In relation with bone health, different dietary patterns are currently being evaluated in adults for the prevention of osteoporosis or the lower risk of future hip fractures [9, 10]. The Women’s Health Initiative study and a Swedish cohort of more than 71,000 men and women observed that a higher adherence to a Mediterranean diet is associated with a lower risk for hip fractures. In contrast, a processed food pattern was inversely associated with bone mineral density (BMD) in the Aberdeen Prospective Osteoporosis Screening Study [11].

In children and adolescents, the limited number of studies that use data-driven dietary pattern approaches has found no consistent associations. In a Korean adolescent sample, Shin et al. observed that adolescents in the highest tertile of the “milk and cereal” dietary pattern score had a significantly reduced likelihood of having low BMD compared to those in the lowest tertile [12]. Monjardino et al. [13] found no association between forearm BMD and different dietary patterns, like the Mediterranean Diet Quality Index or the dietary approach to stop hypertension (DASH) diet index.

Inconsistent results are also due to the different methods used for assessing bone mineral content (BMC). The dual-energy X-ray absorptiometry (DXA) is a gold standard instrument for BMC. It measures both bone and soft tissue masses in a reliable and precise way, and thus, the measurement of total body BMC has a high degree of precision [14]. Although, the economic cost of this instrument sometimes makes its use hard in epidemiological studies, it allows the measure of different skeletal regions, and it has the advantage that the data acquisition and analysis are fast and easy to perform.

For this reason, the aim of the present study was to assess the associations between the MDS-A and the DQI-A and BMC measured with DXA at different bone sites among Spanish adolescents. We hypothesize that an overall dietary score or index like the MDS-A and the DQI-A is positively associated with adequate BMC levels in adolescents.

Methods

Study design and subjects

The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) is a cross-sectional study of the nutritional and lifestyle status of male and female adolescents aged 12.5–17.5 years old in 10 European cities [15]. For the current analysis, only the sample from Zaragoza (Spain) was considered, as this was the only center with available DXA bone measurements ($n = 373$). In addition, 194 out of 373 adolescents did not provide two 24-h dietary recalls yielding a total final sample of 179 adolescents (48% males). Sensitivity analyses were performed between the study sample and the full cohort and we did not observe differences for BMC at any site.

The HELENA study was performed following the ethical guidelines of the Declaration of Helsinki 1964 (revision of Edinburgh 2000). The study protocol was approved by the Ethics Committee of Clinical Research from the Government of Aragon (CEICA, Spain). Written informed consent was obtained from parents or guardians and adolescents [15].

Physical examination

Body weight (kg) was measured using an electronic scale (Type SECA 861, UK), precision 100 g, and range 0–150 kg. Standing height (to the nearest cm) was measured on a stadiometer (Type Seca 225, UK), precision 0.1 cm, and range 70–200 cm. Body mass index (BMI) was calculated as body weight in kilograms divided by the square of height in meters. All measurements were performed by trained researchers following a standard protocol [16].

Identification of sexual maturation was performed by a physician who visually assessed each adolescent and classified him/her into the appropriate Tanner stage in one of the five stages (stages I–V) of pubertal maturity according to Tanner and Whitehouse [17].

Sociodemographic factors (socioeconomic status and educational level)

A self-reported validated questionnaire was used to collect data on living conditions, family structure, employment status, and parental occupation and education level [18]. The Family Affluence Scale (FAS) index was used as an indicator of the adolescents' material affluence (reflecting family expenditure and consumption) [19]. The scale ranged from 0 to 8 and was re-coded and dichotomized into a 2-point scale: "low familial wealth" (0–4) and "high familial wealth" (5–8). Maternal educational level was also recorded (primary education, lower secondary education, higher secondary education, or university degree) and recorded later into a 2-point scale, namely as a low (primary and lower secondary education) and high (higher secondary education and university degree score) education.

Physical activity

Uni-axial accelerometers (Actigraph MTI, model GT1M, Manufacturing Technology Inc., Fort Walton Beach, FL, USA) were used to objectively measure physical activity. Adolescents were asked to wear the accelerometer for seven consecutive days during all waking hours, except for water-based activities. At least 3 days of recording, with a minimum of 8 h of registration per day, was set as an inclusion criterion. The time sampling interval was set at 15 s and bouts of ≥ 20 min of consecutive zero counts were deleted from the datasets. Total physical activity was expressed as total counts recorded divided by total daily registered time (counts/min).

Dietary assessment

Dietary intake was assessed by two non-consecutive 24-h recalls, including weekdays and weekend days. The 24-h recalls were collected using the HELENA-Dietary Intake Assessment Tool (HELENA-DIAT) [20]. Trained dieticians assisted the adolescents to complete the 24-h recalls that were later checked for quality. Adolescents autonomously selected all the consumed foods and beverages from a food list in the HELENA-DIAT. Two different dietary patterns the MDS-A and the DQI-A were calculated.

An adapted version of the traditional MDS developed for adults [5] was calculated and validated for adolescents (MDS-A) showing strong associations with nutrient and food intakes [21]. In our proposal, seven positive components (fruits, vegetables, pulses, cereals, fish and seafood, monounsaturated/saturated fats ratio, and dairy products) and two negative components (meat and alcohol) were included. Since ethanol consumption is not recommended for children and adolescents, alcohol intake was scored as a detrimental component; and intake of dairy products was also scored as a beneficial component because dairy products are recommended in growing age [22, 23]. We used age- and sex-specific median intakes of the study participants as a cut-off value for each component. Furthermore, MDS-A was also calculated as continuous variables using standardized z-scores (in which each component was included as a z-score rather than a binary variable) with energy adjustment.

A previously validated diet quality index, originally developed for preschool-aged children [24], was adapted for use in adolescents (DQI-A) to measure their compliance to the Flemish food-based dietary guidelines (FBDG) (28). The ranges in these FBDG were based upon the nutrient recommendations of the Belgian Health Council [25] and the WHO, combined with data on habitual dietary intake in the Belgian population. These FBDG were very similar to dietary guidelines in other countries and to the CINDI (Countrywide Integrated Non-Communicable Disease Intervention program) pyramid developed by the WHO [26], making the index applicable for a European population. These FBDG put forward three basic principles for a healthy and balanced diet, namely dietary quality, dietary diversity, and dietary equilibrium. Furthermore, the daily diet was divided into nine recommended food groups, namely (1) water, (2) bread and cereals, (3) grains and potatoes, (4) vegetables, (5) fruit, (6) milk products (7), cheese, (8) meat, fish, eggs, and substitutes, and (9) fat and oils. Dietary quality expressed whether the adolescent made the optimal food quality choices within a food group. For example, the meat, fish, eggs, and substitutes group was represented by a "preference group" (fish), an "intermediate group" (minced meat), and a "low-nutrient, energy-dense group" (chicken nuggets), scoring as + 1, 0, and − 1 for the preference, the intermediate, and the low-nutrient energy-dense group, respectively. Dietary diversity expressed the degree of variation in the diet. This diversity component was obtained by giving points ranging from 0 to 9 when at least one serving of food of a recommended food group was consumed. Dietary equilibrium was calculated from the difference between the adequacy component (which was the percentage of the minimum recommended intake for each of the main food groups, truncated to 1) and the excess component (which was the percentage of intake exceeding the upper level of the recommendation, truncated to 1 if larger than 1 and truncated to 0 when below 0) [27].

These three components of the DQI-A were presented in percentages. The dietary quality component ranged from − 100 to 100%, while dietary diversity and dietary equilibrium ranged from 0 to 100%. To compute the DQI-A, the mean of these components was calculated; as such, the DQI-A ranged from − 33 to 100%, with higher scores reflecting a higher diet quality. The score was calculated for each day and a mean of the daily scores was taken as global index score of the individual.

Bone measurements

Bone mineral evaluations were made using DXA (pediatric version of the QDR-Explorer software, Software version 12.4; Hologic Corp., Bedford, MA) calibrated using a lumbar spine (LS) phantom. Subjects were scanned at a high resolution in supine position. Lean mass (in grams), total area (in square centimeter), and BMD (grams per square centimeter) were calculated based on the total and regional analysis of the whole body scan. BMC (in grams) was calculated (BMC = BMD × area). Additional examinations were conducted to estimate total body less head (TBLH), removing head, LS (L1–L4), hip, and femoral neck (FN). The coefficient of variation for BMC in our lab was 2.3% [28].

Statistical analysis

The Statistical Package for Social Sciences version 20.0 (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.) was used to analyze the data. All statistical tests and corresponding *p* values were two-sided, and a *p* value of less than 0.05 was considered statistically significant.

BMC z-scores were calculated using a reference standard obtained by age and sex [29] in the aforementioned bone regions. Once obtained, BMC was dichotomized in adolescents with low BMC [at least 1 standard deviation (SD) below the mean] and those with adequate BMC. This selection was to assess the prevalence of low BMC in adolescents with adherence or non-adherence to the MDS-A and with a low or high DQI-A.

Relationships of diet (the continuous variables of the MDS-A and DQI-A) with different bone mass-related variables (TBLH, LS, FN, and hip) were analyzed using logistic regression models. Model 1 included Tanner, FAS, and mother's education as covariates and model 2 included model 1 + total lean mass and moderate and vigorous physical activity (MVPA). These confounders have been previously shown to be associated with bone outcomes in adolescent population [28, 30–32]. Adequate BMC was used as the reference value. Results are presented as odds ratios and their 95% confidence interval.

Results

Table 1 shows the main characteristics of the study sample by the two dietary scores. One hundred twenty-three and 93 adolescents were included in the ideal MDS-A and the high DQI-A, respectively. No differences were observed for sex, age, sexual maturation, body mass, height, BMI, FAS, mother education, and MVPA between those adolescents in the ideal and the non-ideal MDS-A and in the high and the low DQI-A.

Results from the 492 logistic regression models are presented in Tables 2, 3, and 4. From these models, only few dietary components show to provide significant ORs with regard to BMC. Table 2 shows the results of the logistic regression analysis for BMC in relation to the MDS-A and the DQI-A. The risk of having low BMC reduced by 32% (OR 0.684; CI 0.473–0.988) for FN when following the ideal MDS-A after adjustment for Tanner, mother education, and FAS. Nevertheless, this association lost significance when adjusting for lean mass and physical activity.

Table 3 shows the results of the logistic regression analysis for BMC in relation to the MDS-A components. For every 1-point increase in the cereal and root components, the risk of having low FN and hip BMC diminished by 56% (OR 0.442; CI 0.216–0.901) and 48% (OR 0.519; CI 0.279–0.965), respectively, although the association for hip did not remain significant after adjusting for lean mass and physical activity. For every 1-point increase in the fruit and nut components, the risk of having low FN BMC diminished by 67% (OR 0.332; CI 0.146–0.755) and this association remained significant after further adjustment for models 1 and 2. For every 1-point increase in the alcohol component, the risk of having low LS BMC diminished by 93% (OR 0.072; CI 0.008–0.668) and this association remained significant after further adjustment for models 1 and 2. For every 1-point increase in the vegetable component, the risk of having low LS BMC increased by 101% when adjusting for model 2 (OR 2.102; CI 1.200–3.683). For every 1-point increase in the pulse component, the risk of having low LS slightly increased when adjusting for model 1 (OR 1.346; CI 1.006–1.801). Supp1 includes the mean food intakes by ideal and non-ideal MDS-A for further information.

Table 4 shows the results of the logistic regression analysis for BMC in relation to the DQI-A components. For every 1-point increase in the bread and cereal equilibrium or the adequacy component, the risk of having low hip BMC diminished by 2% (OR 0.980; CI 0.963, 0.997) and this association remained significant when adjusting for models 1 and 2. For every 1-point increase in the fruit adequacy component, the risk of having low TBLH (OR 0.985; CI 0.972–0.999) and LS (OR 0.986; CI 0.974–0.999) BMC slightly diminished, but this association did not remain significant when adjusting for model 2. For every 1-point increase in the fat and oil equilibrium component, the risk of having low TBLH BMC slightly diminished by 2% (OR 0.978; CI 0.959–0.998) when adjusting for model 2. For every 1-point increase in the cheese equilibrium component, the risk of having low hip BMC

Table 1 Descriptive characteristics of the study sample (*n* = 179)

	All (*n* = 179)	Ideal MDS-A (*n* = 123)	Non-ideal MDS-A (*n* = 56)	High DQI-A (*n* = 93)	Low DQI-A (*n* = 86)
Females	90 (50.3)	61 (67.8)	29 (32.2)	50 (55.6)	40 (44.4)
Age (years)	14.7 ± 1.3	14.7 ± 1.3	14.6 ± 1.3	14.5 ± 1.2	14.8 ± 1.3
12.5–13.99	63 (35.2)	43 (68.3)	20 (31.7)	49 (77.8)	14 (22.2)
14–14.99	38 (21.2)	28 (73.7)	10 (26.3)	28 (73.3)	10 (26.3)
15–15.99	43 (24)	25 (58.1)	18 (41.9)	34 (79.1)	9 (20.9)
16–17.49	35 (19.6)	27 (77.1)	8 (22.9)	26 (74.3)	9 (25.7)
Sexual maturation					
Tanner I	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tanner II	1 (0.6)	0 (0)	1 (1.8)	1 (0.7)	0 (0)
Tanner III	7 (3.9)	6 (4.9)	1 (1.8)	6 (4.4)	1 (2.4)
Tanner IV	33 (18.4)	23 (18.7)	10 (17.9)	26 (19)	7 (16.7)
Tanner V	138 (77.1)	94 (76.4)	44 (78.6)	104 (75.9)	34 (81)
Body mass (kg)	58.0 ± 10.1	58.5 ± 10.2	57.0 ± 9.8	59.4 ± 10.3	56.5 ± 9.7
Height (cm)	164.8 ± 8.7	165.2 ± 8.9	163.9 ± 8.2	165.3 ± 8.8	164.3 ± 8.5
BMI (kg/m^2)	21.3 ± 3.2	21.4 ± 3.3	21.2 ± 3.0	21.7 ± 3.2	20.9 ± 3.1
Whole body lean mass (kg)	40.3 ± 0.7	40.6 ± 0.8	39.8 ± 0.7	40.8 ± 0.8	39.8 ± 0.7
Mother's education					
Low	70 (39.1)	48 (39)	22 (39.3)	54 (39.4)	16 (38.1)
High	109 (60.9)	75 (61)	34 (60.7)	83 (60.6)	26 (61.9)
FAS					
Low	106 (59.2)	70 (56.9)	36 (64.3)	77 (56.2)	29 (69)
High	73 (40.8)	53 (43.1)	20 (35.7)	60 (43.8)	13 (31)
MVPA (min/week)	58.1 ± 25.2	59.4 ± 24.7	55.4 ± 26.3	54.7 ± 19.7	61.8 ± 29.8

Mean ± SD for continuous variables; *n* (%) for categorical variables

MDS-A, Mediterranean Diet Score for Adolescents; *DQI-A*, Diet Quality Index for Adolescents; *BMI*, body mass index; *BMC*, bone mineral content; *FAS*, Family Affluence Scale; *MVPA*, moderate and vigorous physical activity

slightly increased (OR 1.012; CI 1.000–1.023) and this association remained significant when adjusting for models 1 and 2.

Discussion

This is the first study in reporting Mediterranean diet scores associations with BMC in adolescents and evaluating the risk of low BMC with diet quality scores and its components of equilibrium and diversity. Our data do not support an association between the DQI-A or the MDS-A and BMC.

Little research has been done examining the relationship between dietary scores or indices and bone quality. Monjardino et al. [13] studied the associations between forearm BMD in early and late adolescence and adherence to the Mediterranean Diet Quality Index in early adolescent. They found a linear trend towards increased BMD at 13 years with increasing adherence to the Mediterranean diet pattern, but this was not significant. In a recent review, Movassagh et al. [9] observed that the adherence to a healthy dietary pattern like the Mediterranean diet and the Healthy Eating Index can improve bone mineral status and decrease osteoporosis and fracture risk in Western adults. Taking into account the weak and few significant associations found in the present study, we hypothesize that dietary patterns may not be the primary factor in determining BMC in this age group. It is possible that dietary patterns may not have the impact on the bone in adolescents as they do in adult's populations. Another explanation may be that our adolescent sample is very homogeneous, since they are from the same city, making it much more difficult to find consistent associations between diet and BMC. Moreover, the low number of individuals with the outcome low BMC is the most likely explanation to the weak and few significant associations. For the same reason, the many secondary analyses of food groups in relation to BMC are likely to result in chance findings.

When we evaluated the MDS-A components, the bread and cereal, the fruit and nut, and the alcohol components were associated with BMC, but these results were not consistent

Table 2 Logistic regression analysis for BMC as regards the MDS-A and the DQI-A ($n = 179$)

	MDS-A			
	TBLH	FN	LS	Hip
	18 (10.1) vs. 161 (89.9)*	16 (8.9) vs. 163 (91.1)	24 (13.4) vs. 155 (86.6)	20 (11.2) vs. 159 (88.8)
OR (95% CI)	0.968 (0.680–1.377)	0.734 (0.513–1.049)	0.823 (0.823–1.648)	0.890 (0.639–1.239)
OR (95% CI)^1	0.885 (0.604–1.297)	*0.684 (0.473–0.988)*	1.074 (0.758–1.523)	0.843 (0.595–1.196)
OR (95% CI)^2	0.787 (0.516–1.200)	0.710 (0.494–1.021)	1.097 (0.769–1.566)	0.838 (0.587–1.194)
	DQI-A			
	TBLH	FN	LS	Hip
	18 (10.1) vs. 161 (89.9)*	16 (8.9) vs. 163 (91.1)	24 (13.4) vs.155 (86.6)	20 (11.2) vs. 159 (88.8)
OR (95% CI)	0.994 (0.934–1.056)	0.985 (0.925–1.050)	0.982 (0.928–1.038)	0.993 (0.936–1.052)
OR (95% CI)^1	0.982 (0.918–1.050)	0.974 (0.911–1.041)	0.978 (0.922–1.037)	0.982 (0.922–1.046)
OR (95% CI)^2	1.012 (0.931–1.100)	0.980 (0.916–1.048)	0.999 (0.937–1.065)	0.996 (0.931–1.066)

Model 1: adjusted for Tanner, mother education, and family affluent index. Model 2: model 1 + lean mass and physical activity

DQI; Diet Quality Index for Adolescents; *MDS-A*, Mediterranean Diet Score for Adolescents; *BMC*, bone mineral content; *TBLH*, total body less head; *FN*, femoral neck; *LS*, lumbar spine; *OR*, odds ratio; *CI*, confidence interval

**n* (%) of adolescents defined with low vs. high BMC

Significant values ($p < 0.05$) in italics

for all the bone sites. Similarly, we observed associations between some DQI-A components (bread and cereal equilibrium and adequacy, fruit adequacy, fat and oil equilibrium and cheese equilibrium, and adequacy components) and BMC, but again, results were not consistent for all the bone sites.

Cereal and root MDS-A and bread and cereal equilibrium and adequacy components showed to decrease the risk of low hip BMC. No previous studies have studied the association between bread and cereal intakes and bone health in adolescents. Similarly, Noh et al. studied the effect of a milk and cereal pattern on BMD in Korean adolescents [33]. The milk and cereal dietary pattern had a 64% reduction in the likelihood of having low BMD at the LS [33]. However, when they studied the sole effect of calcium and milk intake on the likelihood of having low BMD, they did not find significant associations. Further research on the reason for the effects of cereal breakfast consumption on specific bone sites is needed.

We also observe that the risk of low FN BMC decreased with the consumption of fruits and nuts according to the MDS-A. Movassagh et al. [9] studied the impact of fruit and vegetable intakes on long-term bone adaptation in distal tibia in young adulthood. They observed that adolescents consuming moderate (3.7 ± 0.5 servings/day) and high intakes (4.5 ± 1.3 servings/day) of fruits and vegetables had greater adjusted mean tibia shaft total area. In our sample, the vegetable MDS-A component showed to be detrimental for LS BMC. This finding is surprising as previous literature has found positive effects of vegetable intake on bone health [34]. Nevertheless, we should keep in mind that a small number of adolescents reached the vegetable recommendations, an intake of 300–450 g/day. In fact, the mean vegetable intake of the HELENA sample was 98 g/day [35] and those with high adherence to the vegetables intake according to the MDS-A presented mean intakes of 106.4 g/day (Supp1).

Alcohol intakes showed to be positively associated with BMC in adolescents. This result does not agree with previous literature reporting heavy alcohol drinking as predictor of lower BMC in adolescents [36, 37]. Nevertheless, moderate alcohol intakes in adults, especially in women, have shown to be beneficial in BMD [38, 39]. Our results agree with the ones from Eleftheriou et al. [40] where moderate alcohol consumption was associated with greater BMD in young adults. There are no existing data on the beneficial effect of alcohol drinking in BMC in adolescents. Nevertheless, we should keep in mind that alcohol intake, in our sample, was very low with a mean intake of 2 g/day and this observation could be due to an age effect, because the older adolescents were the ones drinking alcohol.

Inconsistent results are observed between both dietary pattern methods, the DQI-A vs. the MDS-A, despite the fact that

Table 3 Logistic regression analysis for BMC as regards the Mediterranean Diet Score for Adolescents ($n = 179$)

	TBLH 18 (10.1) vs. 161 (89.9)*			FN 16 (8.9) vs. 163 (91.1)		
MDS-A components	OR (95% CI)^1	OR (95% CI)^2	OR (95% CI)^3	OR (95% CI)^1	OR (95% CI)^2	OR (95% CI)^3
Vegetables	1.087 (0.641–1.842)	1.097 (0.610–1.971)	1.354 (0.603–3.042)	1.136 (0.657–1.964)	1.078 (0.607–1.917)	1.244 (0.667–2.319)
Fruits and nuts	0.580 (0.310–1.084)	0.534 (0.275–1.037)	0.596 (0.271–1.314)	*0.332* *(0.146–0.755)*	*0.257* *(0.102–0.646)*	*0.274* *(0.106–0.710)*
Cereals and roots	0.784 (0.437–1.404)	0.675 (0.352–1.295)	0.836 (0.374–1.871)	*0.442* *(0.216–0.901)*	*0.377* *(0.171–0.834)*	*0.433* *(0.192–0.981)*
Pulses	1.137 (0.827–1.563)	1.175 (0.840–1.645)	0.971 (0.627–1.505)	1.151 (0.827–1.602)	1.150 (0.823–1.607)	1.097 (0.768–1.568)
Dairy products	1.149 (0.639–2.068)	0.942 (0.489–1.816)	0.882 (0.414–1.878)	1.172 (0.633–2.172)	0.998 (0.509–1.957)	1.209 (0.627–2.329)
Fish	1.161 (0.808–1.668)	1.080 (0.730–1.597)	1.072 (0.644–1.785)	0.912 (0.584–1.425)	0.803 (0.497–1.300)	0.758 (0.462–1.244)
FU_FS	1.212 (0.819–1.795)	1.233 (0.794–1.917)	1.152 (0.699–1.901)	0.775 (0.477–1.258)	0.761 (0.467–1.241)	0.707 (0.422–1.184)
Meat	1.004 (0.619–1.629)	0.979 (0.586–1.636)	1.321 (0.651–2.681)	1.138 (0.689–1.880)	1.187 (0.712–1.979)	1.277 (0.705–2.313)
Alcohol	0.277 (0.036–2.122)	0.257 (0.024–2.770)	0.267 (0.025–2.849)	0.380 (0.049–2.922)	0.390 (0.046–3.290)	0.369 (0.048–2.830)
		LS 24 (13.4) vs.155 (86.6)			Hip 20 (11.2) vs. 159 (88.8)	
MDS-A components	OR (95% CI)^1	OR (95% CI)^2	OR (95% CI)^3	OR (95% CI)^1	OR (95% CI)^2	OR (95% CI)^3
Vegetables	1.433 (0.904–2.207)	1.585 (0.965–2.604)	*2.102* *(1.200–3.683)*	1.087 (0.657–1.801)	1.065 (0.613–1.851)	1.216 (0.633–2.333)
Fruits and nuts	0.644 (0.369–1.123)	0.619 (0.350–1.094)	0.743 (0.417–1.325)	0.760 (0.448–1.289)	0.746 (0.430–1.295)	0.870 (0.484–1.564)
Cereals and roots	0.682 (0.389–1.199)	0.613 (0.338–1.110)	0.656 (0.341–1.261)	*0.519* *(0.279–0.965)*	*0.415* *(0.206–0.836)*	0.491 (0.229–1.051)
Pulses	1.307 (0.992–1.722)	*1.346* *(1.006–1.801)*	1.326 (0.959–1.833)	1.248 (0.937–1.663)	1.303 (0.966–1.759)	1.231 (0.867–1.747)
Dairy products	0.981 (0.553–1.743)	0.950 (0.518–1.744)	1.157 (0.601–2.229)	1.367 (0.789–2.368)	1.200 (0.667–2.159)	1.263 (0.666–2.397)
Fish	1.135 (0.798–1.616)	1.001 (0.680–1.472)	1.038 (0.669–1.611)	1.269 (0.907–1.776)	1.227 (0.858–1.755)	1.249 (0.831–1.878)
FU_FS	1.209 (0.836–1.746)	1.166 (0.791–1.717)	1.090 (0.715–1.662)	0.957 (0.640–1.431)	0.951 (0.620–1.459)	0.896 (0.563–1.425)
Meat	1.100 (0.704–1.718)	1.127 (0.718–1.769)	1.428 (0.823–2.477)	1.116 (0.707–1.761)	1.126 (0.696–1.200)	1.330 (0.727–2.436)
Alcohol	*0.072* *(0.008–0.668)*	*0.071* *(0.007–0.753)*	*0.061* *(0.006–0.675)*	0.265 (0.038–1.867)	0.254 (0.028–2.293)	0.229 (0.026–2.022)

Model 1: adjusted for Tanner, mother education, and family affluent index. Model 2: model 1 + lean mass and physical activity

MDS-A, Mediterranean Diet Score for Adolescents; *BMC*, bone mineral content; *FU_FS*, monounsaturated/saturated fats ratio; *TBLH*, total body less head; *FN*, femoral neck; *LS*, lumbar spine; *OR*, odds ratio; *CI*, confidence interval

**n* (%) of adolescents defined with low vs. high BMC

Significant values ($p < 0.05$) in italics

both include similar grouping of dietary components. Nevertheless, we must acknowledge that the DQI-A is a more indirect method to calculate food group intakes compared to the MDS-A, as specific components of each food group are studied. Contrary, the MDS-A calculation is based on median food intakes, a more direct method to register diet.

We should acknowledge the limitations and strengths of our study. As strengths, this is the first study that associates

Table 4 Logistic regression analysis for BMC as regards the diet quality index ($n = 179$)

	TBLH 18 (10.1) vs. 161 (89.9)*			FN 16 (8.9) vs. 163 (91.1)		
DQI-A components	OR (95% CI)	OR (95% CI)^1	OR (95% CI)^2	OR (95% CI)	OR (95% CI)^1	OR (95% CI)^2
DQI	1.002 (0.982–1.022)	0.998 (0.977–1.020)	1.011 (0.981–1.042)	0.999 (0.978–1.020)	0.995 (0.974–1.017)	0.996 (0.973–1.019)
DQI-Diversity	0.968 (0.924–1.014)	0.962 (0.914–1.014)	0.932 (0.864–1.005)	1.036 (0.981–1.093)	1.033 (0.976–1.093)	1.033 (0.973–1.096)
DQI-Equilibrium$^{\beta}$	0.963 (0.909–1.020)	0.953 (0.893–1.016)	0.975 (0.900–1.056)	0.960 (0.903–1.020)	0.952 (0.893–1.016)	0.961 (0.897–1.029)
Water	0.989 (0.972–1.006)	0.986 (0.967–1.005)	0.996 (0.971–1.021)	0.988 (0.970–1.007)	0.987 (0.968–1.006)	0.989 (0.969–1.010)
Bread and cereals	0.998 (0.983–1.013)	0.991 (0.975–1.008)	1.003 (0.981–1.05)	1.002 (0.987–1.017)	1.001 (0.9805–1.017)	1.008 (0.990–1.026)
Grains and potatoes	0.995 (0.983–1.008)	0.993 (0.979–1.007)	0.997 (0.982–1.013)	0.994 (0.981–1.008)	0.994 (0.980–1.008)	0.996 (0.983–1.010)
Fruits	0.987 (0.973–1.001)	0.987 (0.972–1.003)	0.987 (0.968–1.007)	0.990 (0.975–1.004)	0.986 (0.971–1.002)	0.987 (0.971–1.003)
Vegetables	1.004 (0.990–1.018)	1.009 (0.994–1.025)	1.006 (0.988–1.023)	1.005 (0.990–1.019)	1.006 (0.990–1.022)	1.005 (0.989–1.021)
Milk products	0.999 (0.983–1.015)	0.995 (0.977–1.012)	0.991 (0.970–1.012)	1.001 (0.984–1.018)	1.002 (0.984–1.020)	1.001 (0.983–1.020)
Cheese	0.998 (0.984–1.012)	0.997 (0.983–1.012)	0.996 (0.980–1.013)	1.008 (0.995–1.020)	1.007 (0.995–1.020)	1.007 (0.994–1.020)
Meat, fish, eggs, and substitutes	0.994 (0.978–1.010)	0.995 (0.979–1.012)	0.998 (0.978–1.019)	0.994 (0.978–1.011)	0.994 (0.977–1.011)	0.996 (0.978–1.013)
Fat and oils	0.988 (0.974–1.003)	0.985 (0.967–1.002)	*0.978 (0.959–0.998)*	0.996 (0.982–1.009)	0.996 (0.982–1.010)	0.991 (0.977–1.006)
DQI-Adequacy	0.971 (0.923–1.022)	0.957 (0.905–1.013)	0.986 (0.926–1.050)	0.995 (0.945–1.049)	0.992 (0.942–1.046)	1.011 (0.957–1.067)
Water	0.989 (0.973–1.006)	0.987 (0.968–1.006)	0.997 (0.973–1.022)	0.989 (0.971–1.007)	0.988 (0.969–1.006)	0.990 (0.970–1.010)
Bread and cereals	0.997 (0.983–1.012)	0.991 (0.975–1.008)	1.003 (0.981–1.024)	1.001 (0.986–1.016)	1.000(0.985–1.016)	1.008 (0.990–1.026)
Grains and potatoes	0.996 (0.984–1.008)	0.994 (0.981–1.008)	0.997 (0.982–1.013)	0.993 (0.980–1.006)	0.993 (0.980–1.006)	0.995 (0.982–1.009)
Fruits	*0.985 (0.972–0.999)*	*0.984 (0.968–0.999)*	0.986 (0.967–1.005)	0.988 (0.974–1.002)	*0.984 (0.968–0.999)*	0.985 (0.969–1.001)
Vegetables	1.008 (0.995–1.020)	1.008 (0.994–1.022)	1.007 (0.999–1.023)	1.009 (0.996–1.022)	1.011 (0.997–1.026)	1.011 (0.996–1.026)
Milk products	1.002 (0.986–1.017)	0.995 (0.978–1.012)	0.992 (0.972–1.013)	0.998 (0.982–1.015)	0.998 (0.981–1.015)	1.000 (0.982–1.018)
Cheese	0.999 (0.988–1.010)	0.999 (0.988–1.011)	1.001 (0.987–1.015)	1.010 (0.999–1.021)	1.010 (0.999–1.021)	1.011 (0.999–1.023)
Meat, fish, eggs, and substitutes	1.011 (0.965–1.059)	1.013 (0.967–1.062)	1.023 (0.963–1.088)	1.012 (0.962–1.065)	1.016 (0.963–1.071)	1.014 (0.960–1.071)
Fat and oils	1.002 (0.991–1.013)	1.001 (0.990–1.013)	0.998 (0.984–1.012)	1.005 (0.993–1.016)	1.005 (0.993–1.017)	1.002 (0.990–1.015)
DQI-Moderation	1.001 (0.936–1.071)	0.991 (0.923–1.064)	1.005 (0.911–1.109)	1.051 (0.979–1.128)	1.049 (0.978–1.125)	1.082 (0.998–1.173)
Water	1.019 (0.901–1.153)	1.064 (0.932–1.215)	1.057 (0.918–1.217)	1.024 (0.905–1.158)	1.049 (0.921–1.195)	1.039 (0.909–1.188)
Bread and cereals	0.000 (0.000-)	0.000 (0.000-)	0.002 (0.000-)	0.942 (0.693–1.282)	0.934 (0.665–1.311)	0.978 (0.725–1.317)
Grains and potatoes				0.013 (0.000-)	0.015 (0.000-)	0.020 (0.000-)

Table 4 (continued)

	TBLH 18 (10.1) vs. 161 (89.9)*			FN 16 (8.9) vs. 163 (91.1)		
DQI-A components	OR (95% CI)	OR (95% CI)^1	OR (95% CI)^2	OR (95% CI)	OR (95% CI)^1	OR (95% CI)^2
	1.005 (0.973–1.038)	1.010 (0.970–1.051)	0.988 (0.919–1.063)			
Fruits	0.119 (0.000-)	0.130 (0.000-)	0.127 (0.000-)	0.121 (0.000-)	0.120 (0.000-)	0.112 (0.000-)
Vegetables	1.017 (0.995–1.039)	1.004 (0.973–1.035)	1.014 (0.972–1.058)	1.019 (0.997–1.041)	1.025 (1.000–1.050)	1.031 (1.003–1.060)
Milk products	1.012 (0.984–1.041)	1.002 (0.971–1.033)	1.032 (0.904–1.177)	0.000 (0.000-)	0.000 (0.000-)	0.000 (0.000-)
Cheese	1.000 (0.983–1.017)	1.002 (0.985–1.020)	1.010 (0.989–1.031)	1.009 (0.995–1.024)	1.009 (0.995–1.025)	1.013 (0.997–1.029)
Meat, fish, eggs, and substitutes	1.006 (0.992–1.021)	1.006 (0.991–1.021)	1.004 (0.987–1.021)	1.006 (0.991–1.021)	1.007 (0.992–1.022)	1.005 (0.989–1.021)
Fat and oils	1.011 (1.000–1.022)	1.013 (1.000–1.025)	1.015 (1.000–1.030)	1.009 (0.997–1.021)	1.009 (0.997–1.021)	1.010 (0.997–1.023)
	LS 24 (13.4) vs.155 (86.6)			Hip 20 (11.2) vs. 159 (88.8)		
DQI-A components	OR (95% CI)	OR (95% CI)^1	OR (95% CI)^2	OR (95% CI)	OR (95% CI)^1	OR (95% CI)^2
DQI	1.002 (0.983–1.021)	1.001 (0.982–1.020)	1.014 (0.989–1.038)	1.006 (0.986–1.026)	1.003 (0.982–1.024)	1.010 (0.985–1.036)
DQI-Diversity	0.981 (0.939–1.024)	0.978 (0.933–1.025)	0.960 (0.908–1.016)	0.992 (0.949–1.038)	0.994 (0.947–1.044)	0.986 (0.932–1.043)
DQI-Equilibrium$^{\beta}$	0.963 (0.913–1.016)	0.963 (0.909–1.019)	0.979 (0.921–1.040)	0.954 (0.903–1.009)	0.944 (0.887–1.005)	0.956 (0.892–1.026)
Water	0.995 (0.979–1.0101)	0.995 (0.979–1.011)	1.002 (0.984–1.020)	0.997 (0.981–1.013)	0.996 (0.978–1.013)	1.004 (0.983–1.025)
Bread and cereals	1.000 (0.986–1.013)	0.996 (0.981–1.010)	1.000 (0.984–1.016)	*0.980 (0.963–0.997)*	*0.972 (0.953–0.991)*	*0.974 (0.952–0.996)*
Grains and potatoes	0.996 (0.985–1.008)	0.996 (0.983–1.008)	0.997 (0.984–1.010)	0.997 (0.985–1.009)	0.995 (0.982–1.008)	0.999 (0.985–1.012)
Fruits	0.986 (0.973–1.000)	0.986 (0.972–1.000)	0.986 (0.971–1.001)	0.995 (0.983–1.008)	0.996 (0.983–1.010)	0.999 (0.983–1.014)
Vegetables	1.006 (0.993–1.019)	1.009 (0.995–1.023)	1.007 (0.993–1.022)	1.008 (0.995–1.021)	1.013 (0.999–1.028)	1.012 (0.996–1.027)
Milk products	0.998 (0.983–1.013)	0.998 (0.983–1.014)	0.999 (0.983–1.016)	1.000 (0.985–1.015)	0.998 (0.981–1.014)	0.996 (0.978–1.014)
Cheese	1.007 (0.996–1.018)	1.007 (0.995–1.019)	1.006 (0.994–1.018)	*1.012 (1.000–1.023)*	*1.013 (1.001–1.025)*	*1.014 (1.001–1.027)*
Meat, fish, eggs, and substitutes	0.990 (0.974–1.007)	0.991 (0.975–1.008)	0.991 (0.973–1.009)	0.996 (0.982–1.011)	0.997 (0.982–1.012)	1.000 (0.983–1.017)
Fat and oils	1.002 (0.991–1.014)	1.002 (0.991–1.014)	1.000 (0.988–1.013)	0.990 (0.977–1.004)	0.988 (0.974–1.003)	*0.982 (0.966–0.999)*
DQI-Adequacy	0.968 (0.922–1.016)	0.963 (0.915–1.014)	0.973 (0.922–1.027)	0.959 (0.912–1.008)	0.949 (0.899–1.001)	0.968 (0.914–1.025)
Water	0.995 (0.979–1.010)	0.995 (0.979–1.011)	1.001 (0.984–1.019)	0.997 (0.981–1.013)	0.996 (0.979–1.014)	1.004 (0.984–1.025)
Bread and cereals	0.999 (0.986–1.013)	0.995 (0.981–1.010)	1.000 (0.984–1.016)	*0.980 (0.963–0.997)*	*0.972 (0.953–0.991)*	*0.974 (0.952–0.996)*
Grains and potatoes	0.997 (0.986–1.008)	0.996 (0.984–1.008)	0.996 (0.984–1.008)	0.996 (0.984–1.008)	0.995 (0.982–1.007)	0.998 (0.985–1.011)
Fruits	*0.986 (0.974–0.999)*	*0.984 (0.970–0.998)*	0.986 (0.971–1.000)	0.993 (0.981–1.005)	0.993 (0.980–1.007)	0.996 (0.982–1.011)
Vegetables	1.002 (0.990–1.014)	1.004 (0.992–1.017)	1.004 (0.990–1.017)	1.008 (0.996–1.021)	1.009 (0.995–1.022)	1.008 (0.994–1.022)

Table 4 (continued)

	TBLH 18 (10.1) vs. 161 (89.9)*			FN 16 (8.9) vs. 163 (91.1)		
DQI-A components	OR (95% CI)	OR (95% CI)^1	OR (95% CI)^2	OR (95% CI)	OR (95% CI)^1	OR (95% CI)^2
Milk products	1.000 (0.986–1.015)	0.998 (0.983–1.014)	0.999 (0.983–1.016)	0.997 (0.983–1.012)	0.993 (0.977–1.009)	0.993 (0.975–1.011)
Cheese	1.000 (0.990–1.010)	1.000 (0.990–1.011)	1.000 (0.989–1.011)	1.008 (0.998–1.018)	1.009 (0.999–1.019)	1.012 (1.000–1.024)
Meat, fish, eggs, and substitutes	1.015 (0.967–1.064)	1.015 (0.968–1.065)	1.019 (0.965–1.076)	1.013 (0.966–1.062)	1.017 (0.969–1.067)	1.019 (0.966–1.075)
Fat and oils	1.003 (0.993–1.013)	1.003 (0.992–1.013)	1.000 (0.989–1.011)	0.999 (0.989–1.009)	0.999 (0.988–1.010)	0.995 (0.983–1.007)
DQI-Moderation	0.997 (0.935–1.063)	0.989 (0.925–1.056)	0.979 (0.908–1.056)	0.991 (0.929–1.058)	0.984 (0.921–1.053)	0.997 (0.918–1.082)
Water	0.218 (0.000-)	0.215 (0.000-)	0.207 (0.000-)	1.015 (0.897–1.148)	1.060 (0.929–1.209)	1.047 (0.910–1.205)
Bread and cereals	0.931 (0.679–1.278)	0.929 (0.658–1.311)	0.964 (0.703–1.321)	0.000 (0.000-)	0.000 (0.000-)	0.000 (0.000-)
Grains and potatoes	1.002 (0.970–1.035)	1.000 (0.961–1.041)	0.973 (0.909–1.041)	0.980 (0.913–1.051)	0.983 (0.913–1.058)	0.968 (0.890–1.053)
Fruits	0.987 (0.943–1.033)	0.983 (0.940–1.027)	0.991 (0.947–1.037)	0.117 (0.000-)	0.128 (0.000-)	0.122 (0.000-)
Vegetables	0.861 (0.539–1.374)	0.840 (0.519–1.361)	0.809 (0.462–1.416)	1.007 (0.982–1.032)	0.973 (0.906–1.045)	0.973 (0.907–1.044)
Milk products	1.009 (0.981–1.038)	0.999 (0.969–1.031)	0.999 (0.941–1.060)	0.000 (0.000-)	0.000 (0.000-)	0.000 (0.000-)
Cheese	0.978 (0.945–1.012)	0.979 (0.948–1.012)	0.979 (0.947–1.013)	0.998 (0.981–1.015)	0.999 (0.982–1.016)	1.003 (0.984–1.022)
Meat, fish, eggs, and substitutes	1.009 (0.995–1.024)	1.009 (0.994–1.024)	1.009 (0.993–1.025)	1.004 (0.991–1.018)	1.004 (0.991–1.018)	1.002 (0.988–1.017)
Fat and oils	1.002 (0.991–1.013)	1.001 (0.989–1.013)	1.000 (0.987–1.012)	1.007 (0.996–1.017)	1.008 (0.997–1.020)	1.009 (0.996–1.022)

Model 1: adjusted for Tanner, mother education, and family affluent index. Model 2: model 1 + lean mass and physical activity

BMC, bone mineral content; *DQI-A*, Diet Quality Index for Adolescents; *DQI*, diet quality index; *TBLH*, total body less head; *FN*, femoral neck; *LS*, lumbar spine; *OR*, odds ratio; *CI*, confidence interval

**n* (%) of adolescents defined with low vs. high BMC

$^{\beta}$ DQI-Equilibrium is the difference between the adequacy component and the moderation component

Significant values ($p < 0.05$) in italics

different dietary scores and indices with bone mineral content in an adolescent sample. Dietary intake was assessed using an accurate method, repeated two 24-h recalls, a widely accepted tool to be used in epidemiological studies. The MDS-A and the DQI-A have been previously validated and show a good correlation with food intake and some biomarkers [13, 19]. The use of sophisticated methods, such as DXA, to assess bone mass, is also a strength of our study. In addition, the important set of confounders included in the analysis facilitates the interpretation of the data.

In contrast, results cannot be interpreted in terms of cause-effect relations due to the cross-sectional design of the study. In addition, a great number of analyses were conducted and no correction for repeated testing was applied; therefore, false associations are more likely to occur. Assessing the diets of younger age groups is considered to be challenging, because their diets are highly variable from day to day. Thus, although adolescents are able to report their dietary intake, the provided information may be less accurate compared with that from adults [41, 42]. Therefore, limitations in relation to the use of recalls as a method of assessment should be considered.

In summary, an overall dietary score or index is not associated with BMC in our Spanish adolescent sample. Nevertheless, some dietary components like fruit and nut intakes may contribute to a higher FN BMC. Efforts to improve specific components of the diet from adolescence may prevent future diseases related to bone health. Further epidemiological studies are needed to corroborate these findings.

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Compliance with ethical standards

Conflicts of interest None.

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